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Sampling airborne radioactive materials from the stacks and ducts of nuclear facilities

Échantillonnage de substances radioactives en suspension dans l'air dans les émissaires de rejet et les conduits des installations nucléaires

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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 of 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 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, *Radiation protection*.

This third edition cancels and replaces the second edition (ISO 2889:2010), which has been technically revised. The main changes are:

— clarification of the circumstances where numerical modelling may be used to perform or assist with meeting the qualifications for sample extraction locations;

— clarification of passages allowing the use of alternate aerosol particle sizes for the purpose of testing to meet various performance criteria described in this document;

— changes for the discussion of standard uncertainty with regard to setting action levels (Annex I).

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

Introduction

This document focuses on monitoring the activity concentrations and activity releases of radioactive substances in air in stacks and ducts. Other situations for monitoring the activity concentrations and activity releases of radioactive substances in air (environmental or workplace monitoring) are being addressed in subsequent standards. This document provides performance-based criteria for the use of air-sampling equipment, including probes, transport lines, sample collectors, sample monitoring instruments and gas flow measuring methods. This document also provides information covering sampling programme objectives, quality assurance, development of air monitoring control action levels, system optimization and system performance verification.

ISO 2889 was first published in 1975 as a guide to sampling airborne radioactive materials in the ducts, stacks, and working environments of installations where work with radioactive materials is conducted. Since then, an improved technical basis has been developed for each of the major sampling specialities. The focus of this document is on the sampling of airborne radioactive materials in ducts and stacks.

The goal of achieving an unbiased, representative sample is best accomplished where samples are extracted from airstreams in which potential airborne contaminants are well mixed in the airstream. This document sets forth performance criteria and recommendations to assist in obtaining valid measurements of the concentration of airborne radioactive materials in ducts or stacks.

Sampling airborne radioactive materials from the stacks and ducts of nuclear facilities

1 Scope

This document sets forth performance-based criteria and recommendations for the design and use of systems for sampling of airborne radioactive materials in the effluent air from the ducts and stacks of nuclear facilities.

The requirements and recommendations of this document are aimed at sampling that is conducted for regulatory compliance and system control. If existing air-sampling systems are not designed to the performance requirements and recommendations of this document, an evaluation of the performance of the system is advised. If deficiencies are discovered, a determination of whether or not a retrofit is needed and practicable is recommended.

It can be impossible to meet the requirements of this document in all conditions with a sampling system designed for normal operations only. Under off-normal conditions, the criteria or recommendations of this document still apply. However, for accident conditions, special accident air sampling systems or measurements can be used.

This document does not address outdoor air sampling, radon measurements, or the surveillance of airborne radioactive substances in the workplace of nuclear facilities.

NOTE Reference [1] addresses the instrumentation that is frequently used in nuclear air monitoring. Reference [5] addresses air sampling in the workplace of nuclear facilities. References [6] and [7] describe the performance characteristics of air monitors.

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 10780:1994, *Stationary source emissions — Measurement of velocity and volume flowrate of gas streams in ducts*

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
abatement equipment
apparatus used to reduce contaminant concentration in the airflow exhausted through a stack or duct

3.2
absorbent
material that takes up a constituent through the action of diffusion, allowing the constituent to penetrate into the structure of the absorbent (if a solid) or dissolve in it (if a liquid)

Note 1 to entry: When a chemical reaction takes place during absorption, the process is called chemisorption.

3.3
accident (conditions)
any unintended event, including operating errors, equipment failures and other mishaps, the consequences or potential consequences of which are not negligible from the point of view of protection and safety

3.4
accuracy
closeness of agreement between a measured quantity and the true quantity of the measurand

3.5
action level
threshold concentration of an effluent contaminant at which it is necessary to perform an appropriate action

3.6
adsorbent
material, generally a solid, that retains a substance contacting it through short-range molecular forces that bind the adsorbed material at the surface of the material

3.7
aerodynamic diameter
D_a
for a particle of arbitrary shape and density, the diameter of a sphere with density 1 000 kg/m^3 that has the same sedimentation velocity in quiescent air as the arbitrary particle

3.8
aerosol
dispersion of solid or liquid particles in air or other gas

Note 1 to entry: An aerosol is not only the aerosol particles.

