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Evaluation of surface contamination —

Part 3:
Isomeric transition and electron capture emitters, low energy beta-emitters
($E_{\beta max} < 0,15$ MeV)

Évaluation de la contamination de surface —

*Partie 3: Émetteurs à transition isomérique et capture électronique,
émetteurs bêta basse énergie ($E_{\beta max} < 0,15$ MeV)*

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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 voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 7503-3 was prepared by Technical Committee ISO/TC 85, *Nuclear energy*, Subcommittee SC 2, *Radiation protection*.

ISO 7503 consists of the following parts, under the general title *Evaluation of surface contamination*:

— *Part 1: Beta-emitters (maximum beta energy greater than 0,15 MeV) and alpha-emitters*

— *Part 2: Tritium surface contamination*

— *Part 3: Isomeric transition and electron capture emitters, low energy beta-emitters* ($E_{\beta max} < 0,15$ MeV)

Annexes A to D form an integral part of this part of ISO 7503. Annexes E and F are for information only.

Introduction

This part of ISO 7503 provides recommendations for surface contamination measurements for two groups of radionuclides.

a) Radionuclides which can only be detected and measured with the aid of the following emissions:

— gamma radiation and X-rays from isomeric transitions and electron capture processes,

— electrons from internal conversion processes and Auger-electrons,

— Low-energy beta radiation ($E_{\beta\max} < 0,15$ MeV) from classical beta decay.

b) Beta-emitters which do not emit one electron per decay.

Widespread application and involvement of such radionuclides in nuclear medicine, industrial processes and research, under conditions which do not allow full control of the radionuclide spread, have led to the necessity to view critically surface contamination problems in connection with unconfined use. Health and sanitation problems may occur due to the fact that the possible existence and/or extent of surface contamination remains undetected because measurements are made with an instrument not suited to the purpose. Such problems may arise due to the low energy and complexity of the characteristic emissions of the nuclides.

The wide range of particle types and energies makes it necessary to select an instrument appropriate to the radionuclide, if satisfactory health and safety information is to be obtained. It is the purpose of this document to provide the necessary information for the selection of measurement and calibration methods.

Evaluation of surface contamination —

Part 3:
Isomeric transition and electron capture emitters, low energy beta-emitters ($E_{\beta max} < 0,15$ MeV)

1 Scope

This part of ISO 7503 applies to the evaluation of contamination on surfaces of facilities and equipment, containers of radioactive materials and sealed sources in terms of activity per unit area. It does not apply to the evaluation of contamination of skin or clothing.

It is restricted to the direct measurement by portable probes and to the indirect measurement of the radionuclides mentioned in the Introduction and listed in table A.1 of annex A.

For each radionuclide, the energy spectrum as well as the intensity of each type of emitted particle or photon is unique. This type of information can be found in the bibliographic references given in annex F.

For the purpose of this part of ISO 7503, the term "beta energy" refers to the maximum energy of particles from classical beta decay.

NOTE — Evaluation of surface contamination by beta-emitters (beta energy greater than 0,15 MeV) and alpha-emitters is dealt with in ISO 7503-1. Evaluation of tritium surface contamination is dealt with in ISO 7503-2.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 7503. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 7503 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 7503-1:1988, *Evaluation of surface contamination — Part 1: Beta-emitters (maximum beta energy greater than 0,15 MeV) and alpha-emitters*.

ISO 8769-2:—[1], *Reference sources for the calibration of surface contamination monitors — Part 2: Electrons of energy less than 0,15 MeV and photons*.

IEC 248:1984, *Dimensions of planchets used in nuclear electronic instruments*.

IEC 325:1981, *Alpha, beta and alpha-beta contamination meters and monitors*.

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1) To be published.

3 Definitions

For the purposes of this part of ISO 7503, the following definitions apply.

3.1 decay efficiency of a radionuclide, ε_d: Ratio of the number of photons or electrons of a given energy created per unit time by a given radionuclide to the number of decays of this radionuclide per unit time.

3.2 efficiency of a source, ε_s: Ratio of the surface emission rate of a source to the respective production rate in the source.

NOTE — The term "source" includes any structural material in which the activity is dispersed or that may be covering the front surface of the active layer.

3.3 production rate: Number of electrons produced by the decay process(es) in the source, or the number of photons of given energy(ies) produced by decay in the source, per unit time.

