INTERNATIONAL STANDARD

ISO 6980-1

First edition
2006-08-01

Nuclear energy — Reference beta-particle radiation —

Part 1: Methods of production

Énergie nucléaire — Rayonnement bêta de référence —

Partie 1: Méthodes de production

Reference number
ISO 6980-1:2006(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 6980-1 was prepared by Technical Committee ISO/TC 85, *Nuclear energy*, Subcommittee SC 2, *Radiation protection*.

This first edition of ISO 6980-1, together with the first edition of ISO 6980-2 and the first edition of ISO 6980-3 cancels and replaces ISO 6980:1996, which has been technically revised.

ISO 6980 consists of the following parts, under the general title *Nuclear energy — Reference beta-particle radiations*:

— *Part 1: Methods of production*

— *Part 2: Calibration fundamentals related to basic quantities characterizing the radiation field*

— *Part 3: Calibration of area and personal dosemeters and the determination of their response as a function of beta radiation energy and angle of incidence*

Nuclear energy — Reference beta-particle radiation —

Part 1: **Methods of production**

1 Scope

This part of ISO 6980 specifies the requirements for reference beta radiation fields produced by radionuclide 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 $H_p(0,07)$ and $H'(0,07)$, and for the determination of their response as a function of beta particle energy and angle of incidence. It 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 66 keV[1)] and 3,6 MeV and the dose equivalent rates are in the range from about 10 µSv h^{-1} to at least 10 Sv h^{-1}. In addition, for some sources variations of the dose equivalent rate as a function of the angle of incidence are given.

This part of ISO 6980 proposes 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 radionuclide 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 $^{90}Sr + ^{90}Y$, ^{85}Kr, ^{204}Tl and ^{147}Pm produce maximum dose equivalent rates of approximately 200 mSv 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 radionuclides used are those of series 1 with the addition of the radionuclides ^{14}C and $^{106}Ru + ^{106}Rh$; these sources produce dose equivalent rates of up to 10 Sv h^{-1}.

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.

International vocabulary of basic and general terms in metrology, (VIM), *BIPM/IEC/IFCC/ISO/IUPAC/IUPAP/OIML*

ICRU 51:1993, *Quantities and Units in Radiation Protection Dosimetry*

ISO 6980-3, *Nuclear energy — Reference beta-particle radiations — Part 3: Calibration of area and personal dosemeters and determination of their response as a function of beta radiation energy and angle of incidence*

1) The lower limit of the energies being considered is the energy of an electron that can just penetrate to the depth of interest, 0,07 mm[1].

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ICRU Report 51, VIM and ISO 6980-3 and the following apply.

3.1
absorbed dose
D
quotient of d$\bar{\varepsilon}$ by dm, where d$\bar{\varepsilon}$ is the mean energy imparted by ionizing radiation to matter of mass dm

$$D = \mathrm{d}\bar{\varepsilon} / \mathrm{d}m \tag{1}$$

NOTE The unit of the absorbed dose is joule per kilogram (J kg^{-1}) with the special name of gray (Gy).

3.2
absorbed dose rate
$\dot{D}$
quotient of dD by dt, where dD is the increment of absorbed dose in the time interval, dt

$$\dot{D} = \mathrm{d}D / \mathrm{d}t \tag{2}$$

NOTE The SI unit of absorbed dose rate is gray per second (Gy s^{-1}). Units of absorbed dose rate are any quotient of the gray or its decimal multiples or submultiples by an appropriate unit of time (e.g. mGy h^{-1}).

3.3
dose equivalent
H
product of the absorbed dose, D, and the quality factor, Q, at a point in an irradiated medium

$$H = DQ \tag{3}$$

NOTE 1 For beta, X and gamma radiation, Q can be taken as equal to unity for external radiation[1].

NOTE 2 The SI unit of dose equivalent is joule per kilogram (J kg^{-1}) with the special name of sievert (Sv).

3.4
dose equivalent rate
$\dot{H}$
quotient of dH by dt, where dH is the increment of dose equivalent in the time interval, dt

$$\dot{H} = \mathrm{d}H / \mathrm{d}t \tag{4}$$

NOTE The SI unit of dose equivalent rate is the sievert per second (Sv s^{-1}). Units of dose equivalent rate are any quotient of the sievert or its decimal multiples and a suitable unit of time (e.g. mSv h^{-1}).

