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Secretariat: AFNOR

Nuclear energy — Reference beta-particle radiation — Part 1: Methods of production

Énergie nucléaire — Rayonnement bêta de référence — Partie 1 :Méthodes de production

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Contents

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.

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~~document 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).~~www.iso.org/directives).

~~Attention is drawn~~ISO draws attention to the possibility that ~~some of~~ the ~~elements~~implementation of this document may ~~be~~involve the ~~subject~~use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights~~.~~ in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. 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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This document was prepared by Technical Committee ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection*.

This third edition of ISO 6980-1 cancels and replaces ISO 6980-1:2022, of which it constitutes a minor revision.

The main changes are ~~the following~~as follows:

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— editorial changes throughout the document.

A list of all the parts in the ISO 6980 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at ~~www.iso.org/members.html~~www.iso.org/members.html.

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Introduction

ISO 6980 series covers the production, calibration, and use of beta-particle reference radiation fields for the calibration of dosemeters and dose-rate meters for protection purposes. This document describes the methods of production and characterization of the reference radiation. ISO 6980-2 describes procedures for the determination of absorbed dose rate to a reference depth of tissue from beta particle reference radiation fields. ISO 6980-3 describes procedures for the calibration of dosemeters and dose-rate meters and the determination of their response as a function of beta-particle energy and angle of beta-particle incidence.

For beta particles, the calibration and the determination of the response of dosemeters and dose-rate meters is essentially a three-step process. First, the basic field quantity, absorbed dose to tissue at a depth of 0,07 mm (and optionally also at a depth of 3 mm) in a tissue-equivalent slab geometry is measured at the point of test, using methods described in ISO 6980-2. Then, the appropriate operational quantity is derived by the application of a conversion coefficient that relates the quantity measured (reference absorbed dose) to the selected operational quantity for the selected irradiation geometry. Finally, the reference point of the device under test is placed at the point of test for the calibration and determination of the response of the dosemeter. Depending on the type of dosemeter under test, the irradiation is either carried out on a phantom or free-in-air for personal and area dosemeters, respectively. For individual and area monitoring, this document describes the methods and the conversion coefficients to be used for the determination of the response of dosemeters and dose-rate meters in terms of the ICRU operational quantities, i.e., directional dose equivalent, $H'(0{,}07;\Omega)$ and $H'(3;\Omega)$, as well as personal dose equivalent, $H_p(0{,}07)$ and $H_p(3)$.

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Nuclear energy — Reference beta-particle radiation — Part 1: Methods of production

1 Scope

This document specifies the requirements for reference beta radiation fields produced by radioactive sources to be used for the calibration of personal and area dosemeters and dose-rate meters to be used for the determination of the quantities $H_p(0,07)$, $H'(0,07;\Omega)$, $H_p(3)$ and $H'(3;\Omega)$, and for the determination of their response as a function of beta particle energy and angle of incidence. The basic quantity in beta dosimetry is the absorbed-dose rate in a tissue-equivalent slab phantom. This document gives the characteristics of radionuclides that have been used to produce reference beta radiation fields, gives examples of suitable source constructions and describes methods for the measurement of the residual maximum beta particle energy and the dose equivalent rate at a depth of 0,07 mm in the International Commission on Radiation Units and Measurements (ICRU) sphere. The energy range involved lies between 0,22 MeV and 3,6 MeV maximum beta energy corresponding to 0,07 MeV to 1,2 MeV mean beta energy and the dose equivalent rates are in the range from about 10 $\mu Sv \cdot h^{-1}$ to at least 10 $Sv \cdot h^{-1}$. In addition, for some sources, variations of the dose equivalent rate as a function of the angle of incidence are given. However, as noted in ICRU Report 56,[3], the ambient dose equivalent, $H^*(10)$, used for area monitoring, and the personal dose equivalent, $H_p(10)$, as used for individual monitoring, of strongly penetrating radiation, are not appropriate quantities for any beta radiation, even that which penetrates 10 mm of tissue (E_{max} > 2 MeV).

This document is applicable to two series of beta reference radiation fields, from which the radiation necessary for determining the characteristics (calibration and energy and angular dependence of response) of an instrument can be selected.

Series 1 reference radiation fields are produced by radioactive sources used with beam-flattening filters designed to give uniform dose equivalent rates over a large area at a specified distance. The proposed sources of $^{106}Ru/^{106}Rh$, $^{90}Sr/^{90}Y$, ^{85}Kr, ^{204}Tl and ^{147}Pm produce maximum dose equivalent rates of approximately 200 $mSv \cdot h^{-1}$.