3.4 surface emission rate: Number of electrons above a certain energy, or number of photons whose origin is as described for production rate, emerging from the surface of the source per unit time.

3.5 instrument efficiency, ε_i: Ratio of the instrument net reading to the surface emission rate of a source for photons or electrons of a given energy under given geometric conditions.

For a given instrument, the instrument efficiency depends on the energy of the radiations emitted by the source. The instrument efficiency is also influenced by absorbers (including air where appropriate) between source and detector.

4 Measurement techniques

4.1 General

For the measurement of radionuclides listed in table A.1 of annex A, various measurement techniques exist. Where direct measurement is not suitable, indirect methods shall be used.

Basic requirements and guidelines for direct and indirect measurements, including the use of smears for sampling, are dealt with in ISO 7503-1.

The detector types listed in table 1 are also suitable for indirect measurements if they are adequately equipped (see annex D).

4.2 Direct measurements

4.2.1 General

Direct measurements are used for the following purposes:

a) to evaluate the total amount of contamination on a surface (fixed and movable);

b) to determine whether a subsequent indirect measurement is necessary;

c) when indirect measurements are unsuitable due to long delays and possible loss of activity between sampling and measurement.

Detector size should be chosen in relation to the contaminated area, in order to complete the survey in a reasonable time. For practical purposes a detector with a minimum area of 100 cm^2 is recommended, though smaller detectors may be necessary in circumstances of restricted geometry and can also be useful in locating active spots. The surface area on which a detector receives photons is dependent on the distance from the surface contaminated and the emission energies of the radionuclides. This is of special importance for the quality of the measurement results, when the detector is not in contact with the surface or the detector is equipped with a collimator.

4.2.2 Instruments for direct measurement

Information on the application of different detector types is presented in table 1. The properties of these detectors are described in annex C.

4.3 Indirect measurements

4.3.1 General

For indirect measurements, i.e. the measurement of the amount of activity of a sample removed from the contaminated surface, a stationary well-shielded instrument offers great advantages. Such instruments can normally be operated for long counting times. Also, in some situations the background contribution may be reduced by the use of pulse-height discrimination. The user can, therefore, compensate for low instrument efficiencies by the use of long counting periods at a low background level.

However, the indirect method is restricted to the measurement of removable activity, and has a low accuracy due to uncertainties of the sampling efficiency and possible losses of activity between obtaining the smear sample and the subsequent measurement.

Indirect measurements are used for one or more of the following purposes:

a) to evaluate the amount of removable contamination on a surface;

b) to evaluate radionuclides that are difficult to measure by direct measurement due to their radiation characteristics;

c) to obtain information about the radionuclides present and the composition of mixtures;

d) to measure contamination of a surface when the surface shape does not allow direct measurement;

e) to measure contamination of surfaces which are located in radiation fields which interfere with direct measurement;

f) to detect contamination on surfaces which have overlying material that reduces the intensity of radiation available for direct measurement (wiping can remove a layer of dirt of substantial thickness; as a result, activity covered by or distributed in this layer may become better exposed on the surface of the wiped sample).

4.3.2 Instruments for indirect measurement

Information on the application of different detector types is presented in table 2. The properties of these detectors are described in annex D.

5 Suitability of various types of measuring instruments

Tables 1 and 2 indicate the suitability of different instruments for the detection of some important radionuclides included in this part of ISO 7503.

In table 1 the instruments are divided into different classes on the basis of the time t_n necessary to detect a contamination of 3,7 $Bq \cdot cm^{-2}$ (averaged over an area of no more than 200 cm^2) as follows:

Necessary detection time

$0 < t_n \leqslant 20$ s	Adequate
20 s $< t_n \leqslant 60$ s	Poor
$t_n > 60$ s	Not recommended

Instruments which cannot detect a radionuclide even with counting times of 1 000 s are represented by a barred code number followed by the sign [§].

