INTERNATIONAL STANDARD

ISO 20041-1

First edition
2022-07

Tritium and carbon-14 activity in gaseous effluents and gas discharges of nuclear installations —

Part 1: Sampling of tritium and carbon-14

Activité du tritium et du carbone 14 dans les effluents gazeux et les rejets gazeux des installations nucléaires —

Partie 1: Prélèvement du tritium et du carbone 14

Reference number
ISO 20041-1:2022(E)

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Foreword

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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 20041 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

Discharges from nuclear installations are subject to regulatory requirements established by various regulatory bodies. Rigorous control of the discharges is implemented by the facility operations within the framework of water and air discharge permits. This control is carried out from commissioning of the installation and throughout its entire lifetime. In particular, this involves making measurements of the physical, chemical and radioactivity characteristics in the gaseous and liquid effluents. The decommissioning of these nuclear installations also generates liquid and gaseous effluents that should be characterized and quantified before their discharge.

Tritium and carbon-14 are usually present in the gaseous effluents of nuclear power plants and other types of nuclear installations. ISO 2889 presents the methods and provisions for sampling airborne substances from the exhaust stacks of nuclear facilities. The provisions defined therein cover all physical forms of the materials present in gaseous effluents: aerosol particles, vapours and gases. These provisions are more restrictive for radioactive aerosol particle measurements, given greater possibilities of losses in the transport lines.

Therefore, ISO 20041 goes further by addressing, in detail, the provisions specific to sampling methods, and sample preparation and calculations for determining the tritium and carbon-14 emissions. ISO 20041-1 covers the sampling methods or techniques for tritium and carbon-14. The future ISO 20041-2 will cover activity analysis of tritium and carbon-14 sampled by the bubbling technique and the future ISO 20041-3 will cover the activity analysis of tritium and carbon-14 sampled by molecular sieve.

Tritium and carbon-14 activity in gaseous effluents and gas discharges of nuclear installations —

Part 1: Sampling of tritium and carbon-14

1 Scope

This document presents the methods and provisions for sampling tritium and carbon-14 in the gaseous effluents generated by nuclear facilities during operation and decommissioning. Specifically included are sample withdrawal location, extraction, transport flow measurement, and collection for later analysis.

This document doesn't address to real time measurements of tritium activity and carbon-14 activity in the effluent air of stacks and ducts. Information about real time measurements can be found in ISO 2889:2021, Annex H.

Sample processing, analysis and calculations of tritium and carbon-14 emissions will be addressed in future parts of ISO 20041.

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

ISO 5667-3, *Water quality — Sampling — Part 3: Preservation and handling of water samples*

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 terminology 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
absolute humidity
mass of water per unit volume of moist air

3.2
activity
average number of disintegrations per second of a radionuclide

Note 1 to entry: The activity a is expressed in Becquerels (Bq).

Note 2 to entry: The discharged activity is calculated by multiplication of the activity concentration c and the discharged volume V.

3.3
activity concentration
activity (3.2) per unit volume of the *sample* (3.22)

Note 1 to entry: Activity concentration c is expressed in Becquerel per cubic meter ($Bq \cdot m^{-3}$) or in Becquerel per litre ($Bq \cdot l^{-1}$ or $Bq \cdot L^{-1}$).

3.4
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

[SOURCE: ISO 2889:2021, 3.6]

3.5
aerosol
dispersion of solid or liquid particles in air or other gas

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

[SOURCE: ISO 2889:2021, 3.8]

3.6
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.

[SOURCE: ISO 2889:2021, 3.18]

3.7
collector
component of a *sampling system* (3.27) that is used to retain radionuclides for analysis

[SOURCE: ISO 2889:2021, 3.19, modified — The example was deleted.]

3.8
continuous measurement
real-time and in situ measurement of the characteristics of an *effluent* (3.11) without waiting and without conditioning and transport operations for the *sample* (3.22)

3.9
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 of a wrong decision, namely that the true value of the measurand is not zero if in fact it is zero, is less or equal to a chosen probability α.

Note 2 to entry: If the result is below the decision threshold, it is decided to conclude that the result cannot be attributed to the physical effect; nevertheless, it cannot be concluded that it is absent.

[SOURCE: ISO 11929-1:2019, 3.12]

3.10
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, 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, β, when, in fact, the true value of the measurand is not zero. The probability of being detectable is consequently $(1 - \beta)$.