3.5
directional dose equivalent for weakly penetrating radiation
$H'(0{,}07;\vec{\Omega})$
dose equivalent that, at a point in a radiation field, is produced by the corresponding expanded field in the ICRU sphere at a depth of 0,07 mm on a radius in a specified direction, $\vec{\Omega}$

NOTE 1 The unit of the directional dose equivalent is joule per kilogram (J kg^{-1}) with the special name sievert (Sv).

NOTE 2 In the expanded field, the fluence and its angular and energy distributions have the same value over the volume of interest as in the actual field at the point of measurement.

NOTE 3 See ICRU 56[2].

3.6
personal dose equivalent for weakly penetrating radiation
$H_p(0,07)$
dose equivalent in soft tissue below a specified point on the body at a depth of 0,07 mm

NOTE 1 The unit of the personal dose equivalent is joule per kilogram ($J\ kg^{-1}$) with the special name sievert (Sv).

NOTE 2 In a unidirectional field, the direction can be specified in terms of the angle, α, between the direction opposing the incident field and a specified normal on the phantom surface.

3.7
total mass stopping power
S/ρ
the quotient of dE by ρdl, where dE is the energy lost by a charged particle in traversing a distance, dl, in a material of mass density, ρ

$$\frac{S}{\rho} = \frac{1}{\rho}\frac{dE}{dl} \quad (5)$$

NOTE 1 The SI unit of mass stopping power is joule per square metre ($J\ m^2\ kg^{-1}$). E can be expressed in electronvolts (eV) and hence S/ρ can be expressed in $eV\ m^2\ kg^{-1}$.

NOTE 2 S is the total linear stopping power.

NOTE 3 For energies at which nuclear interactions can be neglected, the total mass stopping power is

$$\frac{S}{\rho} = \frac{1}{\rho}\left(\frac{dE}{dl}\right)_{col} + \frac{1}{\rho}\left(\frac{dE}{dl}\right)_{rad} \quad (6)$$

where

$(dE/dl)_{col} = S_{col}$ is the linear collision stopping power;

$(dE/dl)_{rad} = S_{rad}$ is the linear radiative stopping power.

3.8
ICRU tissue
material with a density of $1\ g\ cm^{-3}$ and a mass composition of 76,2 % oxygen, 10,1 % hydrogen, 11,1 % carbon, and 2,6 % nitrogen

NOTE See ICRU report 39[10].

3.9
tissue equivalence
property of a material that approximates the radiation attenuation and scattering properties ICRU tissue

NOTE See Annex A; more tissue substitutes are given by ICRU report 44 [3].

3.10
maximum beta energy
E_{max}
highest value of the energy of beta particles emitted by a particular nuclide that can emit one or several continuous spectra of beta particles with different maximum energies

3.11
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

3.12
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 Energy of the reference radiation fields

The energy of the reference radiation field is defined to be equal to E_{res} (see 3.11 and 6.1.2).

4.2 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.

4.3 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 $E_{res} \geqslant 300$ keV and by not more than ± 10 % for $E_{res} < 300$ keV (see 6.2.2).

4.4 Photon contamination

The photon dose rate contributing to $H_p(0,07)$ due to contamination of the reference radiation by gamma, X-ray and bremsstrahlung radiation should be less than 5 % of the beta particle dose rate recorded by the detector under calibration.

4.5 Variation of the beta-particle emission with time

The beta-particle emission rate decreases with time due to the radioactive decay of the beta particle source. 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.

Note that a radionuclide normally requires encapsulation to be a practical source and that the encapsulating material produces bremsstrahlung and characteristic X-rays.

Table 1 — Beta particle radionuclide data

Radionuclide	Half life[a] days	Maximum energy emitted [b] E_{max} MeV	Photon radiation
^{14}C	2 093 000	0,156	None
^{147}Pm	958,2	0,225	γ: 0,121 MeV (0,01 %) Sm X-rays: 5,6 to 7,2 keV 39,5 to 46,6 keV
^{85}Kr	3 915	0,687	γ: 0,514 MeV (0,4 %)
^{204}Tl	1 381	0,763	Hg X-rays: 9,9 to 13,8 keV 68,9 to 82,5 keV
$^{90}Sr + ^{90}Y$	10 523	2,274	None
$^{106}Ru + ^{106}Rh$	373,6	3,54	^{106}Rh γ: 0,121 MeV (0,01 %) 0,622 MeV (11 % doublet) 1,05 MeV (1,5 % doublet) 1,13 MeV (0,5 % doublet) 1,55 MeV (0,2 %)

a The values in this column taken from ISO 6980-2:2004 Table C.4 [11].

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

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.