Table 1 — Types of hand-held surface-contamination measuring instruments and their suitability for the direct detection of important low-energy emitters at 3,7 Bq·cm⁻² (background measuring time: 1 000 s)

Type of instrument	Code
Windowless argon-methane gas flow proportional detector	1
Butane-propane gas-filled, large-area proportional detector	2
Argon-methane gas flow, large-area proportional detector	3
Xenon-filled large-area proportional detector	4
Windowless plastic scintillation detector	5
Organic crystal/plastic scintillation detector	6
NaI thin-layer scintillation detector	7
Geiger-Müller detector, large area type (window Ø 46 mm)	8

Instrument characterization in terms of detection ability

Radionuclide	Adequate	Poor	Not recommended
^{7}Be		7*	1§ 2§ 3§ 4§ 5 6 7§ 8§
^{51}Cr	1 3 4 5 7*	2 8	6 7
^{54}Mn	1 2 3 4 5 7 8		6
^{55}Fe	1 3 4 5 7*	2	6 7§ 8
^{57}Co	1 2 3 4 5 7 8		6
^{63}Ni	1 2 3 5	2	4 6 7§ 8
^{65}Zn	1 3 4 7* 8	7	
^{67}Ga	1 2 3 4 5 7	6 8	
^{73}As	1 2 3 4 5 7 8		6
^{75}Se	1 2 3 4 5 7 8		6
^{85}Sr	1 2 3 4 5 7 8		6
^{88}Y	1 2 3 4 5 7 8		6
^{99m}Tc	4 5 7	1 2 3 6	8
^{111}In	1 2 3 4 5 6 7 8		
^{113}Sn/^{113m}In	1 2 3 4 5 6 7*	7 8	
^{123}I	1 2 3 4 5 6 7	8	
^{125}I	1 2 3 4 5 7	8	6
^{133}Ba	1 2 3 4 5 7 8		6
^{139}Ce	1 3 4 7	2 8	
^{191}Os	1 2 3 4 7	8	
^{195}Au	1 2 3 4 5 7	8	6
^{197}Hg	1 2 3 4 5 7	6 8	
^{199}Au	1 3 4 7	2	8
^{201}Tl	1 2 3 4 5 7	6 8	
^{203}Hg	3 4 7	2	8
^{207}Bi	1 2 3 4 5 6 7 8		
^{210}Pb	1 2 3 4 5 7 8		6

NOTES

1   The code numbers for instrument types are listed in numerical order. Numbers in bold typeface denote CHAOSCAL calibrations (underlined) or experimental evidence as basis for instrument characterization data.

2   The asterisk (*) indicates large-area detector is necessary (window of more than 100 cm² area).

3   The sign § indicates detector cannot detect the radionuclide in less than 1 000 s.

Table 2 — Types of instruments for indirect measurements under laboratory conditions and their suitability for the detection of important low-energy emitters at 3,7 Bq·cm^{-2}, (averaged over 100 cm^2)

Type of instrument	Code
Installed gas-flow large-area proportional counters[1] with thin window	A
Installed gas-flow large-area proportional counters[1] with sample inside detector	B
Liquid scintillation counters	C
Thick crystal NaI (Tl)-scintillational counters	D
Semiconductor spectrometers	E
Installed Geiger-Müller counters	F

Instrument characterization in terms of detection ability

Radionuclide	Adequate	Poor	Not recommended
^{7}Be	D E	C	A B F
^{51}Cr	C D E		A B F
^{54}Mn	C D E	F	A B
^{55}Fe	B C E	A	D F
^{57}Co	B C D E	A F	
^{63}Ni	B C E	A	D F
^{65}Zn	A B C D E	F	
^{67}Ga	A B C D E	F	
^{73}As	B C D E	F	A
^{75}Se	B C D E F	A	
^{85}Sr	B C D E F	A	
^{88}Y	B C D E F	A	
^{99m}Tc	C D E		A B F
^{111}In	A B C D E	F	
^{113}Sn/^{113m}In	A B C D E	F	
^{123}I	A B C D E		F
^{125}I	A B C D E		F
^{133}Ba	A B C D E F		
^{139}Ce	B C D E		F
^{191}Os	B C D E		F
^{195}Au	A B C D E		F
^{197}Hg	A B C D E	F	
^{199}Au	A B C D E	F	
^{201}Tl	A B C D E		F
^{207}Bi	A B C D E F		
^{210}Pb	A B C D E F		

NOTES

1 The code letters for instrument types are listed in alphabetical order.

2 Hand-held instruments can also be used for indirect measurements. Guidelines and restrictions for this purpose are given in table 1 and annex D.

1) For optimal detection of low-energy photons, the use of an argon-based gas mixture is necessary.

