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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).

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).

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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*

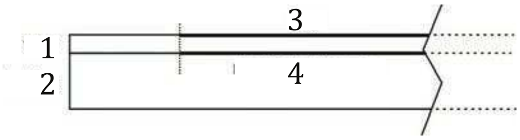
3 Terms and definitions

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 × 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 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.

The uniformity of a Class 1 reference source minus its relative standard uncertainty shall be greater than 90 %. For the purpose of specifying the uniformity of a source with respect to surface emission rate per area, the source shall be considered as comprising a number of portions of equal area and shape. For rectangular sources, the shape of the portions shall be identical to the shape of the active area of the source.

The area of the portions shall be 10 cm^2 or less. For the recommended sizes (see 5.2.1), a reference source active area of 10 cm × 10 cm shall be divided into 16 quadratic portions and a source of 10 cm × 15 cm shall be divided into 16 rectangular portions.

The individual emission rates shall be determined with a relative uncertainty that shall be consistent with that specified for the whole source in 5.2.2 and 5.3.2. These uncertainties shall be taken into account when calculating the experimental standard deviation to determine the uniformity resulting in an uncertainty for the uniformity itself (see Reference [12]).

Uniformity may be measured by using the image plate technique, position sensitive measurement systems, or by inserting a masking plate between the source and the detector. The masking device shall have an aperture of appropriate size and provide sufficient shielding of the detector. For the masking plate technique, care should be taken to always use the same portion of the detector to minimize effects due to possible non-uniformity of response to radiation across the surface of the detector. For the other techniques, care should be taken to minimize effects due to possible non-uniformity of the detection efficiency across the whole detector.

In those situations where the detector window area is less than the active source area, it is possible to avoid the requirement to have a detailed knowledge of the uniformity by characterizing, in an integral manner, the emission rate from that part of the source that is exposed to the detector window.

5.2.4 Radionuclides

Class 1 reference sources should be prepared, if possible, from any of the radionuclides in Table 1, Table 2, and Table 3. The decay data given in these tables are for indicative information only, the data used for calibrations and calibration certificates shall be taken from Reference [16].

Table 2 and Table 3 have “preferred” and “possible alternative” categories. The preferred radionuclides are chosen for their general availability, suitably long half-lives, high specific activity, and ability to cover the normal range of energies encountered in typical monitoring situations. The possible alternatives may suffer from concerns such as the need to replace them regularly due to their relatively short half-lives; due to their low specific activity which makes it difficult to provide sufficient activity in an infinitely thin active layer; because they emit additional unwanted radiation; due to the difficulty in providing sufficient radioactive purities.

Table 2 — Radionuclides for alpha-emitting sources

Radionuclide	**Half-life** in days	**Maximum energy** in keV	**Comments**
Preferred			
^{241}Am	1,58 × 10^5	5 544	—
^{230}Th	2,75 × 10^7	4 688	—
Possible alternatives			
^{238}Pu	3,20 × 10^4	5 499	—

Table 3 — Radionuclides for beta-emitting sources

Radionuclide	**Half-life** in days	**Maximum energy** in keV	**Comments**
Preferred			
^{14}C	$2{,}08 \times 10^6$	156	Depending on the nature of the manufacturing process, it might be necessary to re-calibrate more frequently because of possible isotopic exchange with C in atmosphere.
^{99}Tc	$7{,}72 \times 10^7$	294	—
^{36}Cl	$1{,}10 \times 10^8$	710	—
^{90}Sr/^{90}Y	$1{,}05 \times 10^4$(^{90}Sr) 2,67 (^{90}Y)	546 (^{90}Sr) 2 280 (^{90}Y)	If only the higher-energy betas from ^{90}Y are required, a filter of 130 mg·cm^{-2} is needed but this results in significant spectral degradation of the ^{90}Y emission spectrum.
^{106}Ru/^{106}Rh	372 (^{106}Ru) 0,000 35 (^{106}Rh)	39 (^{106}Ru) 3 546 (^{106}Rh)	Relatively short half-life.
Possible alternatives			
^{147}Pm	958	224	Relatively short half-life.
^{204}Tl	$1{,}38 \times 10^3$	764	Approximately 3 % of decays are by electron capture and produce X-ray emissions of about 70 keV to 90 keV.
^{60}Co	$1{,}93 \times 10^3$	317	Not a pure beta-emitter. Emits photons at 1,173 MeV and 1,332 MeV.
^{3}H	$4{,}50 \times 10^3$	19	Depending on the nature of the manufacturing process, it may be necessary to re-calibrate more frequently because of possible isotopic exchange with H in the atmosphere.
^{63}Ni	$3{,}61 \times 10^4$	67	—

NOTE 1 Most commonly used monitoring instruments cannot detect ^{3}H or ^{63}Ni, with a useful efficiency. Monitoring for these radionuclides normally requires specialized detectors and these radionuclides are not normally included in routine calibrations.

