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Reference sources — Calibration of surface contamination monitors — Alpha-, beta- and photon emitters

Sources de référence — Étalonnage des contrôleurs de contamination de surface — Émetteurs alpha, bêta et photoniques

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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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.

The committee responsible for this document is ISO/TC 85, *Nuclear energy*, Subcommittee SC 2, *Radiological protection*.

This third edition cancels and replaces the second edition (ISO 8769:2010), which has been technically revised.

Introduction

Radioactive contamination of surfaces can result from spilling, splashing, or leakage from unsealed sources, or breakage or loss of integrity of sealed sources 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 released 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 International Standard originated from the need for standard calibration sources in those 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 sources that are specified primarily in terms of surface emission rate, as well as activity. The manner in which these sources 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 International Standard. Appropriate guidance on this process is addressed in ISO 7503 series[5][6][7]. However, some estimate of the activity of the calibration source 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 International Standard.

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

Reference sources — Calibration of surface contamination monitors — Alpha-, beta- and photon emitters

1 Scope

This International Standard specifies the characteristics of reference sources of radioactive surface contamination, traceable to national measurement standards, for the calibration of surface contamination monitors. This International Standard 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 sources for the calibration of surface contamination monitors. Such procedures are specified in IEC 60325[8], IEC 62363[9], and other documents.

NOTE Since some of the proposed photon sources include filters, the photon sources are to be regarded as sources of photons of a particular energy range and not as sources 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 source that emits photons with an average energy of approximately 60 keV.

This International Standard 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 rates which are traceable to national standards.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

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

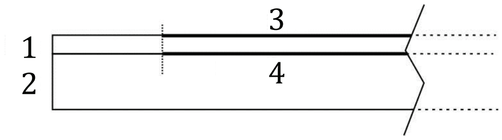
3 Terms and definitions

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

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 time 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 standard source 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 time after background subtraction) and the surface emission rate of the source (particles emitted per time) in a specified geometry relative to a source

Note 1 to entry: The instrument efficiency depends on the energy of the radiation emitted by the source, the area of the source, 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[10] to the Expression of Uncertainty in Measurement.

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

4 Traceability of reference sources

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 sources and reference transfer instruments.

Reference sources shall be of the following two types:

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

— **Class 2:** reference sources 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 source of the same radionuclide and of the same general construction using the same geometry, at a laboratory that has been accredited to ISO 17025 for such measurements.

National metrology institutes shall, at their discretion, provide the means whereby Class 1 reference sources of a specified range of radionuclides may be certified by them. For those countries which are signatories to the Mutual Recognition Arrangement (MRA)[11], 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 [11].

The activity and surface emission rate of Class 1 reference sources shall be measured, using, for example, a windowless gas-flow proportional detector, or by using an instrument that has been calibrated using sources that have been measured absolutely. Calibration procedures for activity determination are discussed for example, in References [12],[13],[14] and [15].

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 sources. The purpose of a working source 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 standard sources for the routine confirmation of the calibration of their surface contamination monitoring instruments require access to a reference transfer instrument with which to calibrate such sources in terms of surface emission rate against a Class 1 or Class 2 reference source. Where the working source is used either in a jig or under a particular geometry, the reference transfer instrument on which its emission rate is measured shall have been calibrated using a reference source under identical conditions and geometry; alternatively, the working source 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 sources may be used as working sources; in such cases, the frequency of re-calibration shall be that for working sources. National regulations may require more frequent calibrations.

5 Specification of standard sources

5.1 General

Reference standard sources may be 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.

b) Sources comprising a layer of material within which the radionuclide is uniformly distributed and the thickness of which is at least equal to the saturation layer thickness of the particulate radiation. For the purposes of this International Standard, the activity of the source shall be taken as the activity contained within a surface layer of thickness equal to 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 needs 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 should 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 instruments.

