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Ventilation systems for nuclear facilities — In-situ efficiency test methods for iodine traps with solid sorbent —

Part 1:
General requirements

Systèmes de ventilation pour les installations nucléaires — Méthodes d'essai in-situ de l'efficacité des pièges à iode à sorbant solide —

Partie 1: Exigences générales

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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).

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 World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection*.

A list of all parts in the ISO 16659 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

In nuclear facilities, iodine traps are usually used on ventilation systems to limit radioactive iodine effluent releases into the environment, to reduce iodine concentration in the air of facilities by recycling or to prevent radioactive iodine from entering into protected areas (such as control room for example). Some examples of the iodine trapping systems are shown in Annex B. The knowledge or the warranty of the capacity of these devices to trap iodine could be necessary, particularly when they are valued in the safety demonstration.

The IAEA recommends in the Safety Guide SSG-53[21] to test periodically the efficiency of confinement systems used to limit gaseous radioactive effluents releases into the environment. This recommendation is transcribed in some national rules by requirements about testing the efficiency of filtration or scrubbing devices of facilities' ventilation systems but, no international standard exists for the methods to be used for testing them in situ. ISO 17873 and ISO 26802 recommend periodic testing after their installation as well. Some design recommendations may also be found in national standards (e.g. ASTM standard[8]).

This document is the general part of a set of standards on the different current methods of tests. It describes common provisions to use to test in situ the iodine trap scrubbing efficiency of ventilation systems of nuclear facilities. These provisions deal with the methods used according to the expected role of this iodine trap, requirements about workers protections, and requirements for environment protection to take into account during these tests. Specific methods will be presented in the different parts of ISO 16659, using radioactive nuclides (e.g. $^{131}ICH_3$ in order to determine the filters efficiency or gases such as cyclohexane in order to perform integrity tests).

Ventilation systems for nuclear facilities — In-situ efficiency test methods for iodine traps with solid sorbent —

Part 1: General requirements

1 Scope

The scope of ISO 16659 series is to provide different test methods aiming at assessing the efficiency of radioactive iodine traps in ventilation systems of nuclear facilities. The ISO 16659 series deals with iodine traps containing a solid sorbent — mainly activated and impregnated charcoal, the most common solid iodine sorbents used in the ventilation systems of nuclear facilities — as well as other sorbents for special conditions (e.g. high temperature zeolites).

The scope of this document is to provide general and common requirements for the different test methods for industrial nuclear facilities. The different methods will be described in other specific parts of ISO 16659 series. Nuclear medicine applications are excluded from the scope of ISO 16659 series.

In principle, ISO 16659 series is used mainly for filtering radioactive iodine, but other radioactive gases can also be trapped together with iodine. In such a case, some specificity may have to be adapted for these other radioactive gases in specific parts of ISO 16659 series.

This document describes the main general requirements in order to check in situ the efficiency of the iodine traps, according to test conditions that are proposed to be as reproducible as possible.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2889:2021, *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.

ISO and IEC maintain terminological 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
activated and impregnated charcoal
carbon fiber filter
charcoal or carbon fiber filters often obtained from biomass or synthetic fiber precursors and for which its specific surface is drastically increased by physical or chemical activation during a high temperature thermal treatment

Note 1 to entry: Its specific surface area is so high and so its adsorption capacity, that it is largely used in iodine trap in nuclear installations or mask for workers.

Note 2 to entry: The activated charcoal can be impregnated with potassium iodide (KI) and/or triethylenediamine (TEDA) to enhance the decontamination factor by increasing respectively isotopic exchange and chemical adsorption.

Note 3 to entry: Activated carbon fiber filter are also used for nuclear applications for iodine trap in nuclear installations or mask for workers; their principle is to use microporous trapping phenomena (increasing the specific surface area) instead of macro-porous trapping phenomena in conventional charcoal filters.

3.2
adsorption
surface phenomenon that results in the increase of the density of an adsorbate, a substance that is adsorbed (atoms, ions or molecules from a gas, liquid or dissolved solid), due to fixation to a surface by different physical (physisorption) or chemical (chemisorption) processes with different energies

Note 1 to entry: It differs from absorption, in which a fluid (the absorbate) is dissolved by or permeates a liquid or solid (the absorbent), respectively. Absorption is a volume phenomenon.

Note 2 to entry: Charcoal, argil or zeolite are good adsorbent due to their crystalline structure.

3.3
chemical adsorption
chemisorption
adsorption (3.2) resulting from a surface chemical reaction between the adsorbate and the impregnated surface of the sorbent with formation of a chemical bond

Note 1 to entry: This irreversible phenomenon leads to a deep modification of the repartition of the electronic charges of the adsorbed molecules, the forces are similar to the chemical bond.

3.4
contact time
gas flow transit time through sorbent layer (or sorbent bed)

Note 1 to entry: Contact time, τ, is expressed using the ratio: sorbent thickness (in metres)/frontal speed (in meter per second) or using the ratio: sorbent volume (in cubic meter)/flow rate throw the sorbent (in cubic metres per second).