[SOURCE: ISO 11929-1:2019, 3.13]

3.11
effluent
exhaust (waste) stream beginning at the ventilated air space and flowing away from a process, plant, or facility to the environment

Note 1 to entry: A gaseous effluent is a fluid conveyed by a gas vector and may consist of gas, dust and/or particulates. In this document, the focus is on the gaseous and vaporous constituents of a gaseous effluent.

Note 2 to entry: An effluent can be subject to treatments, filtration, storage, recycling, controls and/or monitoring; and strict and regulated management. An effluent can be eliminated by dispersion into the receiving medium from a production site or within the immediate vicinity.

Note 3 to entry: The ventilated air space is the plane of entry of the effluent where the duct connects to a hood or snorkel or room vent.

[SOURCE: ISO 2889:2021, 3.30, modified — Modification in definition and additional Notes to entry.]

3.12
effluent sampling
action that involves taking one or more *samples* (3.22) of *effluent* (3.11)

3.13
flow rate
rate at which a mass or volume of gas (air) crosses an imaginary section in either a *sampling system* (3.27), 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; the rate at which the mass crosses the imaginary area is called either the mass flow rate or volumetric flow rate under standard conditions.

[SOURCE: ISO 2889:2021, 3.34]

3.14
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.

[SOURCE: ISO 2889:2021, 3.38]

3.15
nozzle
device used to extract a *sample* (3.22) from an *effluent* (3.11) stream and transfer the *sample* (3.22) to a *transport line* (3.31) 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. The nozzle is frequently a separate component and the nozzle exit plane is clearly defined as the downstream end of that component.

Note 2 to entry: The nozzle inlet corresponds to the imaginary cross-sectional inlet plane of a nozzle where the air stream first enters the transport system. In the special case of a shrouded nozzle, the inlet plane shall be taken as that of the nozzle and not that of the shroud.

Note 3 to entry: The nozzle exit (plane) is an imaginary plane across the cross-section of a transport system that divides the nozzle region from the transport line. If there is no separate component, the nozzle exit corresponds to the end of the transition zone of the nozzle air stream.

[SOURCE: ISO 2889:2021, 3.47, 3.48, 3.49]

3.16
off-line measurement
measurement of the characteristics of an *effluent* (3.11) *sample* (3.22) requiring either a waiting time before the measurement or conditioning and transport operations for the *sample* (3.22)

3.17
penetration
ratio of the concentration at the outlet of the *sampling system* (3.27), *transport lines* (3.31) included, to that in the duct or the stack

[SOURCE: ISO 2889:2021, 3.54]

3.18
probe
tubing or apparatus inserted into a stack or duct through which a *sample* (3.22) of the stream is withdrawn

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

Note 2 to entry: Sometimes used colloquially to refer to the equipment inserted into a stack or duct for measurement of volumetric flow or amount of activity present.

[SOURCE: ISO 2889:2021, 3.57, modified — An additional Note 2 to entry was added.]

3.19
recording
action that fixes measurement data on a material support for their conservation

3.20
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 ensure correct results.

[SOURCE: ISO 2889:2021, 3.62]

3.21
representative sample
sample (3.22) with the same quality and characteristics for the material of interest as that of its source at the time of *sampling* (3.25)

[SOURCE: ISO 2889:2021, 3.63]

3.22
sample
portion of an air stream of interest, or one or more collected constituents from a portion of an air stream of interest

Note 1 to entry: The volume of the portion of the air stream has to be known.

[SOURCE: ISO 2889:2021, 3.65, modified — Note 1 to entry was added.]

3.23
sample-extraction location
sampling location
location of extraction of a *sample* (3.22) from the air

Note 1 to entry: Location of inlet of the sampling system.

[SOURCE: ISO 2889:2021, 3.66, modified — Definition and Note 1 to entry were modified.]

3.24
sampler
device that collects or analyses constituents of the air *sample* (3.22)

[SOURCE: ISO 2889:2021, 3.67]

3.25
sampling
process of collecting constituents from the air stream of interest on media such as filters, absorbents or *adsorbents* (3.4) and transporting them to a *collector* (3.7) or monitor for analysis or a container

3.26
sampling environment
conditions of the gas and airflow within a stack that can influence the *sampling* (3.25) process

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

[SOURCE: ISO 2889:2021, 3.70]

3.27
sampling system
system consisting of an inlet, a *transport line* (3.31), a flow conditioning system and a *collector* (3.7) or monitor

Note 1 to entry: Depending upon the application, a flow conditioner might not be used in the sampling system.

Note 2 to entry: Record samples are usually analysed off-line in a laboratory.

[SOURCE: ISO 2889:2021, 3.72, modified — An additional Note 2 to entry was added.]

3.28
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, when this calibration curve shows output values of an instrument as a function of input values.

