INTERNATIONAL STANDARD

ISO 8769

Second edition
2010-09-01

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

Reference number
ISO 8769:2010(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 8769 was prepared by Technical Committee ISO/TC 85, *Nuclear energy*, Subcommittee SC 2, *Radiation protection*.

This second edition cancels and replaces the first edition (ISO 8769:1988) and the first edition of ISO 8769-2:1996, which have 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 may give rise to the following health hazards:

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

b) inhalation, ingestion or entry into the body through wounds, of radioactive material released from the surface.

The need for effective monitoring of surface contamination has long been recognised, see References [1] and [2]. 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 [3] and [4]. 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. Traceability of calibration sources to international 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, IEC 62363 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 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 specifies also reference radiation for the calibration of surface contamination monitors, which takes the form of adequately characterized large area sources specified, without exception, in terms of surface emission rates, the evaluation of these quantities being traceable to national standards.

2 Normative references

The following referenced documents are indispensable for the application 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 921, *Nuclear energy — Vocabulary*

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

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

IEC 60325, *Radiation protection instrumentation — Alpha, beta and alpha/beta (beta energy > 60 keV) contamination meters and monitors*

IEC 60050-394, *International Electrotechnical Vocabulary — Part 394: Nuclear instrumentation — Instruments, systems, equipment and detectors*

IEC 62363, *Radiation protection instrumentation — Portable photon contamination meters and monitors*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 921 and IEC 60050-394 and the following apply.

3.1
activity
⟨of an amount of a radionuclide in a particular energy state at a given time⟩ quotient of the expectation value of the number of spontaneous nuclear transitions, dN, from that energy state in the time interval, dt

NOTE SI unit: s^{-1}. The special name for the SI unit of activity is the becquerel, Bq; (1 Bq = 1 s^{-1})

3.2
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 unit time

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

NOTE 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
traceability
property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties

3.7
uncertainty
standard uncertainties (k = 1) unless otherwise stated

The treatment of uncertainties is in accordance with the ISO/IEC Guide 98-3 for the Expression of Uncertainty in Measurement.

3.8
uniformity
⟨of a surface in respect of a given property expressed as a measured quantity per unit area⟩ indication of the reproducibility 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 via a clearly defined traceability chain using reference sources and reference transfer instruments.

Reference sources shall be of two types:

— **Class 1:** reference sources that have been calibrated directly in terms of 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), 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 the MRA.

The surface emission rate of Class 1 reference sources shall be measured by absolute methods, 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.

The activity of Class 1 reference sources will have been derived by the manufacturer in a manner which provides results that are directly traceable to the SI unit of activity (the becquerel). The manufacturer shall make available to purchasers the details of the method of activity determination, its validation and the uncertainties associated with that measurement.

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 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 test 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 2 reference source. Where the working source will be 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 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 two kinds.

a) Sources comprising an electrically conducting backing material with a given radionuclide permanently deposited upon or incorporated into one face 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 surface contamination monitoring, 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.

Reference standard sources shall be of adequate radionuclidic purity. It shall be the responsibility of the manufacturer to determine and report the radionuclidic purity to the extent necessary to ensure that the use of the source is not compromised by emissions from any impurity. As a minimum, all radionuclide impurities with an activity of at least 1 % of the activity of the principal radionuclide shall be determined and reported. For those sources which may contain radionuclidic impurities, users should take due account that the relative level of the impurity will change with time and could produce a significant effect on the emission rate from the source.

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

Approximate mean photon energy[a] keV	Half-life days	Radionuclide and filter[b]
5,9	$1{,}00 \times 10^3$	^{55}Fe (none)
16	$3{,}20 \times 10^4$	^{238}Pu with a 32,5 mg·cm^{-2} zirconium filter
32	$5{,}88 \times 10^9$	^{129}I with a 81 mg·cm^{-2} aluminium filter
60	$1{,}58 \times 10^5$	^{241}Am with a 200 mg·cm^{-2} stainless steel filter
124	272	^{57}Co with a 200 mg·cm^{-2} stainless steel filter
660	$1{,}10 \times 10^4$	^{137}Cs with a 800 mg·cm^{-2} stainless steel filter
1 250	$1{,}93 \times 10^3$	^{60}Co with a 81 mg·cm^{-2} aluminium filter

NOTE These are sources of photons or electrons of a particular energy range and *not* sources of a particular radionuclide.

[a] The approximate mean photon energy is equal to $(\Sigma n_i \times E_i)/\Sigma n_i$ 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 face in such a manner as to minimize source self absorption and to maintain electrical conductivity across the whole of the active surface (see Note). The active area shall be at least 10^4 mm^2; recommended sizes are 100 mm × 100 mm and 100 mm × 150 mm.

NOTE A Class 1 reference source is intended to approximate as closely as practicably possible to 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/Rh sources where the thickness would need to be increased to 4,6 mm). The mass per unit area 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.

Photon-emitting sources shall include the filtration specified in Table 1. The filters should normally be an integral part of the source; they should not be removable. The area of the filter should be such that it extends for at least 10 mm beyond the active area of the source. The mass per unit area 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 and its half-life [1)];

b) source identification number;

c) surface emission rate, its uncertainty and the reference date;

d) activity, calculated to correspond to the same reference date as in c) above, and its uncertainty;

e) active area and dimensions of source and its uncertainty;

f) depth of active layer as measured from the front surface of the active layer;

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

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

i) uniformity and 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. 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 to 10 000 s^{-1} in order to optimize between background, statistical and dead-time errors. The activity shall be stated with an uncertainty not exceeding ± 10 % ($k = 1$). The surface emission rate shall be measured by the national metrology institute with an uncertainty not exceeding:

± 3 % for alpha-sources;

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

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

± 10 % for photon sources.