3.5
decontamination factor
f_D
measure of the efficiency achieved by a filter and corresponding to the ratio of activity, A, of the species, expressed in Bq at the inlet of the filter (or concentration of tracer, $C_{upstream}$) and the activity of the species in Bq, a, (or concentration of tracer, $C_{downstream}$) at the outlet of the filter

Decontamination factor f_D is expressed using the following formula:

$$f_D = A/a = C_{upstream}/C_{downstream}$$

where A and a are the activity upstream and downstream and $C_{upstream}$ and $C_{downstream}$ are the concentration upstream and downstream, the f_D being greater than 1.

Note 1 to entry: The decontamination factor is related to efficiency, E, and penetration, P, by the following relation:

$$f_D = \frac{1}{1-E} = \frac{1}{P}$$

Note 2 to entry: The decontamination factor considers both the intrinsic quality of the sorbent and leaks of the in situ complete integrated device (internal, due to mounting, by-pass, etc.).

Note 3 to entry: The notion of decontamination factor applies particularly to tests with radioactive tracer gas.

3.6
desorption
inverse phenomenon of the physical *adsorption* (3.2) due to physical or chemical modification of the sorbent (increase of temperature, decrease of pressure, etc.)

3.7
efficiency
E
ratio of the quantity of species (particles or gas) retained by the filter to the quantity entering it

Note 1 to entry: Efficiency is always less than or equal to 1.

3.8
frontal speed
speed of gaseous radioactive wastes through sorbent bed layer

3.9
hygrometric and thermal equilibrium
conditions for which hygrometric or thermal parameters of the air flow containing water vapor crossing the sorbent start to reach asymptotic value downstream the sorbent such as it can be considered that the sorbent and air flow are in equilibrium

3.10
integrity test
in situ test indicating whether the filter or material is performing as designed, such as to identify potential non-filtered leaks

3.11
iodine sorbent
sorbent intended for trapping radioiodine in gaseous radioactive effluent, usually based on activated and impregnated charcoal, silver impregnated zeolite or silver nitrite impregnated catalytic devices

3.12
iodine trap
device intended to trap radioiodine in gaseous radioactive effluents by using a solid sorbent in an enclosure

3.13
isotopic exchange
permutation of two isotopes of the same chemical element within a molecule

EXAMPLE An atom of iodine 131 in a CH_3I molecule in a gas form exchanges its position with a stable iodine 127 in a KI molecule impregnated on the surface of the sorbent.

3.14
nominal user flow rate
volume flow rate specified by the user which pass through the *iodine trap* (3.12) during the test

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

3.15
penetration
P
ratio of the quantity of species (particles or gas) penetrating the filter to the quantity entering it

Note 1 to entry: Penetration is always less than or equal to 1.

3.16
physical adsorption
physisorption
adsorption (3.2) with low energy of adhesion (e.g. Van der Waals) and reversible phenomenon

3.17
sorbent thickness
thickness of the sorbent layer

3.18
sorbent volume
quantity of solid sorbent present in the *iodine trap* (3.12)

3.19
specific surface area of the sorbent
total surface area (exchange surface) of the sorbent, expressed in square meter per a mass unity (in g)

Note 1 to entry: This parameter can be calculated from the surface area of a monolayer of an adsorbed probe molecule (adsorbate) at standard temperature and pressure (STP) and normalized per mass unit of sorbent.

Note 2 to entry: The specific surface area of the sorbent defines the surface available for adsorption and accessibility to adsorption sites.

Note 3 to entry: The most widely used method for determining specific surface area is the Brunauer, Emmett and Teller (BET) method. The determination of the specific surface area according to the BET method is defined in ISO 9277.

3.20
tracer gas
gas used in test

3.21
zeolite
crystalline aluminosilicate minerals that form microporous frameworks, commonly used as commercial adsorbents and catalysts

Note 1 to entry: These are commonly referred to as molecular sieves.

4 Trapping phenomena and influencing factors

4.1 Type of iodine to be filtered in nuclear facilities

Radioactive iodine is a fission product representing a serious radiological impact due to its radiotoxicity as well as its affinity toward the thyroid gland. Different isotopes of iodine (mainly ^{131}I, ^{132}I, ^{133}I, ^{135}I) can be produced from fission reactions occurring within the fuel matrix of nuclear reactors. The ^{129}I isotope can also be produced from fission process, and may be released by other nuclear facilities (e.g. fuel reprocessing plants, isotope production facilities).

Isotope ^{131}I with a half-life of about 8 days is the main contributor to iodine radiological consequences to the environment for nuclear power plants (NPPs). Isotopes with long half-lives such as ^{129}I (half-life about $1{,}6 \times 10^7$ years) could be released by spent fuel reprocessing facilities. Finally, beta minus (β–) decay iodine isotopes ^{129}I, ^{131}I, ^{132}I, ^{133}I, ^{134}I, ^{135}I and beta plus (β+) decay iodine isotopes ^{123}I, ^{124}I, ^{125}I, ^{126}I with half-lives of less than 2 months could be produced or released by laboratories or isotope production facilities.