The combinations of instruments and radionuclides described as "adequate" are the recommended combinations. The combinations described as "poor" should be used only after thorough evaluation since it may not be possible to meet requirements of national regulations. The combinations described as "not recommended" should not be used unless careful calibration with that combination has shown that it is possible to detect the radionuclide according to relevant national regulations.

The information compiled in tables 1 and 2 is based on an uncertainty level as allowed by IEC 325, on instrument efficiency data obtained by measurements or CHAOSCAL calibrations (see 6.2), on plausible theoretical estimates and comparisons of radionuclides using their decay data.

The tables were compiled assuming that a given type of instrument is used under the most favourable conditions, i.e. covered with a window material of minimum available thickness, positioned as close as practicable to the surface examined and handled under background radiation conditions as stated in the manufacturer's specifications.

In the case of thin-layer NaI-scintillation detectors, a distinction is made between the normal small-area type (8 cm^2) and the less common large-area type (more than 100 cm^2).

The listing of instrument types in the lower part of the tables is in numerical order of code and not in order of preference.

Instruments which primarily measure electrons are not suitable for calibration or measurements with an absorber between the source and the detector. Use of an absorber is part of a recommended calibration techniques for many radionuclides in this part of ISO 7503 (MSA-, SSA-methods: see 6.2/6.3, table A.1, annex A). When the code numbers in table 1 are based on CHAOSCAL calibrations without absorber, the response of the instruments to electrons was not taken into account. Therefore, the actual total response to photons plus electrons may be somewhat higher than that used as basis for the classification.

6 Calibration

6.1 General

The principal considerations concerned with calibration and reference sources are covered in ISO 7503-1 and ISO 8769-2, respectively.

However, since the types of radiation and the energy distributions of the radionuclides considered in this part of ISO 7503 are quite different to those relating to pure higher-energy beta-emitters, the actual calibration methods cannot be the same. The diversity of the emission characteristics of the radionuclides under consideration makes it necessary to determine specific calibration factors for each of these radionuclides. This can be done in two principal ways:

a)   The instrument efficiency is measured versus radiation energy using sources emitting monoenergetic radiation. Instrument efficiency values for the radionuclides under consideration are then calculated individually, using the energy and emission probability data relating to the monoenergetic components of the radiation.

Most of the radionuclides under consideration emit monoenergetic photons and electrons, both of which may contribute to the response of a measuring instrument. A full calibration for both types of radiation would, therefore, need separate measurements of the instrument efficiency as a function of energy for both photons and electrons.

For detectors that are capable of responding to the low-energy electron radiation that is emitted by the radionuclides under consideration, the response of the instrument will be very dependent upon the construction of the calibration and contamination sources. Also, the response of the instrument can be very dependent on the geometric conditions of the measurement (e.g. air-path attenuation). Therefore, in order to minimize errors and provide consistency of measurement, it is recommended that the assessment of surface contamination be generally made from the measurement of photon emissions. In addition, since sources for monoenergetic electrons in the energy range under consideration are not available, the calibration has to be restricted to the photon emissions.

b) For each of the radionuclides to be measured, a specific calibration source made from the same radionuclide is used.

For some the radionuclides with sufficiently long half-lives (e.g. [55]Fe and [63]Ni), large-area calibration sources are commercially available. In the case of radionuclides with shorter half-lives, a rough calibration of measuring instruments can be done using working sources produced periodically from calibrated radionuclide solutions.

6.2 Multisource calibration with respect to photon emissions

This method is based on the measurement of photon emissions of a group of pseudo monoenergetic calibration sources with the help of the detector to be calibrated. The calibration sources are defined in ISO 8769-2 and cover a photon energy range from 5,9 keV to 1 250 keV. They are designed to filter out other interfering surface emissions of electrons, alpha particles and lower-energy photons by the radionuclide. For measurements of the calibration source, no additional absorber is used between source and detector.

In applying the method, it is assumed that electron emissions from the actual contamination sources do not contribute to the response of the measuring instrument. This can be ensured by using detectors not sensitive to electrons in the energy range being considered. The detector can either be insensitive to electrons by virtue of its construction (sensitive window of sufficient thickness) or it can be made insensitive by covering the sensitive window with a filter foil of sufficient thickness.