NOTE 2 Many calibration laboratories just use a sub-set of beta-emitting sources which cover the useful energy range that is being monitored for. Typically, the subset comprises ^{14}C, ^{36}Cl and ^{90}Sr/^{90}Y.

5.3 Class 2 reference sources

5.3.1 General requirements

Class 2 reference sources shall comply with the same general requirements as specified for Class 1 reference sources. They shall be marked with the same information as Class 1 reference sources and shall be accompanied by a calibration certificate in accordance with 5.2.1.

5.3.2 Activity and surface emission rate

The emission rate of a Class 2 reference source of the preferred size should be as required by the user and depends on the type of instrument being calibrated and the particular test being carried out. The activity shall have been determined in a manner which provides traceability to the International System of Units (SI) and shall be stated with a relative uncertainty not exceeding 10 %. The surface emission rate shall be determined by means of a reference transfer instrument (see Clause 6) with a relative uncertainty not exceeding the following:

a) 5 % for alpha-sources;

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

c) 10 % for beta-sources with an end-point energy less than 150 keV;

d) 15 % for photon sources.

Class 2 reference sources shall be re-calibrated in terms of activity, surface emission rate, and uniformity at a frequency of not less than once every four years (see notes 1 and 2, in 5.2.2).

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.

5.3.3 Uniformity

The uniformity of a Class 2 reference source minus its relative standard uncertainty shall be greater than 90 %.

5.3.4 Radionuclides

Class 2 reference sources shall be prepared from among the same radionuclides as provided for Class 1 reference sources in accordance with 5.2.4.

5.4 Working sources

5.4.1 General requirements

The detailed requirements specified for working sources shall be the responsibility of the user. Such sources may often be manufactured in-house and due recognition shall be given to any relevant national regulations. In specifying working sources, the following points need to be considered.

a) Working sources shall be provided in a quantity and variety of sizes to meet the needs of the organization in respect of the routine calibration of its surface contamination monitors.

b) Working sources shall be marked with the surface emission rate at a reference date, the radionuclide and the serial number, and shall be accompanied by a note detailing the geometry for which they have been calibrated and hence should be used. Where the size of the source minimizes the space available for marking, the source shall bear a unique identifier and shall be accompanied by a calibration certificate which also contains the unique identifier together with details of the radionuclide, surface emission rate, and reference date.

c) Working sources shall be sufficiently robust to withstand day-to-day handling.

d) In the absence of conflicting requirements, working sources shall comply, as far as possible, with the requirements specified for reference sources in 5.3.

5.4.2 Activity and surface emission rate

The surface emission rate of a working source should be as agreed upon between the user and the manufacturer. The activity of a working source shall be stated by the manufacturer and shall be traceable to the SI. The surface emission rate shall have been measured on a reference transfer instrument that has been calibrated using a Class 1 or a Class 2 reference source of the same construction. The surface emission rate of a working source needs to be known to the uncertainty specified by the appropriate instrument calibration regulations.

Working sources shall be re-calibrated at a frequency of not less than once every two years.

5.4.3 Uniformity

The uniformity of a working source should preferably be the same as specified for a Class 2 reference source.

5.4.4 Radionuclides

Working sources shall be prepared from such alpha-emitting, beta-emitting, and photon-emitting radionuclides as might be required by the user.

6 Reference transfer instruments

6.1 Reference transfer instrument for alpha-sources and beta-sources

A reference transfer instrument for alpha-radiation and beta-radiation shall have instrument efficiency greater than 35 % over the range of energies covered by this International Standard. It should be of such size that the variation in spatial response over a measurement area of 100 mm × 150 mm may be ignored. The recommended type of reference transfer instrument for alpha-emitters and beta-emitters is a large-area, windowless, gas-flow proportional counter, together with a regulated gas supply.

6.2 Reference transfer instrument for photon sources

It is unlikely that a single reference transfer instrument would cover the full range of photon energies proposed in this International Standard. The instrument used for a particular energy should have the following characteristics:

a) high detection efficiency;

b) uniformity of response over its surface;

c) stability;

d) low background noise.

Large-area proportional counters with appropriate gas filling are suitable for the measurement of the lower-energy photon emitters. Scintillation detectors such as NaI(Tl) are suitable for the higher-energy photon emitters.