Series 2 reference radiation fields are produced without the use of beam-flattening filters, which allows large area planar sources and a range of source-to-calibration plane distances to be used. Close to the sources, only relatively small areas of uniform dose rate are produced, but this series has the advantage of extending the energy and dose rate ranges beyond those of series 1. The series also include radiation fields using polymethylmethacrylate (PMMA) absorbers to reduce the maximum beta particle energy. The radionuclides used are those of series 1; these sources produce dose equivalent rates of up to 10 $Sv \cdot h^{-1}$.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments (AMD)) applies.

ISO 29661, *Reference radiation fields for radiation protection — Definitions and fundamental concepts*

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ISO/IEC Guide 99, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*</std>

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 29661, ISO/IEC Guide 99 and the following apply.

ISO and IEC maintain ~~terminological~~terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at ~~https://www.iso.org/obp~~https://www.iso.org/obp

— IEC Electropedia: available at ~~https://www.electropedia.org/~~https://www.electropedia.org/

3.1
tissue equivalence
property of a material that approximates the radiation attenuation and scattering properties of ICRU tissue

Note 1 to entry: See Annex A; more tissue substitutes are given by ICRU ~~report~~Report 44[4].

Note 2 to entry: Further details are given in ISO 6980-2:~~2023.~~ — 6.2.

3.2
maximum beta energy
E_{max}
highest value of the energy of beta particles emitted by a particular radionuclide which can emit one or several continuous spectra of beta particles with different maximum energies

3.3
mean beta energy
E_{mean}
fluence averaged energy of the beta particle spectrum at the calibration distance free in air

3.4
residual maximum beta energy
E_{res}
highest value of the energy of a beta-particle spectrum at the calibration distance after having been modified by scattering and absorption

3.5
residual maximum beta particle range
R_{res}
range in an absorbing material of a beta-particle spectrum of residual maximum energy, E_{res}

4 Requirements for reference beta-particle radiation fields at the calibration distance

4.1 Standard test conditions

All calibrations and measurements shall be conducted under standard test conditions in accordance with Tables B.1 and B.2. The range of values of influence quantities within the standard test conditions are given in Tables B.1 and B.2 for radiation-related and other parameters, respectively.

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4.2 Energy of the reference radiation fields

The energy of the reference radiation field is defined to be equal to E_{res} (see 3.4 and 6.1.2).

4.3 Shape of the beta-particle spectrum

The beta-particle spectrum of the reference radiation should ideally result from one beta decay branch from one radionuclide. In practice, the emission of more than one branch is acceptable provided that all the main branches have similar energies, E_{max}, within ±20 %. In other cases, the lower energy branches shall be attenuated by the source encapsulation or by additional filtration to reduce their beta emission rates to less than 10 % of the emission rate from the main branch.

4.4 Uniformity of the dose rate

The dose rate at the calibration distance should be as uniform as possible over the area of the detector. Since available sources for series 1 reference radiation fields (see 6.2.2) cannot at present produce high absorbed dose rates with satisfactory uniformity for large radiation field diameters, a further series (series 2) of reference beta-particle radiation fields is proposed (see 6.2.3). A beta-particle radiation field is considered to be uniform over a certain radiation field diameter if the dose rate does not vary by more than ±5 % for $E_{res} \geq 300$ keV and by not more than ±10 % for $E_{res} < 300$ keV (see 6.2.2).

4.5 Photon contamination

The photon dose rate contributing to the total dose rate due to contamination of the reference radiation by gamma, X-ray and bremsstrahlung radiation, H_{photon}, should be less than 2 % of the beta particle dose rate, H_{beta}, i.e. $H_{photon}/H_{beta} < 0{,}02$. This shall be valid for the considered quantity, i.e. for $H_p(0{,}07)$, $H'(0{,}07;\Omega)$, $H_p(3)$ or $H'(3;\Omega)$.

Regarding the determination of the photon contribution and the indication of the instrument under test see 6.1.4.

4.6 Variation of the beta-particle emission with time

The beta-particle emission rate decreases with time due to the radioactive decay of the beta emitting radionuclide. The half-life of a radionuclide should be as long as possible, preferably longer than one year. The half-lives of the recommended sources are given in Table 1.

5 Radionuclides suitable for reference beta-particle radiation fields

Table 1 gives the characteristics of beta-particle-emitting radionuclides of a suitable energy range. Beta–particle–emitting radionuclides should be selected from those listed in this table. These radionuclides emit a continuous spectrum of beta particles with energies ranging from zero up to a maximum value, E_{max}, characteristic of the particular nuclide.

A radionuclide normally requires encapsulation to be a source which may be handled. Such encapsulating material produces bremsstrahlung and characteristic X-rays.