Radioactive iodine can be released in gaseous or particle form (in most cases, iodine aerosol volatile particles could represent up to 95 % of quantity of iodine forms, but this depends on the iodine chemistry with regards to its environment inside the process or inside buildings). In this last case, these iodine aerosol particles are filtered by high efficiency particulate filter (HEPA) whose test method is not considered by this document. This document focuses on the trapping of volatile iodine compounds, represented commonly by molecular iodine (I_2) and methyl iodide (CH_3I).

4.2 Trapping phenomena

The trapping phenomena within the iodine filters are of primary importance for the in situ efficiency tests of the different radioactive products passing through the filters. For radioactive iodine, the removal efficiency results from the balance between different mechanisms for the iodine retention within the sorbent stage. These mechanisms are mainly physical, chemical phenomena, or isotopic exchanges depending on the impregnating molecules. It is worth recalling that nuclear grade activated carbons are generally co-impregnated with both potassium iodide (KI) and triethylenediamine (TEDA) molecules (e.g. 1 % mass fraction of KI and content lower than 5 % mass fraction for TEDA). The adsorption capacity of this type of activated carbons is considered in the range of about 1 g or a few grams of total iodine per kg of adsorbent (for an expected filter efficiency of about 99 %).

The main factors influencing the trapping efficiency are

a) the parameters related to the adsorbent, i.e. nature of the raw material, impregnation type and content, preparation method, granular size, bed depth, and

b) parameters specific to the gas conditioning: temperature, relative humidity, inhibitors, gas velocity described hereafter.

Some other factors influencing trapping efficiency are specific to the testing methods; these will be specified in those methods.

Three main phenomena are associated with the trapping of radioactive iodine:

— physisorption or physical adsorption;

— chemisorption or chemical adsorption;

— isotopic exchange.

NOTE Desorption can occur, because physisorption and isotopic exchange are reversible phenomena.

The relative quantification of these phenomena depends on several parameters:

— characteristics of iodine to be removed (organic, inorganic);

— nature of the adsorbent used (e.g. activated carbon, zeolite) and its characteristics (sorbent thickness, sorbent volume, specific surface area of the sorbent);

— chemical additive used to improve the performance and the stability of trapping;

— gas conditioning parameters (e.g. temperature, relative humidity).

In the following, a brief description of the main mechanisms of iodine retention is presented. Then, a small review about some influencing parameters towards the capture of iodine species is discussed.

4.3 Iodine trapping mechanisms inside porous filters

4.3.1 Physical adsorption

The physical adsorption or physisorption involves very weak interaction energy, such as Van der Waals forces. These forces are sensitive to the distance between the adsorbent and the adsorbed molecule, also known as “adsorbate”. Physisorption interaction occurs without modification of the molecular structure of the adsorbent and is totally reversible. The desorption may occur by a simple changing of gas conditioning process (temperature increase, pressure decrease, replacing the iodine flow with an inert gas…).

In addition, physisorption depends mainly on the accessibility of the adsorbate to the adsorption sites (pores). This is governed by the relative size of the adsorbate molecule to the pore size distribution of the sorbent used. Hence, this mechanism is not specific to iodine species.

4.3.2 Chemisorption

In contrast with physisorption, the chemisorption results from a chemical reaction with formation of chemical bonds between the molecules of adsorbate and adsorbent. Consequently, the involved energy is much stronger, and the associated process is much less reversible and can be in some cases irreversible. This phenomenon improves also the specificity of the trapping of iodine species, which is of great interest especially when considering the real application conditions.

This type of reactivity is widely used for the industrially implemented sorbents for iodine removal in the nuclear context. Depending on the desired application, different chemical additives can be used:

a) Silver-loaded adsorbents.

Owing to the well-known affinity of silver for iodine species, silver-loaded sorbents could be applied in specific circumstances. This interest in the use of silver arises from its high reactivity with iodine, leading to the formation of thermal stable and insoluble AgI precipitates within the internal porosity.

NOTE The total chemisorption capability of a catalytic support impregnated with silver nitrate is around 120-140 mg per adsorbent gram for total iodine.

b) TEDA-impregnated activated carbons.

As outlined before, TEDA impregnation is commonly used for the nuclear grade activate carbons used for the cleaning of ventilation circuits within nuclear reactors of facilities. The use of this molecule is explained by its ability to retain methyl iodide through SN_2 nucleophilic substitution reaction, as seen in Figure 1.

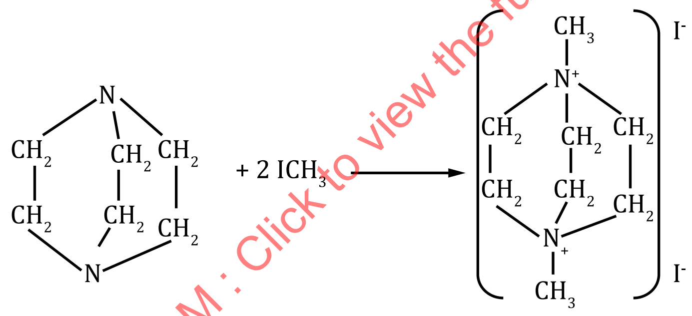


Figure 1 — Chemisorption for methyl iodine with TEDA

TEDA impregnation is necessary in order to improve the adsorption performances of activated carbons towards CH_3I especially under humid conditions.

