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Measurement of radioactivity — Alpha-, beta- and photon emitting radionuclides — Reference measurement standard specifications for the calibration of surface contamination monitors

Mesurage de la radioactivité — Radionucléides émetteurs alpha, bêta et photoniques — Spécifications des étalons de référence pour l'étalonnage des contrôleurs de contamination de surface

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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 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 85, *Nuclear energy*, Subcommittee SC 2, *Radiological protection*.

This fourth edition cancels and replaces the third edition (ISO 8769:2016), which has been technically revised. The changes compared to the previous edition are as follows:

— In order to maintain consistency with terms described in the International Vocabulary of Metrology or ISO/IEC 17025[16], "reference measurement standard", "working measurement standard" and "transfer measurement device" were adopted respectively instead of a "reference source", "working source" and "reference transfer instrument".

— 5.1 b): "a surface layer of thickness equal to the saturation layer thickness" was modified to "a surface layer of thickness equal to or less than the saturation layer thickness".

— 5.2.3 and 5.3.3: The statement of "minus its relative standard uncertainty" was removed.

— 5.4.3: Requirement for the re-measurement of uniformity was added as follows; "In case that significant change not due to half-life is found on the re-calibration of surface emission rate, re-measurement of uniformity is required."

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

Radioactive contamination of surfaces can result from spilling, splashing, or leakage from unsealed sources, or breakage or loss of integrity of sealed sources. It can lead to the spread of contamination, loss of quality control and can give rise to the following health hazards:

a) external exposure to parts of the body in proximity to the contaminated surface;

b) internal exposure through incorporation of radioactive material emanating from the surface.

The need for effective monitoring of surface contamination has long been recognized, see Reference [1]. Surface contamination is quantified in terms of activity per unit area, the quantity which is normally used to specify “derived limits”, i.e. maximum limits of surface contamination. These limits are based on radiological protection considerations and have been derived from the dose equivalent or intake limits recommended by the International Commission on Radiological Protection (ICRP), see References [2] and [3]. Derived limits are incorporated into numerous national and international regulatory documents which relate specifically to surface contamination monitoring.

The requirement for this document originated from the need for calibration measurement standards in International Standards dealing with the calibration of surface contamination monitors.

While regulatory documents refer to surface contamination in terms of activity per unit area, the response of monitoring instruments is related directly to the radiation emitted from the surface rather than to the activity contained upon or within the surface. Due to variations in the absorptive and scattering properties of real surfaces, it cannot be assumed, in general, that there is a simple, known relationship between surface emission rate and activity. Thus, there emerges a clear need for calibration measurement standards that are specified primarily in terms of surface emission rate, as well as activity. The manner in which these standards are used and the associated calibration protocols vary from country to country[4].

Calibration of an instrument in terms of activity for the types of surfaces that are usually encountered in monitoring situations depends on the following considerations:

— mixture and ratios of radionuclides being monitored;

— their types and abundances of emissions;

— nature of the surface;

— depths and distribution profiles within the surface;

— spectral attenuation dependence of the instrument entrance window;

— distance between the instrument entrance window and the surface.

The derivation of appropriate calibration factors in terms of activity is therefore a highly complex process which is outside the scope of this document. Appropriate guidance on this process is addressed in ISO 7503 (all parts)[5]. However, some estimate of the activity of the calibration measurement standard is required for general radiological safety purposes such as handling, leak testing, shielding, packaging, and transport. This is a generic issue for all radioactive sources regardless of their intended use and is not therefore addressed specifically in this document.

Traceability of calibration measurement standards to International Standards or national standards is established by a system of reference transfer instruments.

Measurement of radioactivity — Alpha-, beta- and photon emitting radionuclides — Reference measurement standard specifications for the calibration of surface contamination monitors

1 Scope

This document specifies the characteristics of reference measurement standards of radioactive surface contamination, traceable to national measurement standards, for the calibration of surface contamination monitors. This document relates to alpha-emitters, beta-emitters, and photon emitters of maximum photon energy not greater than 1,5 MeV.

It does not describe the procedures involved in the use of these reference measurement standards for the calibration of surface contamination monitors. Such procedures are specified in IEC 60325[6], IEC 62363[7], and other documents.

