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Neutron reference radiations for calibrating neutron-measuring devices used for radiation protection purposes and for determining their response as a function of neutron energy

Rayonnements neutroniques de référence destinés à l'étalonnage des instruments de mesure des neutrons utilisés en radioprotection et à la détermination de leur réponse en fonction de l'énergie des neutrons

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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 8529 was prepared by Technical Committee ISO/TC 85, *Nuclear energy.*

Annexes A, B, C and D form an integral part of this International Standard. Annex E is for information only.

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Neutron reference radiations for calibrating neutron-measuring devices used for radiation protection purposes and for determining their response as a function of neutron energy

1 Scope

This International Standard specifies the neutron reference 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 variation in response as a function of neutron energy. Reference radiations are given for neutron fluence rates of up to 10^5 cm^{-2}·s^{-1}, corresponding, at a neutron energy of 1 MeV, to dose equivalent rates of up to 100 mSv·h^{-1} (10 rem·h^{-1}). This International Standard applies to radiation protection calibrations in units of the quantity "dose equivalent", but values are also given in units of the quantities "absorbed dose" and "kerma" in "standard man tissue".

It should be noted that at the present time, the definitions of "dose equivalent" quantities to be used for radiation protection purposes are under review by both the ICRU and the ICRP[1]. The definitions of "dose equivalent" and the conversion factors from neutron fluence to dose equivalent given in this International Standard are therefore subject to possible revision.

This International Standard is concerned only with the methods of producing the neutron reference radiations. The procedures for applying these radiations will be described in a future International Standard.

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 International Standard, into two separate clauses:

— In clause 4, radionuclide neutron sources with wide spectra are specified for the calibration of neutron-measuring devices. These sources shall 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, reactor-produced neutrons with wide and quasi-monoenergetic spectra, and special radionuclide sources 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 and related purposes, the following conversion factors are specified:

— "neutron fluence" to "dose equivalent";

— "neutron fluence" to "charged particle absorbed dose";

— "neutron fluence" to "photon absorbed dose";

— "neutron fluence" to "kerma".

The conversion factors given in annexes B and C are based on the spectra presented in annex A, and on the "fluence" to "dose" conversion factors referred to in 3.6, 3.8 and 3.11. This International Standard does not preclude the use of the reference radiations specified in this International Standard with other "fluence" to "dose" conversion factors, if applicable, in particular those obtained for a different phantom and/or dose equivalents defined at different positions in the phantom. At the present time, the "fluence" to "dose" conversion factors presented in this International Standard are the only internationally accepted values.

1) ICRU: International Commission on Radiation Units and Measurements
ICRP: International Commission on Radiological Protection

2 Normative references

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

ISO 1677 : 1977, *Sealed radioactive sources — General.*

ISO 2919 : 1980, *Sealed radioactive sources — Classification.*

ICRP Publication 21, *Protection against Ionizing Radiation from External Sources,* 1973 edition. (Supplement to ICRP Publication 15.)

ICRU Report 26, *Neutron Dosimetry for Biology and Medicine,* 1977 edition.

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

3 Definitions of quantities and units

NOTES

1 The definitions follow the recommendations of ICRU Report 33.

2 Multiples and submultiples of SI units are also used throughout this International Standard.

3.1 neutron fluence, Φ: Quotient of dN by da, expressed in reciprocal square metres (m^{-2}), where dN is the number of neutrons incident on a sphere of cross-sectional area da:

$$\Phi = \frac{dN}{da}$$

3.2 neutron fluence rate; neutron flux density, ϕ: Quotient of $d\Phi$ by dt, expressed in reciprocal seconds reciprocal square metres ($s^{-1}.m^{-2}$), where $d\Phi$ is the increment of neutron fluence (see 3.1) in the time interval dt:

$$\phi = \frac{d\Phi}{dt} = \frac{d^2N}{da\,dt}$$

3.3 spectral distribution of the neutron fluence, Φ_E: Quotient of $d\Phi$ by dE, expressed in reciprocal joules reciprocal square metres ($J^{-1}.m^{-2}$), where $d\Phi$ is the increment of neutron fluence in the energy interval between E and $E + dE$:

$$\Phi_E = \frac{d\Phi}{dE}$$

NOTE — Another unit frequently used is reciprocal electronvolt reciprocal square centimetre ($eV^{-1}.cm^{-2}$).

3.4 spectral neutron fluence rate; spectral neutron flux density, ϕ_E: Quotient of $d\Phi_E$ by dt, expressed in reciprocal joules reciprocal square metres reciprocal seconds ($J^{-1}.m^{-2}.s^{-1}$), where $d\Phi_E$ is the increment of spectral distributions of the neutron fluence in the time interval dt:

$$\phi_E = \frac{d\Phi_E}{dt} = \frac{d^2\Phi}{dE\,dt}$$

NOTE — Another unit frequently used is reciprocal electronvolt reciprocal square centimetre reciprocal second ($eV^{-1}.cm^{-2}.s^{-1}$).

3.5 absorbed dose, D: Quotient of $d\bar{\varepsilon}$ by dm, expressed in grays (Gy)[1], where $d\bar{\varepsilon}$ is the mean energy imparted by ionizing radiation to matter of mass dm:

$$D = \frac{d\bar{\varepsilon}}{dm}$$

NOTE — The special unit of absorbed dose, rad, may be used temporarily; 1 rad = 10^{-2} Gy.

3.6 "neutron fluence" to "absorbed dose" conversion factor, d_Φ: Quotient of absorbed dose, D, and neutron fluence, Φ, expressed in grays square metres ($Gy.m^2$), at the point of reference undisturbed by the irradiated object:

$$d_\Phi = \frac{D}{\Phi}$$

Conversion factors are given in annexes B and C for the following two components:

— the heavy charged particle component of absorbed dose: d_Φ^c

— the neutron capture photon component of absorbed dose for $^1H(n,\gamma)\,^2D$: d_Φ^γ

It should be noted that, for neutron sources emitting gamma radiations, the total absorbed dose from photons will be given by the sum of the doses from incident gamma radiations and from neutron capture photons.

The values for the "fluence" to "absorbed dose" conversion factors given in this International Standard were derived using the analytical functions for d_Φ^c and d_Φ^γ [1].

These functions, based on the original calculations computed in [26], give the mean values for the components of absorbed dose in tissue for the volume element 57 of a cylindrical phantom (diameter 300 mm, height 600 mm) irradiated by a unidirectional broad beam of neutrons incident normally to the axis of the phantom. The phantom was considered to be composed of

1) 1 Gy = 1 $J.kg^{-1}$