4.3.3 Isotopic exchange

In the reaction of isotopic exchange, the elementary composition of the beginning compound does not differ from ultimate compounds. Only the exchange takes place between isotopes. This means that radioactive methyl iodide in the airstream fluid is replaced by a non-radioactive methyl iodide in the same airstream fluid.

The $K^{127}I$ impregnated sorbents traps organic iodine ($CH_3{}^{131}I$) by isotopic exchange:

$$K^{127}I(\text{on sorbent}) + CH_3{}^{131}I\text{gas} \leftrightarrow K^{131}I(\text{on sorbent}) + CH_3{}^{127}I$$

NOTE The total capacity of adsorption iodine of radioactive carbons impregnated with potassium iodide is the order of magnitude of 1 g/kg of adsorbent.

4.3.4 Desorption

This natural phenomenon is associated with the physical adsorption phenomenon. Chemical sorption and isotopic exchanges reduce the risks of desorption. The use of an impregnate makes it possible to shift the balance and limit the phenomena of desorption.

The lower the boiling point, the more important the desorption phenomena is. In particular, the desorption of CH_3I was observed (boiling point of 42,5 °C) at higher levels than those of I_2 (boiling point of 184 °C).

This parameter, relating to the quantification and kinetics of releases from an installation, would require additional research before characterizing it in detail in this document.

4.4 Parameters influencing the performance of iodine traps

4.4.1 Initial conditioning and equilibrium conditions

Temperature is an important parameter although its influence is often correlated with other parameters such as relative humidity.

Relative humidity is one of the more important parameters for the retention of iodine species since the filled pores with the condensed water are not available for the adsorption of the incoming iodine molecules. It is worth mentioning that the water quantity adsorbed by the material is a function of both temperature and the relative humidity. In this respect, the test temperature shall be specified.

The material present in the iodine trap, even before being put in place, stores in its porous network residues from its manufacture, volatile organic compounds (VOC), etc. If the installation wants to compare the tendency of the efficiency of their filters during years, or between each ventilation systems, it is therefore necessary to test them in the same state of cleanliness and saturation with water vapour. Consequently, an initial conditioning is then performed. This conditioning aims to reach a hygrometric and thermal equilibrium between the tested material and the air flow composition used for the test. The conditioning time of the iodine trap shall be specified and be at least 16 h.

NOTE It is worth noting that investigations about the effect of conditioning have showed that a duration of 4 h up to 5 h seems to be sufficient to reach the equilibrium between the tested activated carbons and the air flow containing water vapor (90 % at 20 °C).

4.4.2 Initial tracer gas concentration and composition

The concentration of tracer gas plays an important role in the retention of iodine within a porous material. It is one of the parameters that govern adsorption at the pore level. Articles show that iodine retention is lower at very low concentrations than at higher concentrations. It is therefore important to test an iodine trap with similar concentration of iodine.

A compromise should be obtained when fixing the initial amount of radioactive iodine. The ideal amount of tracer gas should be levels that are easily measured (far enough from the detection limit) while minimizing the amount released to the environment. This quantity is adjusted on the operator's knowledge about the iodine trap and its supposed efficiency. The specific protocol for trapping the iodine requires the accurate specification of the activity and isotopic ratio of the tracer gas. The activity and isotopic ratio of the tracer gas shall be specified.

4.4.3 Effect of relative humidity (hygrometry)

Relative humidity plays a critical role in the effectiveness of a trap and the decontamination factor. It conditions the final decontamination factor of the filter. The relative humidity shall be measured to ensure that the quantity of water on the trap and in the air are approximately in equilibrium.

The measured decontamination factor corresponds to a given relative humidity, the mean value of which during the test shall be specified.

NOTE An extrapolation carried out from the curves giving the decontamination factor of an adsorbent as a function of the relative humidity can only be very approximated. In addition, an in situ measurement of the decontamination factor takes into account all the leaks which most of the time makes this extrapolation hazardous except when the leak rate is low.

4.4.4 Influence of contact time between air and the sorbent (air velocity)

The adsorption is not an instantaneous phenomenon. It is then necessary to ensure a sufficient contact time (versus frontal speed) between the adsorbent and the air to be purified. The minimum contact time of the air to be purified shall be specified and quantified, obtained by knowing the nominal user flow rate and the thickness of the iodine trap. The thickness of the activated carbon iodine traps shall be known in order to determine the contact time of the fluid on the filter. It should be ensured that the ventilation flow rate in the duct during the test corresponds to the nominal conditions of use of the ventilation circuit with regards to air velocity (see ISO 10780). As this parameter is sensitive, it shall be determined with its uncertainties and the values be mentioned in the test performance report including its uncertainties.