NOTE Since some of the proposed photon standards include filters, the photon standards are to be regarded as reference measurement standards of photons of a particular energy range and not as reference measurement standards of a particular radionuclide. For example, a ^{241}Am source with the recommended filtration does not emit from the surface the alpha particles or characteristic low-energy L X-ray photons associated with the decay of the nuclide. It is designed to be a reference measurement standard that emits photons with an average energy of approximately 60 keV.

This document also specifies preferred reference radiations for the calibration of surface contamination monitors. These reference radiations are realized in the form of adequately characterized large area sources specified, without exception, in terms of surface emission rate and activity which are traceable to national standards.

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 12749-2, *Nuclear energy, nuclear technologies, and radiological protection — Vocabulary — Part 2: Radiological protection*

IEC 60050-395, *International Electrotechnical Vocabulary — Part 395: Nuclear instrumentation: Physical phenomena, basic concepts, instruments, systems, equipment and detectors*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12749-2, IEC 60050-395, and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

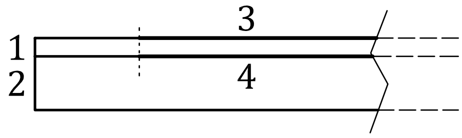
— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
surface emission rate
<of a source> number of particles or photons of a given type above a given energy emerging from the face of the source or its window per second in a mass-free environment

3.2
face
<of a source> vertical projection of the nominal active area onto the front surface of the source

Note 1 to entry: See Figure 1.



Key

1 filter

2 backing

3 face

4 nominal active area

Figure 1 — Cross-sectional drawing of a reference measurement standard with its filter

3.3
saturation layer thickness
<of a source constructed of a homogeneous radioactive material> thickness of the medium equal to the maximum range of the specified particulate radiation

3.4
instrument efficiency
ratio between the instrument net reading (counts per second after background subtraction) and the surface emission rate of the reference measurement standard (particles emitted per second) in a specified geometry relative to a standard

Note 1 to entry: The instrument efficiency depends on the energy of the radiation emitted by the standard, the area of the standard, and the area of the detector entrance window.

3.5
self-absorption
<of a source> absorption of radiation which occurs within the material of the source itself

3.6
uncertainty
standard uncertainty (k = 1) unless otherwise stated

Note 1 to entry: The treatment of uncertainties is in accordance with the ISO/IEC Guide 98-3[8] to the expression of uncertainty in measurement.

3.7
uniformity
<of a surface in respect of a given property> indication of the lack of variation of that property over the surface

4 Traceability of reference measurement standards

The following scheme is proposed to ensure that working standards used in the field for the routine calibration of surface contamination monitors shall be related to national measurement standards through a clearly defined traceability chain using reference measurement standards and reference transfer measurement devices.

Reference measurement standards shall be of the following two types:

— **Class 1:** reference measurement standards that have been calibrated directly in terms of activity and surface emission rate at a national or international metrology institute.

— **Class 2**: reference measurement standards that have been calibrated in terms of surface emission rate on a reference transfer instrument, the efficiency of which has been measured by calibration with a Class 1 reference measurement standard of the same radionuclide and of the same general construction using the same geometry, at a laboratory that operates according to ISO/IEC 17025[16] for such measurements.

National metrology institutes shall, at their discretion, provide the means whereby Class 1 reference measurement standards of a specified range of radionuclides may be certified by them. For those countries which are signatories to the Mutual Recognition Arrangement (MRA)[9], a certificate of calibration from another participating institute in a second country is recognized as valid in the first country for the quantities, ranges, and measurement uncertainties specified in Appendix C of Reference [9].

The activity and surface emission rate of Class 1 reference measurement standards shall be measured, using, for example, a windowless gas-flow proportional detector, or by using an instrument that has been calibrated using standards that have been measured absolutely. Calibration procedures for activity determination are discussed for example, in References [10], [11], [12] and [13].

Organizations with a requirement to type test and to calibrate instruments to be used for monitoring radioactive surface contamination need to have access to suitable Class 1 or Class 2 reference measurement standards. The purpose of a working measurement standard is to check the calibration of surface contamination monitors in the field; they are not to be confused with check sources, which are only intended to verify that a monitor is operating.