3.9
aerosol, monodisperse
aerosol (3.8) comprised of (solid or liquid) particles that are all of approximately the same size

Note 1 to entry: In general, the geometric standard deviation of the particle-size distribution of a monodisperse aerosol is less than or equal to 1,1.

3.10
aerosol, polydisperse
aerosol (3.8) comprised of particles with a range of sizes

Note 1 to entry: In general, the geometric standard deviation of the particle-size distribution of a polydisperse aerosol is greater than 1,1.

3.11
aerosol particle
solid or liquid particle constituents of an *aerosol* (3.8)

3.12
analyser
device that provides for near real-time data on radiological characteristics of the gas (air) flow in a sampling system or duct

Note 1 to entry: An analyser usually evaluates the concentration of radionuclides in a sampled air stream. However, some analysers are mounted directly in or outside a stack or duct.

3.13
aspiration ratio
ratio of particle mass or number concentration in the nozzle inlet to the concentration in the free stream

3.14
bend
gradual change in direction of a sample transport line

Note 1 to entry: The radius of curvature of a bend should be at least three times the inside diameter of the tubing.

3.15
bulk stream
air flow in a stack or duct, as opposed to the sample flow rate

3.16
burial
imbedding of a particle into a filter medium or the masking of a particle by subsequent deposits of particulate matter

3.17
calibration
operation that, under specified conditions, initially establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and then uses this information to establish a relation for obtaining a measurement result from an indication

3.18
coefficient of variation
C_V
quantity that is the ratio of the standard deviation of a variable to the mean value of that variable

Note 1 to entry: It is usually expressed as a percentage.

3.19
collector
component of a sampling system that is used to retain radionuclides for analysis

EXAMPLE A filter that is used to remove from a sample stream aerosol particles that carry alpha-emitting transuranic radionuclides or other radionuclides.

3.20
conditioning system
apparatus that can be used to purposefully, in a controlled manner, change the *aerosol particle* (3.11) concentration, gas composition, *particle-size distribution* (3.53), temperature or pressure in a *sample stream* (3.68)

3.21
continuous air monitor
CAM
near-real-time sampler and associated detector that provide data on radionuclides [e.g. concentration of alpha-emitting *aerosol particle* (3.11)] in a *sample stream* (3.68)

3.22
continuous monitoring
continuous near-real-time measurements of one or more sampling characteristics

3.23
continuous sampling
either uninterrupted sampling or sequential collection of samples obtained automatically at intervals short enough to yield results that are representative for the entire sampling period

Note 1 to entry: The sample may be analysed in near-real-time (i.e. equivalent to monitoring) or it may be analysed post-sample-collection in a remote laboratory.

3.24
curvature ratio
ratio of bend radius to the tube diameter

3.25
depositional loss
loss of constituents of the sample on the internal walls of a sampling system

Note 1 to entry: See also 3.84.

3.26
decision threshold
value of the estimator of the measurand, which, when exceeded by the result of an actual measurement using a given measurement procedure of a measurand quantifying a physical effect, is used to decide that the physical effect is present

Note 1 to entry: The decision threshold is defined such that in cases where the measurement result exceeds the decision threshold, the probability that the true value of the measurand is zero is less or equal to a chosen probability for a wrong decision, α.

[SOURCE: ISO 11929-1:2019, 3.12 modified – definition identical, but Note 1 to entry changed and Note 2 to entry not included here.]

3.27
detection limit
smallest true value of the measurand which ensures a specified probability of being detectable by the measurement procedure

Note 1 to entry: With the *decision threshold* (3.26), the detection limit is the smallest true value of the measurand for which the probability of wrongly deciding that the true value of the measurand is zero is equal to a specified value, when, in fact, the true value of the measurand is not zero.

[SOURCE: ISO 11929-1: 2019, 3.13 modified – definition identical, but last sentence of Note 1 to entry not included here as well as Note 2 to entry.]

3.28
droplet
liquid *aerosol particle* (3.11)

3.29
effective dose
sum of the products of the dose absorbed by an organ or a tissue and the factors relative to the radiation and to the organs or tissues that are irradiated

3.30
effluent
waste stream flowing away from a process, plant, or facility to the environment

Note 1 to entry: This document applies to the effluent air that is discharged to the atmosphere through stacks and ducts.

3.31
emission
contaminants that are discharged into the environment

3.32
emit
discharge contaminants into the environment

3.33
extractive sampling
diverting a part of the airflow from a stack or duct for the purpose of the collection of a sample of the air

Note 1 to entry: See 3.69 and 3.72.