4.4.5 Ageing of the iodine traps

Activated charcoals can be modified over time due to ageing effects, which induce the decrease of their effectiveness. Two types of ageing are to be considered:

— static ageing of carbon which could be due to oxidation. Static ageing can be slowed down by appropriate storage conditions (sealed envelope);

— dynamic ageing affecting iodine traps in service on a continuous or intermittent basis. Poisoning of charcoal resulting from the adsorption of inhibitors present in the air (solvent vapours, oil vapours, SO_x, NO_x...):

  — painting work or change of insulation are operations to be monitored more particularly;

  — prolonged contact of activated carbon with humid air can contribute to the degradation of its effectiveness.

For installations with impregnated catalytic supports and continuous generation of iodine (examples of fuel reprocessing installations), ageing can be identified by the increase in the iodine load on these supports.

4.4.6 Influence of grain size and density

Range of granulated/crushed grains sizes and bulk density of the sorbent are important parameters for gas trapping, the finer the grain size, the higher the trapping efficiency, but also the higher the pressure drope of the filters is. ISO 18417 provides elements for quantifying these elements.

5 Main principles of test methods of iodine traps

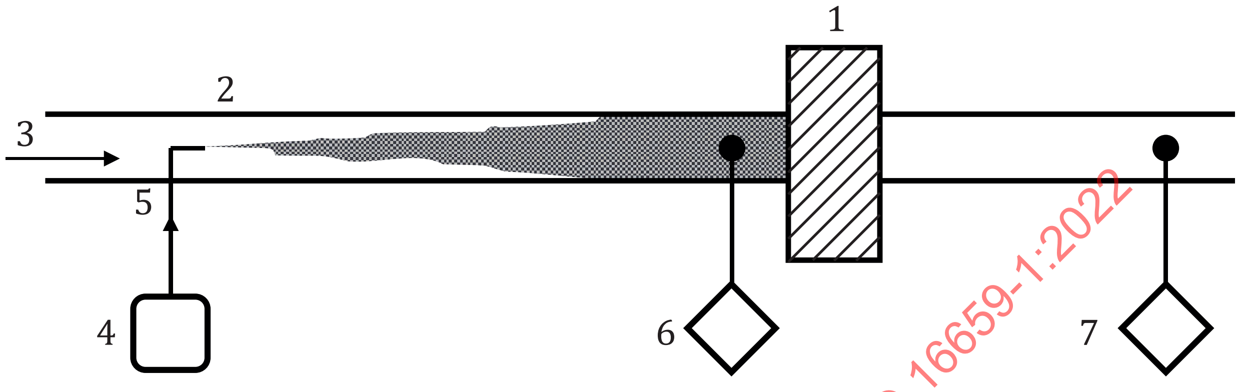
5.1 Method principle

Test methods for iodine traps are usually based on the injection of a gaseous tracer in ventilation ducts upstream of the iodine trap, then measuring (collecting or direct measure) the concentration of the tracer upstream and downstream of the iodine trap (see Figure 2) from sampling in ventilation ducts. The decontamination factor for this gas tracer is calculated and compared to preset criteria.

The decontamination factor f_D is expressed using the formula:

$$f_D = C_{up}/C_{down}$$

where C_{up} and C_{down} are the concentration upstream and downstream.



Key

1 iodine trap to be tested
2 ventilation duct
3 air flow
4 generation of gaseous tracer
5 injection of gaseous tracer
6 upstream direct measure of tracer in duct or sampling of tracer for collection on a test trap (direct or post measure)
7 downstream direct measure of tracer in duct or sampling of tracer for collection on a test trap (direct or post measure)

Figure 2 — General principle for the test methods

The sampling lines shall be designed to capture the gas tracers compatible to the expected efficiency of the filter to be tested.

The test method shall be implementable in situ (adapted and adaptable to the tested ventilation system).

This document does not define a minimum expected decontamination factor, this minimum decontamination factor shall be defined by nuclear operator, in relation with the selected method among the methods defined in the other methods of the series.

HEPA filters are usually implemented upstream of iodine filters, and sometimes downstream of iodine filters. The iodine filters test methods shall be such as the location of the HEPA filters has no influence on the need for representative and qualitative sampling upstream/downstream of the iodine filter.

The capacity range (e.g. efficiency or leakages) of each method should be written in every standard of the series.

5.2 Main considerations

In order to perform adequately the test methods, the following shall be considered for ensuring the homogeneity of the airstream at injection and sampling locations, in consistency with ISO 2889:2021, Clauses 6 and 7:

— the injection point of the tracer gas shall be selected such as to allow a representative sampling or direct measure in duct upstream the iodine trap filter;

— the location of the direct measure in the duct or the sampling lines upstream and downstream of the filter shall be selected in order to ensure an adequate homogeneity of the air stream;

— the sampling system shall be designed to reduce losses of tracer gas such as to quantify the uncertainties induced by these losses.

— the assessment of the uncertainties introduced by the methods (see ISO/IEC Guide 98-3), the sampling points locations, the sampling system itself, and the equipment used for the test shall be performed according to the relevant part of ISO 16659 series.

NOTE In the application of ISO 2889, the requirements related to aerosol particles do not apply here.

Specific additional criteria can be added in the ISO 16659 series standards depending on the influence that the methods may have on the results.