6.3 Calibration

A reference transfer instrument shall be calibrated both initially and at regular time intervals during its working life in accordance with regulatory requirements, codes of practice, or other recommendations. It is recommended that the reference transfer instrument be re-calibrated at least annually **or if less frequently, calibrate before any use as a reference transfer standard.** Calibration of a reference transfer instrument shall be the responsibility of the organization. Where beta-emitting radionuclides not available as Class 2 reference sources are required as working sources, traceability may be maintained by interpolation of the reference transfer instrument efficiency. However, for beta-emitters of maximum energy less than 0,5 MeV where the efficiency of gas-flow proportional detector changes steeply as a function of energy, interpolation could lead to large errors and every effort should be made to obtain suitable Class 1 or Class 2 reference sources.

Annex A
(informative)

Particular considerations for reference sources emitting electrons of energy less than 0,15 MeV and photons of energy less than 1,5 MeV

Radionuclides decaying by electron capture and by isomeric transitions can emit a wide range of different types of radiation including internal conversion electrons and Auger electrons, as well as characteristic X-radiation (e.g. from K, L, M … atomic shells) and gamma radiation. For these mostly low-energy and hence less penetrating types of radiation, the relationship between emission rate and activity is very dependent on the source construction (or nature of contaminated surface). Also, the emitted electron spectra might suffer substantial energy degradation and hence, distortion. This presents difficulties when such sources are used to transfer calibrations from one detector to another when the two detectors have different windows. These effects should not be ignored.

The use of filters on photon-emitting sources leads to a degree of angular collimation whereby the number of photons emitted normally to the surface is greater than that emitted at oblique angles. Thus, the polar emission distribution from the reference source may differ from that emitted by a contaminated surface. For similar reasons, the emissions from a contaminated surface may themselves be anisotropic.

The use of filters is required, partly, to remove unwanted emissions such as alpha-radiation, beta-radiation, or electron-radiation. It should be noted that the filter, which also attenuates the photon emissions, produces secondary electron emission from the attenuation process. Such radiation is in general of low energy and of low probability. However, its possible presence should be considered.

Reference sources that emit significant numbers of electrons, as well as photons, would have the following disadvantages:

a) determination of their emission rates would require the measurement of both electron and photon radiation;

b) emission rate and energy distribution of the lower-energy electron radiation would be very dependent on the type of source construction;

c) if sources emit both types of radiation, but only the photon emission is determined, then, for a given nuclide, the calibration factor obtained for a contamination monitor that responds to both types of radiation would require the knowledge of its response to both photon and electron radiation;

d) if sources as under c) were to be used for the calibration of thin-windowed contamination monitors that detect low energy electrons, the derived calibration factor could be very dependent on the energy distribution resulting from the particular source construction and upon the distance between the contaminated surface and the window of the instrument.

In order to ensure a greater consistency between calibrations which are essentially for photon emissions, a series of reference sources is proposed that emit essentially photon radiation over restricted energy ranges.

Although there are many nuclides in regular use in the workplace, the number that are suitable as reference sources is extremely limited due to considerations of adequately long half-life, cost, availability, and the ability to provide calibrations that have only a single beta branch or a single photon. The photon-emitting radionuclides recommended have been chosen in order to provide sources that produce a range of photon energies suitable for the calibration of the types of instrument most commonly used for the measurement of nuclides decaying by the processes of electron capture and isomeric transition (if there is a requirement to determine a more detailed response of an instrument for energies other than those provided by these sources, reference fluorescence X-radiation from ISO 4037[17][18][19][20] series may be used). It should be noted that, with the exception of ^{55}Fe, all the photon-emitting reference sources have filters over the active material of the source. For ^{55}Fe, it should be noted that low-energy Auger electrons are emitted. These are normally completely absorbed within the detector window but, if windowless counters are used, care should be taken to take account of this particulate radiation and the effect it might have when making transfer measurements.

The purpose of the filters is to eliminate unwanted radiation from the nuclides and thus, to provide sources that emit photons within limited ranges. The eliminated radiation includes the following:

^{129}I	beta-radiation and other low-energy radiation;
^{241}Am	alpha-radiation and characteristic L X-radiation;
^{57}Co	characteristic K X-radiation and lower-energy photons and electrons;
^{238}Pu	reduction of the relative intensity of the characteristic L X-radiation above the K absorption edge of zirconium;
^{137}Cs	beta-radiation, electrons, and characteristic K X-radiation;
^{60}Co	beta-radiation.

If the reference sources specified in this International Standard are referred to in other documents, but used without the specified filtration in order to determine the response of an instrument to a specific nuclide, then such documents should contain an explicit statement to this effect and include details of the actual filtration (if any) used.

Since ^{60}Co emits two coincident photons in most cases with an angular correlation, great care shall be taken when transferring calibrations to other geometries or nuclides.

In particular for photon-emitting sources, it shall also be taken into account that the source environment can have considerable influence on the surface emission rate. For example, the emission rate increases due to backscattering if a source is placed on a massive table.

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