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Reference neutron radiations —

Part 1:
Characteristics and methods of production

Rayonnements neutroniques de référence —

Partie 1: Caractéristiques et méthodes de production

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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 part of ISO 8529 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 8529-1 was prepared by Technical Committee ISO/TC 85, *Nuclear energy*, Subcommittee SC 2, *Radiation protection*.

ISO 8529 consists of the following parts, under the general title *Reference neutron radiations*:

— *Part 1: Characteristics and methods of production*

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

— *Part 3: Calibration of area and personal dosimeters and determination of response as a function of energy and angle of incidence*

Annexes A and C form a normative part of this part of ISO 8529. Annex B is for information only.

Introduction

This part of ISO 8529 supersedes ISO 8529:1989. It is the first of a set of three International Standards concerning the calibration of dosimeters and dose-rate meters for neutron radiation for protection purposes. It describes the characteristics and methods of production of the reference neutron radiations to be used for calibrations. ISO 8529-2 describes fundamentals related to the physical quantities characterizing the radiation field and calibration procedures in general terms, with emphasis on active dose-rate meters and the use of radionuclide sources. ISO 8529-3 deals with dosimeters for area and individual monitoring, describing the respective procedures for calibrating and determining the response in terms of the International Commission on Radiation Units and Measurements (ICRU) operational quantities. Conversion coefficients for converting neutron fluence into these operational quantities are provided in ISO 8529-3.

Reference neutron radiations —

Part 1:
Characteristics and methods of production

1 Scope

This part of ISO 8529 specifies the reference neutron radiations, in the energy range from thermal up to 20 MeV, for calibrating neutron-measuring devices used for radiation protection purposes and for determining their response as a function of neutron energy. Reference radiations are given for neutron fluence rates of up to 1×10^9 $m^{-2} \cdot s^{-1}$, corresponding, at a neutron energy of 1 MeV, to dose-equivalent rates of up to 100 $mSv \cdot h^{-1}$.

This part of ISO 8529 is concerned only with the methods of producing and characterizing the neutron reference radiations. The procedures for applying these radiations for calibrations are described in ISO 8529-2 and ISO 8529-3.

The reference radiations specified are the following:

— neutrons from radionuclide sources, including neutrons from sources in a moderator;

— neutrons produced by nuclear reactions with charged particles from accelerators;

— neutrons from reactors.

In view of the methods of production and use of them, these reference radiations are divided, for the purposes of this part of ISO 8529, into the following two separate sections.

— In clause 4, radionuclide neutron sources with wide spectra are specified for the calibration of neutron-measuring devices. These sources should be used by laboratories engaged in the routine calibration of neutron-measuring devices, the particular design of which has already been type tested.

— In clause 5, accelerator-produced monoenergetic neutrons and reactor-produced neutrons with wide or quasi monoenergetic spectra are specified for determining the response of neutron-measuring devices as a function of neutron energy. Since these reference radiations are produced at specialized and well equipped laboratories, only the minimum of experimental detail is given.

For the conversion of neutron fluence into the quantities recommended for radiation protection purposes, conversion coefficients have been calculated based on the spectra presented in normative annex A and using the fluence-to-dose-equivalent conversion coefficients as a function of neutron energy as given in ICRP Publication 74 and ICRU Report 57.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 8529. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 8529 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 8529-2:2000 *Reference neutron radiations — Part 2: Calibration fundamentals of radiation protection devices related to the basic quantities characterizing the radiation field*.

ISO 8529-3:1998, *Reference neutron radiations — Part 3: Calibration of area and personal dosimeters and determination of response as a function of energy and angle of incidence*.

ICRP Publication 74, *Conversion Coefficients for use in Radiological Protection against External Radiation*, *Annals of the ICRP*, Vol. 26, No.3/4 (1996).

ICRU Report 33:1980, *Radiation Quantities and Units.*

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

ICRU Report 57:1998, *Conversion Coefficients for use in Radiological Protection Against External Radiation*.

3 Tests and definitions

For the purposes of this part of ISO 8529, the terms and definitions given in ICRU Reports 33 and 51 and the following apply.

3.1
neutron fluence
Φ
quotient of dN by da, where dN is the number of neutrons incident on a sphere of cross-sectional area da

$$\Phi = \frac{\mathrm{d}N}{\mathrm{d}a}$$

NOTE The unit of the neutron fluence is m^{-2}; a frequently used unit is cm^{-2}.

3.2
neutron fluence rate
neutron flux density
φ
quotient of dΦ by dt, where dΦ is the increment of **neutron fluence** (3.1) in the time interval dt

$$\varphi = \frac{\mathrm{d}\Phi}{\mathrm{d}t} = \frac{\mathrm{d}^2 N}{\mathrm{d}a \cdot \mathrm{d}t}$$

NOTE The unit of the neutron fluence rate is $\mathrm{m}^{-2} \cdot \mathrm{s}^{-1}$.

