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Reference sources for the calibration of surface contamination monitors — Beta-emitters (maximum beta energy greater than 0,15 MeV) and alpha-emitters

Sources de référence pour l'étalonnage des moniteurs de contamination de surface — Émetteurs bêta (énergie bêta maximale supérieure à 0,15 MeV) et émetteurs alpha

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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 8769 was prepared by Technical Committee ISO/TC 85, *Nuclear energy.*

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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0 Introduction

Radioactive contamination of surfaces may result from spilling, splashing or leakage from unsealed 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 recognized [1]. Surface contamination is quantified in terms of activity per unit area; the latter quantity is used to specify "derived limits", i.e. maximum limits of surface contamination. These limits are based on radiological protection considerations and have been derived [1,2] from the dose equivalent or intake limits recommended by the International Commission on Radiological Protection (ICRP) [3]. In the past there have been considerable variations in the numerical values of the derived limits both from country to country [2] and between different establishments [1]. Derived limits are incorporated into numerous regulatory documents; a recent survey [4] has revealed that in many countries there are national regulations or codes of practice with legal status 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; in particular, the use of such calibration sources is called for in ISO 7503-1.

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. There thus emerges a clear need for calibration sources which are specified in terms of surface emission rate as well as activity. In this International Standard these terms have been related by the introduction of the concept of source efficiency. Traceability of calibration sources to national standards is established by a system of transfer instruments.

1 Scope and field of application

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 and to beta-emitters of maximum beta energy greater than 0,15 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 Publication 325 and other documents.

This International Standard specifies reference radiations for the calibration of surface contamination monitors which take the form of adequately characterized large area sources specified, without exception, in terms of activity and surface emission rate, the evaluation of these quantities being traceable to national standards.

2 References

ISO 921, *Nuclear energy glossary*.

ISO 6980, *Reference beta radiations for calibrating dosemeters and doseratemeters and for determining their reponse as a function of beta radiation energy*.

ISO 7503-1, *Evaluation of surface contamination — Part 1: Beta-emitters (maximum beta energy greater than* 0,15 MeV*) and alpha-emitters*.

IEC Publication 50 (391), *International Electrotechnical Vocabulary — Chapter 391: Detection and measurement of ionizing radiation by electric means*.

IEC Publication 50 (392), *International Electrotechnical Vocabulary — Chapter 392: Nuclear instrumentation — Supplement to chapter 391*.

IEC Publication 325, *Alpha, beta and alpha-beta contamination meters and monitors*.

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 921 and IEC Publication 50 (391 and 392) and the following definitions 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.

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 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) 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 radiations emitted by the source.

3.5 efficiency of a source; source efficiency: Ratio between the surface emission rate and the number of particles of the same type created or released within the source or its saturation layer thickness per unit time.

NOTE — According to this definition, the efficiency of a source would be expected to be not more than 0,5; however, a contribution due to back-scattered particles can enhance this value considerably.

3.6 self-absorption (of a source): Absorption of alpha or beta radiation which occurs within the material of the source itself.

3.7 traceability: The concept of establishing a valid calibration of a measuring instrument or measurement standard, by a step-by-step comparison with better standards up to an accepted or specified standard. In general, the concept of traceability implies eventual reference to an appropriate national or international standard (documentation and use of approved laboratories is assumed).

3.8 uncertainty: For overall uncertainty, see [5]; all uncertainties quoted in this International Standard are at the level of one estimated standard deviation.

3.9 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.

For the purpose of specifiying 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 uniformity shall then be specified as the estimated standard deviation of measurements of the individual portions about the mean value for the whole surface as a percent of the mean value. The area of the portions shall be 10 cm^2 or less.

Uniformity may be measured by inserting a masking plate between the source and the detector. The masking plate should have an aperture of appropriate size and should be thick enough to absorb particles of the maximum energy emitted (see the table). Knowledge of uniformity will make it possible to use smaller areas of the source while maintaining traceability.

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 transfer instruments.

Reference sources shall be of two types:

Class 1: Reference sources which shall have been calibrated directly in terms of surface emission rate at a national standards laboratory.

Class 2: Reference sources which shall have been calibrated at an approved laboratory 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.

National standards laboratories shall at their discretion provide the means whereby Class 1 reference sources of a specified range of radionuclides may be certified by them[1)]. The surface emission rate of Class 1 reference sources would 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 acceptable to the national standards laboratory.

Organizations with a requirement to type test instruments to be used for monitoring radioactive surface contamination need to have access to suitable Class 1 or 2 reference sources. Those with a requirement to calibrate such instruments will need to have access to similar reference sources or to working sources. The purpose of a working source is to calibrate 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 calibration of their surface contamination monitoring instruments require access to a reference

1) It is likely that some countries would accept as valid a Class 1 reference source that had been certified by the national standards laboratory of another country.

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.

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 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. 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.