Reference standard sources 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 source 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 sources which might contain radioactive impurities, users should take due account that the relative level of the impurity changes with time and could produce a significant effect on the emission rate of the source.

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

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

NOTE 1 These are sources of photons of a particular energy range and *not* sources 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 source with energy E_i.

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

5.2 Class 1 reference sources

5.2.1 General requirements

In order to comply with the requirements specified in this International Standard, Class 1 reference sources shall be plane sources comprising an electrically conducting backing material with radioactive material deposited upon or incorporated into one side in such a manner as to minimize source self-absorption and to maintain electrical conductivity across the whole of the face of the source. The active area shall be at least 10^4 mm^2; recommended sizes are 100 mm × 100 mm, 100 mm × 150 mm, and 150 mm × 200 mm.

A Class 1 reference source is intended to approximate as closely as practicably possible an ideal “thin” source (see IEC 60325) with respect to the activity itself. However, it is acknowledged that with alpha-emitters and low-energy beta-emitters, self-absorption can be far from negligible. Maintenance of electrical conductivity is necessary for the correct operation of windowless proportional counters. The thickness of the backing material should be such as to minimize the contribution from backscattered radiation, both particle and photon. The recommended backing material is aluminium of 3 mm thickness (this thickness is sufficient to eliminate particle emission through the back of the source, with the exception of $^{106}Ru/^{106}Rh$ sources where the thickness would need to be increased to 4,6 mm). The thickness of the backing material shall be within 10 % of the value detailed in the certificate. The backing material should extend beyond the active area to such an extent that the backscattering effect is uniform over the whole of the active area. It is recommended that the backing material should extend at least 10 mm beyond the active area of the source.

A photon-emitting source shall include the filtration specified in Table 1. The filter should normally be an integral part of the source, it should not be removable. Their purpose is described in Annex A. The area of the filter should be such that it extends for at least 10 mm beyond the active area of the source. The thickness of the filter shall be within 10 % of the specified value in Table 1.

Sources shall be accompanied by a calibration certificate giving the following information:

a) radionuclide;

NOTE Half-life values and other current nuclear data values are provided by Reference [16].

b) source identification number;

c) surface emission rate and its uncertainty;

d) activity and its uncertainty;

e) reference date [shall be identical for c) and d)];

f) active area: its location and size;

g) nature, thickness, density, and dimensions of substrate;

h) nature, thickness, density, and dimensions of filter (if any);

i) uniformity and uncertainty (table of relative emission rates of all individual portions relating position and emission rate);

j) class of source.

Manufacturers may decide to give further information of help to the user such as the depth of the active layer. Markings on the source itself shall indicate the radionuclide and the source identification number.

5.2.2 Activity and surface emission rate

The activity of a Class 1 reference source of the preferred size should be such as to give a surface emission rate from about 2 000 s^{-1} to 10 000 s^{-1} in order to optimize between background, statistical uncertainty, and dead-time error. The activity shall be stated with a relative uncertainty not exceeding 10 %. The surface emission rate shall be measured by the national metrology institute with a relative uncertainty not exceeding the following:

a) 3 % for alpha sources;

b) 3 % for beta sources with an end-point energy greater than 150 keV;

c) 5 % for beta sources with an end-point energy less than 150 keV;

d) 10 % for photon sources.

Class 1 reference sources should be re-calibrated in terms of activity, surface emission rate, and uniformity at a frequency of not less than once every four years.

NOTE 1 The frequency of recalibration of a reference source might be different from country to country, depending on national regulations.

NOTE 2 Overall source activity has to be related to the source size when the sources are used to calibrate different sized detectors. The source might need sufficient activity/cm^2 to accommodate detectors with a working area of 6,4 cm^2 but not so much activity as to overload a detector with a working area of 200 cm^2.

5.2.3 Uniformity

The uniformity of a source shall be expressed in terms of the standard deviation of the surface emission rates of the individual portions of the whole source divided by the mean value of these emission rates.