[SOURCE: ISO 2889:2021, 3.74]

3.29
stack
duct, channel or chimney for the dispersion and dilution of discharges into the environment

3.30
standard conditions
temperature of 298 K (25 °C) and a pressure of 101 325 Pa

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

[SOURCE: ISO 2889:2021, 3.76]

3.31
transport line
part of a *transport system* (3.32) between the *nozzle* (3.15) exit plane and the inlet plane of a *collector* (3.7) or analyser

[SOURCE: ISO 2889:2021, 3.78]

3.32
transport system
all components of a *sampling system* (3.27), excluding the *collector* (3.7) or analyser

[SOURCE: ISO 2889:2021, 3.79]

3.33
vapour
gaseous form of materials that are liquids or solids at room temperature, as distinguished from non-condensable gases

Note 1 to entry: Vapours are gases but carry the connotation of having been released or volatilized from liquids or solids.

[SOURCE: ISO 2889:2021, 3.83]

3.34
velocity profile
distribution of the velocity values at a given cross-section in a stack or duct

[SOURCE: ISO 2889:2021, 3.84]

3.35
volatile
material having a high vapour pressure, which allows significant quantities of material to become gaseous at prevailing temperature

Note 1 to entry: In this document, the stack temperature is generally considered as the reference temperature.

[SOURCE: ISO 2889:2021, 3.85]

4 Symbols

Symbols that are used in formulae in this document are defined below.

A	Cross sectional area of a stack or duct, in m^2
A_i	Cross sectional area of a stack or duct at the midpoint of the i^{th} element, in m^2
C_{af}	Velocity-averaging correction factor for determining flow rate in a stack or duct from a line average velocity taken with an acoustic flow meter, dimensionless
C_{pt}	Velocity-averaging correction factor for determining flow rate in a stack or duct from a single-point reading with a Pitot tube, dimensionless
C_{ta}	Velocity-averaging correction factor for determining flow rate in a stack or duct from a single-point reading with a thermal anemometer, dimensionless
H_r	Relative humidity, dimensionless
M	Molar mass, in kg·mol^{-1}
M_v	Molar mass of water vapour equal to 0,018 kg·mol^{-1}

N	Number of intervals or elements, dimensionless
p	Pressure, in Pa
p_{std}	Standard pressure equal to 101 325 Pa
p_{SV}	Saturation vapour pressure at a known temperature, in Pa
q	Volumetric flow rate, in $m^3 \cdot s^{-1}$
q_a	Volumetric flow rate at actual conditions, in $m^3 \cdot s^{-1}$
q_{std}	Volumetric flow rate at standard conditions, in $m^3 \cdot s^{-1}$
q_t	Tracer injection flow rate, in $m^3 \cdot s^{-1}$
R	Individual gas constant for a particular gas (equal to R_u/M), in $J \cdot kg^{-1} \cdot K^{-1}$
R_a	Gas constant for air equal to 287 $J \cdot kg^{-1} \cdot K^{-1}$
R_u	Universal gas constant equal to 8,314 $J \cdot mol^{-1} \cdot K^{-1}$
T	Temperature, in K or °C
T_{std}	Standard temperature equal to 298 K (25 °C)
t_s	Sampling period, in s
V	Volume of effluent that produced the sample at stream temperature, pressure, and gas composition, in m^3
V_a	Total volume of gas (air) sampled at actual conditions, in m^3
V_{std}	Total volume of gas (air) sampled at standard conditions, in m^3
v	Velocity, in $m \cdot s^{-1}$
v_i	Velocity at the midpoint of the i^{th} element, in $m \cdot s^{-1}$
v_{std}	Equivalent velocity at standard conditions, in $m \cdot s^{-1}$
$v_{std,\ i}$	Equivalent velocity at standard conditions at the midpoint of the i^{th} element, in $m \cdot s^{-1}$
ρ	Density, in $kg \cdot m^{-3}$
ρ_{std}	Density of air at standard conditions equal to 1,184 $kg \cdot m^{-3}$
ρ_v	Absolute humidity, in $kg \cdot m^{-3}$

5 Sampling location

5.1 General

The sampling location shall provide the possibility to extract a representative sample.

A representative sample is best extracted from a location where the radioactive materials of interest are well mixed within the free stream. The term "well mixed" addresses several criteria that are given in 5.3. The designer should design the ventilation system to provide a favourable location where the sample can be extracted from a well-mixed stream (see 5.4). In this case, the sampling probe may contain a single nozzle. In circumstances where the well mixed criteria are not achieved, a multi-nozzle