3.3
spectral neutron fluence
energy distribution of the neutron fluence
Φ_E
quotient of dΦ by dE, where dΦ is the increment of neutron fluence in the energy interval between E and E + dE

$$\Phi_E = \frac{\mathrm{d}\Phi}{\mathrm{d}E}$$

NOTE The unit of the spectral neutron fluence is $\mathrm{m}^{-2}\cdot\mathrm{J}^{-1}$; a frequently used unit is $\mathrm{cm}^{-2}\cdot\mathrm{eV}^{-1}$.

3.4
spectral neutron fluence rate
spectral neutron flux density
φ_E
quotient of $\mathrm{d}\Phi_E$ by $\mathrm{d}t$, where $\mathrm{d}\Phi_E$ is the increment of spectral neutron fluence in the time interval $\mathrm{d}t$

$$\varphi_E = \frac{\mathrm{d}\Phi_E}{\mathrm{d}t} = \frac{\mathrm{d}^2\Phi}{\mathrm{d}E\cdot\mathrm{d}t}$$

NOTE The unit for the spectral neutron fluence rate is $\mathrm{m}^{-2}\cdot\mathrm{s}^{-1}\cdot\mathrm{J}^{-1}$; a frequently used unit is $\mathrm{cm}^{-2}\cdot\mathrm{s}^{-1}\cdot\mathrm{eV}^{-1}$.

3.5
absorbed dose
D
quotient of $\mathrm{d}\bar{\varepsilon}$ by $\mathrm{d}m$, where $\mathrm{d}\bar{\varepsilon}$ is the mean energy imparted by ionizing radiation to matter of mass $\mathrm{d}m$

$$D = \frac{\mathrm{d}\bar{\varepsilon}}{\mathrm{d}m}$$

NOTE The unit of the absorbed dose is $\mathrm{J}\cdot\mathrm{kg}^{-1}$ with the special name gray (Gy).

3.6
dose equivalent
H

product of Q and D at a point in tissue, where D is the absorbed dose and Q is the quality factor at that point

$$H = QD$$

NOTE The unit for the dose equivalent is $\mathrm{J}\cdot\mathrm{kg}^{-1}$ with the special name sievert (Sv).

3.7
dose-equivalent rate
$\dot{H}$
quotient of $\mathrm{d}H$ by $\mathrm{d}t$, where $\mathrm{d}H$ is the increment of dose equivalent in the time interval $\mathrm{d}t$

$$\dot{H} = \frac{\mathrm{d}H}{\mathrm{d}t}$$

NOTE The unit for the dose-equivalent rate is $\mathrm{J}\cdot\mathrm{kg}^{-1}\cdot\mathrm{s}^{-1}$ with the special name sievert per second ($\mathrm{Sv}\cdot\mathrm{s}^{-1}$).

3.8
neutron fluence-to-dose-equivalent conversion coefficient
h_Φ
quotient of the neutron dose equivalent, H, and the neutron fluence, Φ, at a point in the radiation field, undisturbed by the irradiated object

$$h_\Phi = \frac{H}{\Phi}$$

NOTE Any statement of a fluence-to-dose-equivalent conversion coefficient requires a statement of the type of dose equivalent, e.g. ambient dose equivalent or personal dose equivalent. Their specific definitions and respective conversion coefficients are given in ISO 8529-3.

3.9
activity of an amount of radioactive nuclide in a particular energy state at a given time
A
quotient of dN^+ by dt, where dN^+ is the expectation value of the number of spontaneous nuclear transitions from that energy state in the time interval dt

$$A = \frac{\mathrm{d}N^+}{\mathrm{d}t}$$

NOTE The unit of the activity is s^{-1} with the special name Becquerel (Bq).

3.10
neutron source strength of a neutron source at a given time
B
quotient of dN* by dt, where dN* is the expectation value of the number of neutrons emitted by the source in the time interval dt

$$B = \frac{\mathrm{d}N^*}{\mathrm{d}t}$$

NOTE The unit of the source strength is s^{-1}.

3.11
angular source strength
B_Ω
quotient of dB by dΩ, where dB is the number of neutrons per unit time propagating in a specified direction within the solid angle dΩ

$$B_\Omega = \frac{\mathrm{d}B}{\mathrm{d}\Omega}$$

NOTE The unit of the angular source strength is $s^{-1} \cdot sr^{-1}$.

3.12
spectral source strength
energy distribution of neutron source strength
B_E
quotient of dB by dE, where dB is the increment of neutron source strength in the energy interval between E and E + dE

$$B_E = \frac{\mathrm{d}B}{\mathrm{d}E}$$

NOTE 1 The unit of the spectral source strength is $s^{-1} \cdot J^{-1}$; a frequently used unit is $s^{-1} \cdot eV^{-1}$.