Moreover, the safety of workers (performing the tests or the other workers of the facility), members of the public and the environment shall be considered via adequate provisions, detailed in each part of ISO 16659 series.

5.3 Choice of the tracer gas, choice of the method

The method shall be selected with regards to the objective of the efficiency test itself (e.g. measuring the efficiency in order to compare it with the safety case, or to compare the results with other results, or to demonstrate the results according to a user criterion). In order to compare several tests, the reproducibility of the method has to be acquired.

The tracer gas (radioactive or non-radioactive gas) shall be selected in order to provide adequate information for the methods in terms of efficiency results, as well as the constraints imposed by the layout of the facility or the security of the personnel. The tracer selection shall be made accordingly with the trapping phenomena that are important for the specific test methods and with the different national regulations.

A stable correlation between the tracer gas and the radioactive iodine forms of the nuclear facility shall be established in order to demonstrate the iodine filter efficiency.

The tracer shall be measurable and quantifiable above the background concentration level in the room where the test is performed or in one of the sampled ducts for the situations and conditions for which the efficiency of the trap is requested.

The losses of the selected gas tracer during the test shall be assessed.

6 General requirements for the iodine trap to be tested

6.1 General

Iodine traps covered by this document are made with solid sorbent (e.g. charcoal, carbon fibres, zeolite), which has usually been processed using specific methods regarding impregnation with compounds (e.g. KI, TEDA…).

This sorbent is packed in a casing connected to the ducts of the ventilation system.

The performances of the iodine trap under the facility conditions should be estimated:

— main characteristics of the iodine filter (e.g. impregnated charcoal or zeolite or carbon fibers) versus the trapping phenomena and the influencing factors;

— in-vitro qualified efficiency, or previous results performances;

— safety or user criterion to be achieved.

Beside this, the technical data listed in the corresponding ventilation system and iodine filter data sheets shall be considered, using, when available, the datasheets of the filters' vendors.

6.2 Characteristics of iodine trapping medium

The trapping medium of the on-site iodine traps shall be representative (contact time, apparent density) of the active carbon samples already tested in the laboratory, for which the conditions shall be representative of those of the installed iodine trap on site. The quality of media sample is pre-qualified according to ISO 18417.

Iodine adsorption capacity of the iodine traps shall be higher than the potential iodine releases of the facility in worst accidental scenario.

The implementation of the media inside the iodine trap shall be such that any bypass or leak cannot affect the global media filtration efficiency.

Impregnates such as KI (for isotopic exchange) and TEDA (for chemical sorption) are usually used for improving the performances of the iodine traps.

The mechanical behaviour of the media such as charcoal is generally selected such as it does not degrade over time with regards to aerodynamic (delta P) and efficiency performances.

Iodine traps made with zeolite are characterized in terms of chemical content, and porous sizes.

6.3 Characteristics of the iodine trap housing

The implementation of the iodine trap housing inside the ventilation network shall be such that any bypass or leak cannot affect the global iodine trap filtration efficiency, in particular with regards to housing leaktightness and charcoal tamping.

7 General requirements for the facility in which the iodine trap is tested

7.1 General

Ventilation systems of nuclear facilities are equipped with iodine traps having specific functional purposes. They can have various operation modes as they may have objectives for normal operation circumstances or for accidental circumstances. Supplementary material provisions (e.g. heaters) can also be fitted to ventilation systems.

These facility features can influence the efficiency of iodine traps and the methods implemented to perform the test.

The test methods shall minimize the impact of the tests on the safety functions ensured in the facility, on the workers safety as well as the operational constraints.

The configuration of the facility during the tests shall reproduce stable conditions, in order to allow reproducible tests. Tests shall be performed in conditions that are the most representative of accidental conditions. The influencing parameters important for the planned test method shall be controlled.

Examples of general layout of the iodine filtration systems is indicated in Annex B.

7.2 Preliminary requirements

Before any injection, check that the ventilation circuit is in a test configuration such that no risk is induced by the test and that the activity involved is compatible with authorized discharge limits.

7.3 Conditioning of the ventilation system

As the efficiency of the iodine trap is greatly due to the relative humidity of the air, the conditioning of the ventilation system to achieve hygrometric equilibrium of the trap is important. Nevertheless, if the aim of the test is simply a leak test, the achievement of hygrometric equilibrium is not necessary. On the other hand, for a test to characterize efficiency, it is possible to perform the test even if hygrometric equilibrium is not reached, but comparison between periodic tests loses its pertinence. Finally, depending on the aim and depending on the method, the conditioning of the ventilation system can vary.

The relative humidity of the air in the ventilation system can be either controlled (generally by a thermal contribution making it possible to bring the relative humidity below a given threshold) or uncontrolled. In both cases, it is recommended that the circuit under test be put into service (in particular for heaters) under nominal operating conditions for a sufficient period before injecting the tracer gas. In this way:

— in an installation with controlled relative humidity, the adsorbent of the trap is in a state of equilibrium with respect to the humidity of the incident air, corresponding to a value below the fixed threshold;

— in an installation with uncontrolled relative humidity and if the relative humidity does not undergo significant variations during the conditioning period, the sorbent of the trap is in the equilibrium state corresponding to the relative humidity of the air going through the sorbent.