Table 1 — Beta particle radionuclide data

Radionuclide	Half life[a] days	Maximum energy emitted[ab] E_{max} (approximate values) MeV	Photon radiation[ac] (approximate values)
^{147}Pm	958,18 (0,15)	0,224	γ: 0,121 MeV (0,002 7 %) Sm X-rays: 5,0 to 7,5 keV 39,5 to 46,8 keV

^{85}Kr	3 922 (5)	0,687	γ: 0,514 MeV (0,44 %) Rb X-rays: 13,3 to 15,2 keV
^{204}Tl	1 382 (4)	0,764	γ: none Hg X-rays: 8,7 to 14,8 keV 68,9 to 83,0 keV Pb X-rays: 72,8 to 87,9 keV
^{90}Sr/^{90}Y	10 559 (11)	2,279	Negligible[d]
^{106}Ru/^{106}Rh	371,8 (1,8)	3,546	^{106}Rh γ: 0,512 MeV (21 %) 0,616 MeV (0,7 %) 0,622 MeV (10 %) 0,87 MeV (0,4 %) 1,05 MeV (1,5 %) 1,13 MeV (0,4 %) 1,56 MeV (0,16 %) Pd X-rays: 2,5 to 24,3 keV

[a] The values in this column are taken from the Nuclear Data Sheets (NDS); the values in brackets are the standard uncertainties[5][6][7][8][9].

[b] The values given in this column are for information purposes only.

[c] The values in brackets are emission probabilities per decay.

[d] "Negligible" indicates levels of emissions that do not affect the detection of beta radiation.

6 Source characteristics and their measurement

6.1 Fundamental characteristics of reference sources

6.1.1 Construction of reference sources

The construction of the reference sources should have the following characteristics to meet the requirements of Clause 4.

a) The chemical form of the radionuclide should be stable with time over the range of temperatures and humidities at which it is used and stored.

b) The construction and encapsulation constituting the source containment should be sufficiently robust and stable to withstand normal use without damage to the source and leakage of the radioactivity but shall allow E_{res} to exceed the minimum values recommended in Table 2.

c) The typical set of radionuclides shown in Table 2 can be complemented by two energy-reduced radiation fields from ^{90}Sr/^{90}Y sources. Such fields can be obtained by placing 3 mm or 4 mm thick polymethylmethacrylate (PMMA) absorbers in front of the source. The absorber shall be positioned with its end face 4 cm from the source, i.e. with its front face 3,7 cm and 3,6 cm for the 3 mm and 4 mm plate, respectively, and its diameter shall be at least 20 cm[10][11].

6.1.2 Measurement and/or simulation of characteristics of the reference radiation fields

The values of the residual maximum beta energy, E_{res}, shall equal or exceed the values given in Table 2.

Table 2 — Minimum value of the residual maximum beta energy, $E_{res,min}$, at the calibration distance

Radionuclide	$E_{res,min}$ MeV

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^{147}Pm	0,13
^{85}Kr	0,53
^{204}Tl	0,53
^{90}Sr/^{90}Y	1,80
^{106}Ru/^{106}Rh	2,50

The purpose in setting a lower limit to E_{res} is to prevent the use of sources that have excessive self and/or window absorption.

The residual maximum beta energy, E_{res}, shall be calculated from Formula (1)[12]:

$$E_{res} = \sqrt{\left[(0{,}009\ 1 \cdot R_{res} + 1)^2 - 1\right] / 22{,}4} \quad (1)$$

where

E_{res} is expressed in MeV and R_{res} is the residual maximum beta particle range, expressed in milligrams per square centimetre (mg·cm^{-2}).

R_{res} shall be measured by a suitable detector (extrapolation chamber, thin-window ionization chamber, Geiger Müller counter, beta-sensitive phosphor, etc.) that shall be positioned at the calibration distance with its entrance window facing the source. For the measurements, various thicknesses of absorber shall be placed immediately in front of the detector. The absorber shall be made of a tissue-equivalent substance, e.g. PMMA, polystyrene, polyethylene, polyethylene terephthalate (PET) or an equivalent material. A list of tissue-equivalent substances is given in Annex A. The thickness of the detector window used for these measurements shall be taken into account in the measurement of R_{res}. If the source uses a beam-flattening filter, i.e. a series 1 reference radiation is produced (see 6.2.2), then this filter shall be in position for the measurement of R_{res}. The signal from the detector shall be determined as a function of absorber (mass) thickness and a plot shall be made of the logarithm of signal versus absorber (mass) thickness, expressed in tissue equivalent milligrams per square centimetre (mg·cm^{-2}) or micrometre (µm). The tissue equivalent thickness can be derived with ISO 6980-2:—, Formula (7) ~~in ISO 6980-2,~~). R_{res} is defined as the intersection of the extrapolated linear portion of the measured signal versus (mass) thickness and the lower level signal due to the residual photon background. This is illustrated in Figure 1 for the example of ^{147}Pm.

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