Reference standard sources shall be of adequate radiochemical purity. It is difficult to check for beta-emitting impurities, but their presence may be inferred from the detection of their associated photon radiation, if any, using a high-resolution spectrometer, with, for example, a Ge detector. It may also be possible to determine the residual maximum beta energy, E_{res} (see ISO 6980) to detect beta-emitting impurities which have a maximum energy, E_{max}, greater than the specified nuclide.

Sources of maximum beta energy greater than or equal to 0,4 MeV shall have an efficiency greater than 0,25; those of maximum beta energy from 0,15 to 0,4 MeV and alpha-emitting sources shall have an efficiency greater than 0,05.

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[1)]. The active area shall be at least 10^4 mm^2; a recommended size is 100 mm × 150 mm. The thickness of the backing material shall be such that addition of further such material would not increase the quantity of emitted particulate radiation resulting from back-scattering. A list of recommended minimum backing thicknesses of commonly used materials is given in the table. These thicknesses are sufficient to eliminate emission through the back of the source.

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

a) activity within the source or within its saturation layer thickness, calculated to correspond to the same reference date as in c) below;

b) active area of source;

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

d) radionuclide and its half-life;

e) source identification number;

f) uniformity;

g) 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 needs to be such as to give a surface emission rate from 2 000 to 10 000 s^{-1} in order to optimize between background, statistical and deadtime errors. The activity shall have been derived by the manufacturer in a manner traceable to national measurement standards and shall be stated with an uncertainty not exceeding ± 10 %. The surface emission rate shall be measured by the national standards laboratory with an uncertainty which shall not exceed ± 3 %.

5.2.3 Uniformity

The uniformity of a Class 1 reference source in terms of surface emission rate shall be better than ± 10 %.

1) A Class 1 reference source is intended to approximate as closely as practicably possible to an ideal "thin" source (see IEC Publication 325) with respect to the activity itself. However, it is acknowledged that with alpha-emitters and low-energy beta-emitters, self-absorption will be far from negligible.

5.2.4 Radionuclides

Class 1 references sources should be prepared, if possible, from any of the following radionuclides as recommended in ISO 6980 (characteristics of these radionuclides for Class 1 reference sources are given in the table):

a) alpha-emitter: ^{241}Am;

b) beta-emitters[1]: ^{14}C, ^{147}Pm, ^{204}Tl or ^{36}Cl, ^{90}Sr + ^{90}Y;

c) other radionuclides as may be agreed from time to time by the national standards laboratory (if a source of higher beta energy is required, ^{106}Ru + ^{106}Rh is suggested).

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 (see 5.2.1).

5.3.2 Activity and surface emission rate

The activity 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 total activity of each Class 2 reference source shall have been derived by the manufacturer in a manner traceable to national measurement standards and shall be stated with an uncertainty not exceeding ± 10 %. The surface emission rate shall be determined by means of a reference transfer instrument (see 6.1) and shall be stated with an uncertainty not exceeding ± 6 %.

5.3.3 Uniformity

The uniformity of a Class 2 reference source in terms of surface emission rate should be better 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 (see 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. 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;

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 (see 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 national measurement standards; 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.

Table — Characteristics of the radionuclides for Class 1 reference sources

Radionuclide	Approximate half-life	Maximum energy	Backing surface		
			Mass per unit area	Minimum thickness	
				Aluminium	Stainless steel
	years	keV	mg·cm^{-2}	mm	mm
^{14}C	5 730	156	22	0,08	0,03
^{147}Pm	2,62	225	35	0,13	0,04
^{204}Tl	3,78	763	180	0,7	0,23
^{36}Cl	300 000	710	170	0,6	0,20
^{90}Sr + ^{90}Y	28,5	2 274	850	3,1	1,1
^{106}Ru + ^{106}Rh	1,01	3 540	1 300	4,8	1,7
^{241}Am	432,6	5 544	6	0,02	0,01

1) The use of filters with ^{90}Sr + ^{90}Y is not excluded. If only the higher beta energy ^{90}Y is required, a filter of 130 mg·cm^{-2} will be needed.

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 [6].)

5.4.4 Radionuclides

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

6 Transfer instruments

6.1 Reference transfer instrument

A reference transfer instrument needs to have an efficiency greater than 0,5 over the range of energies considered in this International Standard. It should be of such size that the variation in spatial response over a measurement area of 100 mm × 150 mm can safely be ignored. The recommended type of reference transfer instrument is a commercially available large-area, gas-flow proportional detector stripped of all protective grills and provided with an electrically conducting window of maximum mass per unit area of 1 $mg \cdot cm^{-2}$ unsupported over the active area, together with a regulated gas supply, high-voltage supply, preamplifier, amplifier, discriminator and detector, each provided with full documentation. Corrections shall be made for electronic dead time and the background counting rate.

The threshold for beta counting shall be set to correspond to a photon energy of 590 eV (0,1 times the energy of the $\varkappa_K$ line of Mn following the decay of ^{55}Fe). For alpha counting, the threshold should be set just above the electronic noise of the system.

6.2 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. 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 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.

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