The comparison of the dew temperature measurements (or of the temperatures making it possible to know them), upstream and downstream of the trap, gives the indication of the hygrometric equilibrium.

In practice, there are three main modes of use for iodine traps in nuclear facilities:

— the trap is used continuously at nominal flow rate with heaters in continuous operation;

— the trap is not used in normal operation but a reduced air flow, which may be heated, goes through it; the trap is connected to the functioning ventilation in accidental situations;

— the trap is isolated in normal operation (it is implemented in a parallel bypassed line) and connected to the functioning ventilation in accidental situations.

If for the first mode the duration of conditioning can be short, the duration of conditioning is longer in the second and even longer for the third one. For iodine trap bypassed in normal operation, the conditioning time has to be analysed regarding the aim and the method of test. The conditioning time can be significant (up to several hours).

7.4 Relative humidity

The measurement of the relative humidity of the air upstream of the trap in the ventilation duct shall be carried out as close as possible to the trap to be controlled (after the heating system if it exists and at the hygrometric equilibrium [difference between relative humidity upstream and downstream]).

Any measurement process with an accuracy of at least ±5 % is acceptable (as an indication for speeds in the duct greater than or equal to 2 m/s, the psychrometric measurement is perfectly suited). Precision could be adapted regarding the aim of the test (leak test for example).

The measurement of the dry temperature and the wet temperature makes it possible to calculate the relative humidity of the air and therefore to determine the dew temperature.

The objective is to put the trap in conditions such as to be as close as possible to a hygrometric equilibrium satisfactory with respect to humidity of the incident air, e.g. by checking that the air dew temperatures, upstream and downstream of the trap, do not differ by more than 1 °C.

It is checked that the trap is in a state of hygrometric equilibrium satisfactory with respect to humidity of the incident air, e.g. by checking that the air dew temperatures, upstream and downstream of the trap, do not differ by more than 1 °C.

7.5 Air flow rate

The efficiency of the iodine trap is partly due to the residence time of the air on the sorbent and the speed of passage. These parameters are directly related to the ventilation air flow.

Air flow rates measured at upstream and downstream of the sampling shall be known and documented at the time of the test. Measurements are performed by a method adapted to the speed of the air in the duct. Taking into account the different corrections specific to each method, the relative error on these measurements shall not exceed 20 %. Regardless, uncertainties shall be quantified on the decontamination factor, regarding the aim of the test and the method.

7.6 Pressure drop of the trap

The value of the pressure drop (read on a suitable differential pressure gauge) allows an approximate verification of the flow rate passing through the trap by comparison with the manufacturer's technical data and gives a guaranty about the good configuration of the ventilation system (important in case of iodine trap normally by-passed).

NOTE A filling method can help to stabilize the pressure drop (for re-fillable filters).

7.7 Representativity of sampling

In consistency with the principles mentioned in 5.2, the sampling lines upstream and downstream of the filter shall be selected in order to ensure a homogeneity of the air stream at the sampling locations in accordance with the specific of ISO 2889:2021, Clauses 6 and 7. Homogeneity is a prerequisite for obtaining reliable and reproducible measurements.

8 General requirements for the safety of workers and members of the public

8.1 Main workers safety provisions

The workers (staff and contractors) may be exposed to risks coming from the facility itself or from the methods used to perform the tests.

Special provisions shall be implemented to protect the workers performing the tests from the risks intrinsic to the facility itself, e.g. if the rooms hosting the iodine filters are in controlled areas. In such a case, the general operational provisions used for the protection of the workers apply. The safety of the workers present inside the facility and who may be exposed to the tracer gas should be optimized by specific provisions that will be detailed in the other parts of ISO 16659 series.

For the methods bringing additional specific risks (e.g. radioactive iodine, chemical risks, fire risks), the specific provisions shall be detailed in the dedicated clauses of the said methods.

Every method eventually used for testing the iodine filters shall be considered such as to minimize the risks for the workers present in the facility. Visual inspection of the housing leaktightness, as well as of the ductwork at positive pressure is a pre-requisite for workers protection when injecting gaseous substances. In particular, the housing shall be inspected such as to check that there are identified leaks from the housing to the room.

Special attention should be paid for supply air systems hosting an iodine filter to be tested, such as the ones equipping the control rooms ventilation systems.

8.2 Main provisions for ensuring safety of members of the public and the environment

The members of the public and the environment may be exposed to risks coming from the facility itself during the tests or from the methods used to perform the tests.

Special provisions shall be implemented to limit the consequences of iodine traps tests on members of the public and the environment during the tests. Therefore, assessments shall be performed in order to implement the provisions limiting the disturbance of the safety functions of the facility (e.g. avoiding the loss of the dynamic confinement function during the tests or putting the facility in a safe state).

For the methods bringing additional specific risks (e.g. radioactive iodine or toxic/carcinogenic products releases), the specific provisions shall be detailed in the dedicated chapters of the said methods.