NOTE 2 The source strength B is derived from B_E as follows:

$$B = \int_0^\infty B_E \mathrm{d}E$$

At a distance l from a point source, the **spectral neutron fluence rate** φ_E (3.4), due to neutrons emitted isotropically from the point source with a spectral neutron source strength B_E (neglecting the influence of surrounding material), is given by

$$\varphi_E = \frac{B_E}{4\pi l^2}$$

3.13
fluence-average neutron energy
$\bar{E}$
neutron energy averaged over the spectral neutron fluence

$$\bar{E} = \frac{1}{\Phi} \int_0^\infty E \cdot \Phi_E (E) \mathrm{d}E$$

3.14
dose-equivalent-average neutron energy
$\tilde{E}$
neutron energy averaged over the dose-equivalent spectrum

$$\tilde{E} = \frac{1}{H} \int_0^\infty E \cdot h_\Phi (E) \Phi_E \mathrm{d}E$$

NOTE In the above equation, $H = \int_0^\infty h_\Phi (E) \Phi_E \mathrm{d}E$.

3.15
response
R
quotient of the reading, M, of a measuring instrument and the conventional true value of the measured quantity

NOTE The type of response should be specified, e.g. “fluence response” (response with respect to Φ):

$$R_\Phi = \frac{M}{\Phi}$$

or “dose-equivalent response” (response with respect to dose equivalent H):

$$R_H = \frac{M}{H}$$

4 Reference radiations for the calibration of neutron-measuring devices

4.1 Introduction

In this clause, reference radiations produced by radionuclide neutron sources are specified which are particularly suited for the calibration of neutron-measuring devices (see ISO 8539-3).

4.2 General properties

4.2.1 Types

The neutron sources given in Table 1 shall be used to produce reference radiations. The numerical values given in Table 1 are to be taken only as a guide to the prominent features of the sources. The neutron source strengths and the dose-equivalent rates may vary with the construction of the source, because of scattering and absorption of neutrons and γ-rays, and with the isotopic impurities of the radioactive material used. Hence details of the source encapsulation are specified (see 4.2.2), and the method for determining the anisotropy of the neutron emission is specified (see 4.4). For ^{252}Cf, the specific photon dose-equivalent rate is dependent upon the age of the source because of the build-up of γ-emitting fission products. However, the increase is not more than 5 % during the first 20 years.

In addition to the sources listed in Table 1, sources such as Pu-Be(α,n) and Am-Li(α,n) are also used. However, it is recommended that laboratories should not start using plutonium-beryllium sources if they are not already doing so.

Table 1 — Reference radionuclide neutron sources for calibrating neutron-measuring devices

Source	Half-life a[d]	Fluence-average energy[a,b] MeV	Dose-equivalent-average energy[a,b] MeV	Specific source strength[c] $s^{-1} \cdot kg^{-1}$	Ratio of photon to neutron dose-equivalent rates[c]	Spectrum averaged fluence-to-dose-equivalent conversion coefficient[b] pSv · cm^2
^{252}Cf (D_2O moderated) [e]	2,65	0,55	2,1	$2,1 \times 10^{15}$	0,18	105
^{252}Cf	2,65	2,13	2,3	$2,4 \times 10^{15}$	0,05 [f]	385
				$s^{-1} \cdot Bq^{-1}$		
^{241}Am-B(α,n)	432	2,72	2,8	$1,6 \times 10^{-5}$	< 0,20 [g]	408
^{241}Am-Be(α,n)	432	4,16	4,4	$6,6 \times 10^{-5}$	< 0,05 [g]	391

a Definitions of the fluence, and dose-equivalent-average energies are given in 3.13 and 3.14 respectively.

b Calculated on the basis of the neutron spectra given in annex A and the conversion coefficients given in ICRU Report 57.

c For ^{252}Cf sources, the specific quantities are related to the mass of californium contained in the source (see normative annex A). For the other sources, they are related to the activity of the ^{241}Am contained in the source. Information on the sources is given for moderated ^{252}Cf in the Bibliography [1], [2], [3] and [5], for ^{252}Cf in [1] and [4], for ^{241}Am-B in [6], and for ^{241}Am-Be in [7].

d 1 a = 1 mean solar year = 31 556 926 s or 365,242 20 days.

e Heavy-water sphere with a diameter of 300 mm, covered with a cadmium shell of thickness approximately 1 mm. Of the source neutrons, 11,5 % are moderated below the cadmium cut-off and captured in the cadmium shell (see annex A).

f For approximately 2,5 mm thick steel encapsulation.

g For a source that has been enclosed within an approximately 1 mm thick lead shield.