3.34
flow rate
rate at which a mass or volume of gas (air) crosses an imaginary cross-sectional area in either a sampling system tube or a stack or duct

Note 1 to entry: The rate at which the volume crosses the imaginary area is called the volumetric flow rate and the rate at which the mass crosses the imaginary area is called either the mass flow rate or the volumetric flow rate at standard conditions.

3.35
geometric mean of a variable
x_g
value for N observations of a random variable x_i given by

$$\ln x_g = \frac{1}{N}\sum_{i=1}^{N} \ln x_i$$

3.36
geometric standard deviation
s_g
the geometric standard deviation for N observations of a random variable, x_i, calculated from:

$$\ln^2 s_g = \frac{1}{N-1}\sum_{i=1}^{N} \left(\ln x_i - \ln x_g\right)^2$$

where x_g is the geometric mean of the random variable

3.37
high-efficiency particulate air filter
HEPA filter
high-efficiency filter used for removing *aerosol particles* (3.11) from an air stream

Note 1 to entry: A HEPA filter usually collects aerosol particles at the most penetrating particle size (between 0,1 µm and 0,3 µm diameter) with a high efficiency and is designed to collect greater fractions of aerosol particles with diameters either larger or smaller. The minimum efficiency of a HEPA filter is not defined in this document.

3.38
hydraulic diameter
type of equivalent duct diameter for ducts that do not have a round cross-section

Note 1 to entry: Generally, it is four times the cross-sectional area divided by the perimeter.

3.39
impaction
process by which *aerosol particles* (3.11) are removed from an air stream by striking an object in the air stream

Note 1 to entry: Curvature of air streamlines, principally on the front side of the object, causes particles with sufficient inertia to strike the object while the airflow passes around it.

3.40
in-line system
system where the detector assembly is adjacent to, or immersed in, the *effluent* (3.30) stream or stream in the duct or stack

3.41
interception
process by which *aerosol particles* (3.11) are removed from an air stream by an object in the flow, where the trajectory of the particle's centre of gravity misses the object but the body of the particle strikes the object

3.42
isokinetic
condition that prevails when the velocity of air at the inlet plane of a nozzle is equal to the velocity of undisturbed air in a stack or duct at the point where the nozzle inlet is located

Note 1 to entry: Anisokinetic is the antonym of isokinetic. Sub-isokinetic refers to the condition where the nozzle inlet velocity is less than the free-stream velocity. Super-isokinetic refers to the condition where the nozzle inlet velocity is greater than the free-stream velocity.

3.43
laminar flow
flow regime in stacks or ducts associated with Reynolds numbers less than about 2 200

Note 1 to entry: This regime is not usually encountered in effluent air flows. Mixing in laminar flow results from molecular diffusion, which is a much slower process than mixing in turbulent flow.

3.44
membrane filter
filter medium consisting of thin, organic-based films having a range of selectable porosities and controlled composition

Note 1 to entry: Thin, porous metallic filters are sometimes also called membrane filters.

3.45
mixing element
device placed in a stack or duct that is used to augment the mixing of the contaminant mass with the fluid

3.46
monitoring
continual measurement of a quantity (e.g. activity concentration) of the airborne radioactive constituent or the gross content of radioactive material, at a frequency that permits an evaluation of the value of that quantity in near-real-time, or at intervals that comply with regulatory requirements

3.47
nozzle
device used to extract a sample from an *effluent* (3.30) stream and transfer the sample to a transport line or collection device

Note 1 to entry: Within the nozzle, there is a transition zone where the sample stream adjusts to the conditions in the transport line.

3.48
nozzle exit (plane)
imaginary plane across the cross-section of a transport system that divides the nozzle region from the transport line

Note 1 to entry: The nozzle is frequently a separate component and the nozzle exit plane is clearly defined as the downstream end of that component. If there is no separate component, the nozzle exit is the end of the transition zone of the nozzle flow.

3.49
nozzle inlet (plane)
imaginary cross-sectional inlet plane of a nozzle where the flow first enters the transport system

Note 1 to entry: In the special case of a shrouded nozzle, the inlet is referenced to the inner nozzle rather than the shroud.