9 Quality assurance and quality control

According to the importance of removal efficiency of iodine traps in the safety demonstration of nuclear facilities, the required quality level could be adapted to the safety, environment, or security issues.

A report identifying the tested plant, the test equipment used, the test conditions, the modifications brought to the layout in order to perform the tests (e.g. via a procedure), all the measurements and calculations, and the uncertainties assessment shall be issued for every method. The uncertainties shall be addressed using ISO GUM methods[7].

The report is subject to the verification and quality assurance checks.

In addition, every method shall detail and record the specific parameters important for defining, understanding and reporting the results related to the iodine filter efficiency.

The safety related information relevant to the method should be noted in the report (e.g. radioactive or toxic releases due to the tests).

The different methods shall identify the need for reporting the main points to control in order to improve the validity of results, particularly in terms of documentation, calibration, maintenance of the equipment of the test, and the specificities in terms of quality to reach this objective.

Examples of information to be noted in a procedure dependent to each method should be reported in specific informative annexes in each part of ISO 16659 series.

Annex A provides the table of content of the other standards of the series in order to provide a consistent approach of the methods.

Annex C provides a typical example of the information important to be written in test reports of each method; nevertheless, any method should complete the test report with its intrinsic important information.

Annex A
(informative)

Generic table of contents for subsequent parts of ISO 16659

Foreword

Introduction

1 Scope

2 Normative reference

3 Terms and definitions

4 Method

4.1 Scope of the method

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5 Test equipment

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6 Safety of workers, members of the public and the environment

6.1 Facility arrangements

7 Mode of performing the test

7.1 Test preparation

7.2 Test execution

7.3 Other specificities

8 Establishing the result

8.1 Expressing the result

8.2 Accuracy of the result

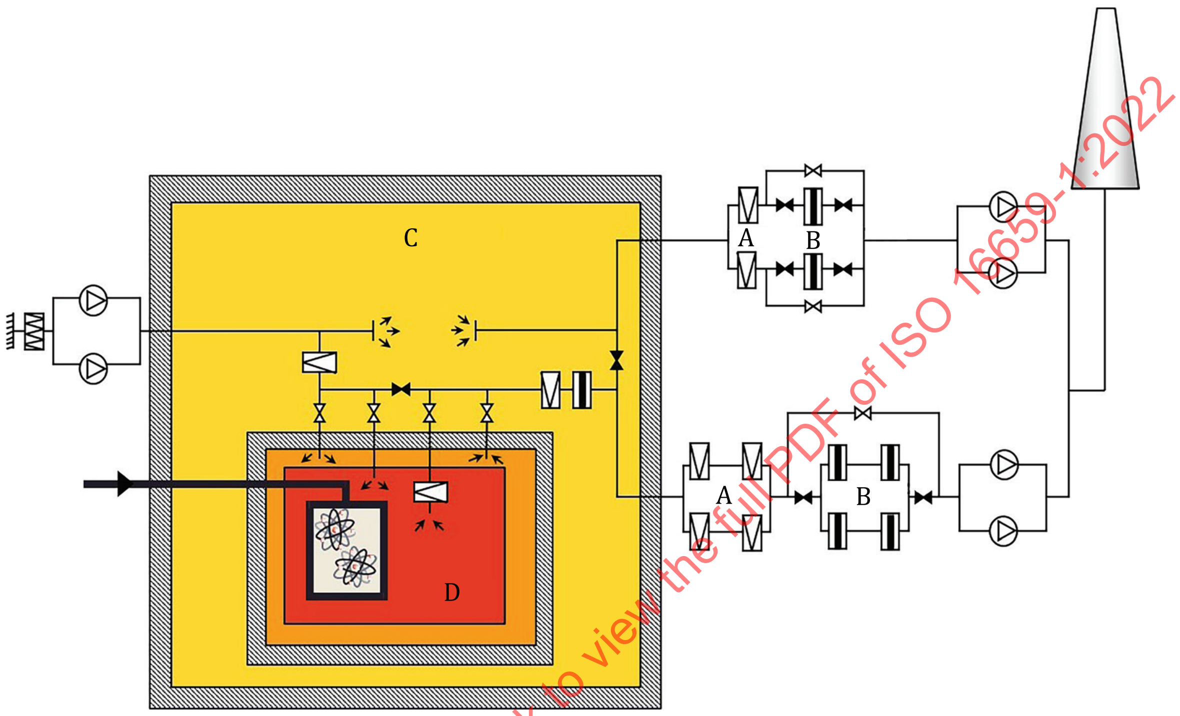
8.3 Evaluation and test report

ANNEX 1 OF THE GENERIC TEMPLATE : (informative) Schematic layout of the method of test

ANNEX 2 OF THE GENERIC TEMPLATE : (informative) Example text for test report

Annex B
(informative)

Examples of facility layout for iodine filters



Key

A HEPA

B iodine trap

C nuclear building

D glove box

Figure B.1 — Example of a nuclear facility with iodine traps under negative pressure on the exhaust ventilation system

This type of configuration layout (see Figure B.1) allows any type of tests, with or without radioactive tracer gases, since the injected product is under negative pressure and released to the environment after monitoring.