For radionuclides emitting both detectable electrons and photons, the calibration shall take into account that, in order to filter the electrons, the measurements on actual contamination sources are done with a 46 mg·cm^{-2} (0,5 mm thick) polyethylene (PE) absorber foil in front of the sensitive window of the detector. (This thickness was considered to be sufficient for electron absorption up to 200 keV energy without serious attenuation of the photons to be measured.) This means that calculated factors have to be applied to correct for the attenuation effects of the 46 mg·cm^{-2} absorber foil.

The measurements of the calibration sources as well as necessary background measurements shall be done with such counting times (pulse counting) or time constants (ratemeters) that a relative standard deviation of the corrected count rate of not greater than 5 % is obtained.

Evaluation of the measured data can be done by help of the computer program CHAOSCAL[2] developed for the application of this part of ISO 7503. Principally, the use of this part of ISO 7503 is not tied to the use of this software. However, the program CHAOSCAL facilitates a substantial range of calculations which otherwise would require a prohibitive effort. The program is described in annex E, which also gives an example printout of calibration results.

In the case of nonideal contamination sources, the source efficiency, the instrument efficiency and the decay efficiency are different for each of the m photon energies, and the activity per unit area, A_s, has to be calculated using the following equation:

$$A_s = \frac{n - n_b}{W \sum_{j=1}^{m} \left(\varepsilon_i^j \varepsilon_d^j \varepsilon_s^j \right)} \qquad \ldots (1)$$

where

n is the measured count rate, in counts per second;

n_b is the background count rate, in counts per second;

W is the area of the source seen by the sensitive window of the detector, in square centimetres.

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2) Available as public domain program. Information on this program can be obtained from the Secretariat of ISO/TC 85 Subcommittee 2.

For an ideal contamination source (no self-absorption, no backscattering) the source efficiency for each of the m discrete photon energies is $\varepsilon_s^j = 0{,}5$ and only the instrument efficiencies ε_i^j and the decay efficiencies ε_d^j remain as variables.

The equation for the calculation of the activity per unit area, A_s, would then be:

$$A_s = \frac{n - n_b}{W \times 0{,}5 \ \sum\limits_{j=1}^{m}\left(\varepsilon_i^j \varepsilon_d^j\right)} \qquad \ldots (2)$$

If the detector is calibrated and used at a distance from the source greater than the smallest practicable distance, the calibration distance and the area from which the sensitive window of the detector receives photons shall be specified by the manufacturer or be derived by the calibrator.

For both ideal and nonideal sources, the measurement of a single radionuclide by an instrument cannot be characterized by two independent values of ε_i and ε_s as can be done for pure beta-emitters of the "one electron per decay-type" (see ISO 7503-1:1988 4.2.3.2). Instead, the simple calibration factor $1/W\varepsilon_i\varepsilon_s$ is replaced by the more complex calibration factors:

$$C_{ni} = \frac{1}{W \ \sum\limits_{j=1}^{m}\left(\varepsilon_i^j \varepsilon_d^j \varepsilon_s^j\right)} \qquad \ldots (3)$$

or

$$C_i = \frac{1}{W \times 0{,}5 \ \sum\limits_{j=1}^{m}\left(\varepsilon_i^j \varepsilon_d^j\right)} \qquad \ldots (4)$$

where

    C_{ni} is the calibration factor for nonideal contamination sources;

    C_i is the calibration factor for ideal contamination sources.

In the case of nonideal contamination sources this calibration factor depends on the thickness of absorbing material, including the source and the distribution of the activity in this material.

6.3 Single-source calibration

The method of direct calibration of an instrument with respect to a specific radionuclide using a working or calibration source made from the same radionuclide can be applied to all radionuclides for which either calibration sources or calibrated solutions that allow the production of sufficiently stable working sources are available.

In principle, all types of radiation emitted can be utilized for such a calibration and the measurements based on it.

However, for nuclides with both photon and electron emissions, a 46 mg·cm^{-2} PE absorber foil in front of the detector shall be used for filtering out electrons, provided that the photon transmission remains acceptable. This will help to reduce errors caused by differences between the calibration and actual measurement conditions (backscatter, self-absorption, geometry).

In cases where filtering out electrons cannot be achieved by the 46 mg·cm^{-2} PE absorber, it is recommended that working sources for single-source calibration be prepared so as to provide the same source efficiency as the contamination source. This is also valid for ^{63}Ni.