3.50
number size distribution
representation of the number of particles associated with intervals of particle size, over the full size range encountered in a sample

Note 1 to entry: For samples consisting of aerosol particles, it is a representation of the relative number of particles (measured number of particles in a size interval divided by the total number of particles in the sample) associated with intervals of aerodynamic diameter.

3.51
off-normal condition
condition that is unplanned and which presents a gap with normal conditions

EXAMPLE Accidents and equipment failure.

3.52
particle
aggregate of molecules, forming a solid or liquid, ranging in size from a few molecular diameters to several millimetres

3.53
particle-size distribution
distribution of *particle* (3.52) size as a function of mass or activity rather than number

3.54
penetration
ratio of the concentration at the outlet of the sampling system, transport lines included, to that in the duct or at the stack

3.55
potential emission
radionuclides that can be released to the environment from a facility in the absence of control equipment

3.56
precision
closeness of agreement between indications obtained by replicate measurements on the same or similar objects under specified conditions.

Note 1 to entry: A value of precision is obtained by repetitive testing of a homogenous sample under specified conditions. The precision of a method is expressed quantitatively as either the standard deviation computed from the results of a series of controlled determinations or as the coefficient of variation of the measurements.

3.57
probe
tubing or apparatus inserted into a stack or duct through which a sample of the stream is withdrawn

Note 1 to entry: A probe usually refers to one or more nozzles and part of the transport line.

3.58
profile
distribution of air velocity, of gas concentration or of *particle* (3.52) concentration over the cross-sectional area of the stack or duct

3.59
quality assurance
QA
planned and systematic actions necessary to provide confidence that a system or component performs satisfactorily in service and that the results are both correct and traceable

3.60
radionuclide
unstable isotope of an element that decays or converts spontaneously into another isotope or different energy state, emitting radiation

3.61
record sample
sample that is collected for reporting purposes

Note 1 to entry: Record samples are often analysed off-line.

3.62
reference method
apparatus and instructions for providing results against which other approaches may be compared

Note 1 to entry: The application of a reference method is assumed to define correct results.

3.63
representative sample
sample with the same quality and characteristics for the material of interest as that of its source at the time of sampling

3.64
response time
time required after a step variation in the measured quantity for the output signal variation to reach a given percentage for the first time, usually 90 %, of its final value

3.65
sample
portion of an air stream of interest or one or more separated constituents from a portion of an air stream

3.66
sample-extraction location
location in a stack or duct that coincides with the *sample* (3.65) *nozzle inlet* (3.49)

Note 1 to entry: By extension from the nozzle inlet, the entire plane that is perpendicular to the longitudinal axis of a stack or duct.

3.67
sampler
device that collects or analyses constituents of the air *sample* (3.65)

3.68
sample stream
air that flows through a sampling system

3.69
sampling
process of removing a *sample* (3.65) from the free air and transporting it to a *collector* (3.19) or an *analyser* (3.12) (monitor)

3.70
sampling environment
conditions of the air flow and gas within a stack or duct that can influence the sampling process

Note 1 to entry: Factors to take into account include pressure, temperature and molecular composition of the gas.

3.71
sampling plane
cross-sectional area where the *sample* (3.65) is extracted from the air flow

3.72
sampling system
system consisting of a nozzle, an inlet, a transport line, a flow *conditioning system* (3.20) and a *collector* (3.19) or monitor

Note 1 to entry: A flow conditioning system may be used to change concentration, temperature, humidity, or other characteristics. Depending upon the application, a flow conditioner might not be used in the sampling system.

3.73
sedimentation velocity
terminal (maximum) velocity an *aerosol particle* (3.11) attains in quiescent fluid (air) as a result of the gravitational force

3.74
sensitivity
change in indication of a mechanical, nuclear, optical or electronic instrument as affected by changes in the variable quantity being sensed by the instrument

Note 1 to entry: This is the slope of a calibration curve of an instrument, where a calibration curve shows output values of an instrument as a function of input values.

3.75
shroud
aerodynamic decelerator placed around and extending beyond a sampling nozzle to reduce sampling biases

3.76
standard conditions
temperature of 25 °C and a pressure of 101,325 kPa

Note 1 to entry: Used to convert air densities to a common basis. Other temperature and pressure conditions may be used but should be applied consistently.

3.77
transmission ratio
ratio of the *aerosol particle* (3.11) concentration at the nozzle outlet to that in the free stream

Note 1 to entry: It is stated whether a mass or activity basis is used.