Organizations with a requirement to provide working measurement standards for the routine confirmation of the calibration of their surface contamination monitoring instruments require access to a reference transfer measurement device with which to calibrate such working measurement standards in terms of surface emission rate against a Class 1 or Class 2 reference measurement standard. Where the working measurement standard is used either in a jig or under a particular geometry, the reference transfer measurement device on which its emission rate is measured shall have been calibrated using a reference measurement standard under identical conditions and geometry. Alternatively, the working measurement standard shall be removable from the jig so that it can be measured in the usual way. Where only a few monitors need calibration or a high degree of accuracy is required, Class 1 or Class 2 reference measurement standards may be used as working measurement standards. In such cases, the frequency of re-calibration shall be that for working measurement standards. National regulations may require more frequent calibrations.

5 Specification of reference measurement standards

5.1 General

Reference measurement standards are of the following kinds:

a) Sources comprising an electrically conducting backing material with a given radionuclide permanently deposited upon or incorporated into one side only; the thickness of the backing material shall be sufficient to prevent emission of the particulate radiation through the back of the source.

or

b) Sources comprising a layer of material within which the radionuclide is uniformly distributed and the thickness of which shall not exceed the thickness of the saturation layer of the particulate radiation. For the purposes of this document, the activity of the source shall be taken as the activity contained within a surface layer of thickness equal to or less than the saturation layer thickness.

Photon-emitting sources shall incorporate filters in accordance with Table 1.

To measure the surface emission rate directly, a threshold corresponding to a minimum energy shall to be set. For beta counting, it shall be set to correspond to a photon energy of 590 eV (0,1 times the energy of the X_K-radiation of Mn following the decay of ^{55}Fe). For alpha counting, the threshold shall be set just above the electronic noise of the system. For photon counting, the threshold shall be set to comprise the photon peak and the whole Compton continuum.

With alpha-emitters and low-energy beta-emitters, self-absorption can be far from negligible. This leads to a degradation of the emission spectrum and might affect measurements with windowed transfer measurement devices.

Reference measurement standards shall be fit for purpose and it shall be the responsibility of the manufacturer to determine and report the radioactive impurities to the extent necessary to ensure that the use of the standard is not compromised by emissions from any impurity. As a minimum, all radioactive impurities with an activity of at least 1 % of the activity of the principal radionuclide shall be determined and reported.

For those standards which might contain radioactive impurities, users of the reference measurement standard shall take into account that the relative activity of the impurity changes with time and could produce a significant effect on the emission rate of the reference measurement standard.

Table 1 — Characteristics and additional filtration of photon-emitting standards

Approximate mean photon energy[a] in keV	**Radionuclide**	**Half-life** in days	**Filter material**[b]	**Filter thickness**
5,9	^{55}Fe	1,00 × 10^3	none	
16	^{238}Pu	3,20 × 10^4	zirconium	0,05 mm 32,5 mg·cm^{-2}
32	^{129}I	5,88 × 10^9	aluminium	0,3 mm 81 mg·cm^{-2}
60	^{241}Am	1,58 × 10^5	stainless steel	0,25 mm 200 mg·cm^{-2}
124	^{57}Co	272	stainless steel	0,25 mm 200 mg·cm^{-2}
660	^{137}Cs	1,10 × 10^4	stainless steel	1 mm 800 mg·cm^{-2}
1 250	^{60}Co	1,93 × 10^3	aluminium	0,3 mm 81 mg·cm^{-2}

NOTE 1 These are standards of photons of a particular energy range and not standards of a particular radionuclide.

NOTE 2 In most cases, ^{60}Co emits two coincident photons with an angular correlation between them. Great care shall be taken when transferring the calibration to other energies or nuclides.

[a] The approximate mean photon energy is equal to $(\sum n_i \times E_i)/\sum n_i$ where n_i is the number of photons emitted from the standard with energy E_i.

[b] For this document, stainless steel is that which has the composition 72 % Fe, 18 % Cr, 10 % Ni.

5.2 Class 1 reference measurement standards

5.2.1 General requirements

In order to comply with the requirements specified in this document, Class 1 reference measurement standards shall be plane ones comprising an electrically conducting backing material with radioactive