Class 1 reference sources shall be re-calibrated at a frequency of not less than once every four years.

1) Half-life values are the current values provided by the Decay Data Evaluation Project (DDEP).

5.2.3 Uniformity

The uniformity of a Class 1 reference source expressed in terms of the standard deviation of the surface emission rates from each individual portion of the whole source shall be no greater than 5 %.

For the purpose of specifying the uniformity of a source with respect to surface emission rate per unit area, the source shall be considered as comprising a number of portions of equal area. The area of the portions shall be 5 cm^2 or less. The uniformity shall be expressed as the relative experimental standard deviation derived from the emission rates from each individual portion of the whole source. These individual emission rates shall be determined with an uncertainty, arising from counting statistics, which is no greater than ± 1 %.

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 to ensure that the contribution from areas outside the aperture area should not be more than 5 % of the measurement result from any individual area. 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.

NOTE 1 Knowledge of the uniformity distribution will make it possible to use smaller areas of the source while maintaining a reasonable level of uncertainty.

NOTE 2 Because of possible edge effects and contributions from neighbouring areas, the total emission rate for the source *cannot* be determined from the summation of the emission rates from the individual areas.

5.2.4 Radionuclides

Class 1 reference sources should be prepared, if possible, from any of the radionuclides in Tables 1, 2 and 3. Characteristics of these radionuclides are given in the tables. See Reference [6].

Tables 1 and 2 have “preferred” and “possible alternative” categories. The preferred radionuclides are chosen for their general availability, suitably long half-lives and reasonably high specific activity. 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 radionuclidic purity.

Table 2 — Radionuclides for alpha-emitting sources

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

Table 3 — Radionuclides for beta-emitting sources

Radionuclide	Half-life days	Maximum energy keV	Comments
Preferred			
^{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 atmosphere.
^{63}Ni	$3{,}61 \times 10^{4}$	67	—
^{14}C	$2{,}08 \times 10^{6}$	156	Depending on the nature of the manufacturing process, it may be necessary to re-calibrate more frequently because of possible isotopic exchange with C in atmosphere.
^{99}Tc	$7{,}82 \times 10^{7}$	292	—
^{36}Cl	$1{,}10 \times 10^{8}$	709	—
$^{90}Sr/Y$	$1{,}05 \times 10^{4}$ (^{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} will be needed but this will result in significant spectral degradation of the ^{90}Y emission spectrum.
$^{106}Ru/Rh$	373 (^{106}Ru) 0,000 35 (^{106}Rh)	40 (^{106}Ru) 3 541 (^{106}Rh)	Relatively short half-life.
Possible alternatives			
^{147}Pm	958	225	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 80 keV.
^{60}Co	$1{,}925 \times 10^{3}$	317	Not a pure beta-emitter. Emits photons at 1,173 MeV and 1,332 MeV.

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 will depend 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 an uncertainty not exceeding ± 10 % ($k = 1$). The surface emission rate shall be determined by means of a reference transfer instrument (see Clause 6) with an uncertainty not exceeding:

± 5 % for alpha-sources;

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

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

± 15 % for photon sources.

Class 2 reference sources shall be re-calibrated at a frequency of not less than once every four years.

5.3.3 Uniformity

The uniformity (as defined in 5.2.3) of a Class 2 reference source expressed in terms of the standard deviation of the surface emission rates from each individual portion of the whole source shall be no greater than 10 %.

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 he 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 5.2.

5.4.2 Activity and surface emission rate

The surface emission rate of a working source should be as agreed 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 working sources will need 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. (An example of the way in which non-uniformity of sources can affect the calibration of monitors is given in Reference [5].)

5.4.4 Radionuclides

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

6 Reference transfer instruments

6.1 Reference transfer instrument for alpha- and beta-sources

A reference transfer instrument for alpha- and beta-radiation shall have an instrument efficiency greater than 50 % 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 beta-emitters is a large-area, windowless, gas-flow proportional counter, together with a regulated gas supply.

The threshold for beta counting shall be set to correspond to a photon energy of 590 eV (0,1 times the energy of the X_K-radiation of ^{54}Mn following the decay of ^{55}Fe). For alpha counting, the threshold should be set just above the electronic noise of the system. Corrections shall be made for electronic dead time and the background counting rate.

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 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.

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 2 reference sources.

Annex A
(normative)

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 K, L and M X-radiation and gamma radiation. For these mostly low-energy and hence less penetrating types of radiation, the relationship between emission rate and activity will be very dependent on the source construction (or nature of contaminated surface). Also, the emitted electron spectra may suffer substantial energy degradation and hence distortion. This will present 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 will lead 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 designed, partly, to remove unwanted emissions such as beta- or electron-radiation. It should be noted that the filter, which will also attenuate the photon emissions, will produce secondary electron emission from the attenuation process. Such radiation will in general be 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) the determination of their emission rates would require the measurement of both electron and photon radiation;

b) the 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 may be used). It should be noted that, with the exception of ^{55}Fe, all the photon-emitting reference sources have filters over the face of the active material of the source. For ^{55}Fe, it should be noted that low-energy Auger electrons are emitted. These will normally be completely

