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Nuclear energy — Reference beta-particle radiation —

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**

Énergie nucléaire — Rayonnement bêta de référence —

Partie 3: Étalonnage des dosimètres individuels et des dosimètres de zone et détermination de leur réponse en fonction de l'énergie et de l'angle d'incidence du rayonnement bêta

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Foreword

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ISO 6980-3 was prepared by Technical Committee ISO/TC 85, *Nuclear energy*, Subcommittee SC 2, *Radiation protection*.

This first edition of ISO 6980-3, together with ISO 6980-1:2006 and ISO 6980-2:2004, 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 radiation*:

— *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*

Introduction

ISO 6980 covers the production, calibration and use of beta-particle reference radiation fields for the calibration of dosemeters and doserate meters for protection purposes. ISO 6980-1 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. This part of ISO 6980 describes procedures for the calibration of dosemeters and doserate meters and the determination of their response as a function of beta-particle energy and angle of beta-particle incidence.

Nuclear energy — Reference beta-particle radiation —

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

1 Scope

This part of ISO 6980 describes procedures for calibrating and determining the response of dosemeters and doserate meters in terms of the International Commission on Radiation Units and Measurements (ICRU) operational quantities for radiation protection purposes. However, as noted in ICRU Report 56, the ambient dose equivalent, $H^*(10)$, used for area monitoring of strongly penetrating radiation, is not an appropriate quantity for any beta radiation, even that which penetrates 10 mm of tissue ($E_{max} > 2$ MeV).

For beta particles, the calibration and the determination of the response of dosemeters and doserate meters is essentially a three-step process. First, the basic field quantity, absorbed dose to tissue at a depth of 0,07 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 part of ISO 6980 describes the methods and the conversion coefficients to be used for the determination of the response of dosemeters and doserate meters in terms of the ICRU operational quantities directional dose equivalent, $H'(0{,}07; \vec{\Omega})$ and personal dose equivalent, $H_p(0{,}07)$.

This part of ISO 6980 is a guide for those who calibrate protection-level dosemeters and doserate meters with beta-reference radiation and determine their response as a function of beta-particle energy and angle of incidence. Such measurements can represent part of a type test during the course of which the effect of other influence quantities on the response is examined. This part of ISO 6980 does not cover the *in situ* calibration of fixed, installed area dosemeters. The term “dosemeter” is used as a generic term denoting any dose or doserate meter for individual or area monitoring. In addition to the description of calibration procedures, this part of ISO 6980 includes recommendations for appropriate phantoms and the way to determine appropriate conversion coefficients. Guidance is provided on the statement of measurement uncertainties and the preparation of calibration records and certificates.

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

ISO 6980-2:2004, Nuclear energy — Reference beta-particle radiation — Part 2: Calibration fundamentals related to basic quantities characterizing the radiation field

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ICRU Report 51, *VIM* and the following apply.

3.1
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.

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

3.3
mean beta energy
$\bar{E}$
fluence average energy of the beta particle spectrum at the calibration distance

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 scatter and absorption

3.5
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

$$D = \frac{\mathrm{d}\bar{\varepsilon}}{\mathrm{d}m} \quad (1)$$

NOTE The unit of the absorbed dose is joule per kilogram (J·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 at that point and Q the quality factor at the point

$$H = D \cdot Q \quad (2)$$

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

NOTE 2 For photon and beta radiation, the quality factor, Q, has a value very close to 1 $Sv \cdot Gy^{-1}$. In the absorbed-dose-to-dose-equivalent conversion coefficient (see 3.12), the quality factor, Q, is included.

3.7
directional dose equivalent for weakly penetrating radiation
$H'(0{,}07;\vec{\Omega})$
dose equivalent that, at a point in a radiation field, would be 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 ($J \cdot kg^{-1}$) 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.

3.8
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 ($J \cdot kg^{-1}$) with the special name sievert (Sv).

NOTE 2 In ICRU Report 47, the ICRU has considered the definition of the personal dose equivalent to include the dose equivalent at a depth of 0,07 mm in a phantom having the composition of the ICRU tissue. Then, $H_p(0{,}07)$ for the calibration of personal dosemeters is the dose equivalent at a depth of 0,07 mm in a phantom composed of ICRU tissue (see 3.1), but of the size and shape of the phantom used for the calibration (see 6.3.1).

NOTE 3 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.

3.9
reference absorbed dose
D_R
personal absorbed dose, $D_p(0{,}07)$, in a slab phantom made of ICRU tissue with an orientation of the phantom in which the normal to the phantom surface coincides with the (mean) direction of the incident radiation

NOTE 1 The personal absorbed dose, $D_p(0{,}07)$, is defined in ICRU Report 51. For the purposes of this part of ISO 6980, this definition is extended to a slab phantom.

NOTE 2 The slab phantom is approximated with sufficient accuracy by the material surrounding the standard instrument (extrapolation chamber) used for the measurement of the beta radiation field.

NOTE 3 D_R is approximated with sufficient accuracy by the directional absorbed dose in the ICRU sphere, $D'(0{,}07;\ 0°)$.

3.10
conventional true value of directional dose equivalent
H'_t
best estimate of the value of the quantity to be measured, determined by a primary or secondary standard or by a reference instrument that has been calibrated against a primary or secondary standard, for which, for the quantity directional dose equivalent, $H'(0{,}07; \vec{\Omega})$, at a depth of 0,07 mm measured in the direction, $\vec{\Omega}$, the conventional true value under calibration conditions defined by the angle, α, is given by Equation (3):

$$H'_t(0{,}07; \vec{\Omega}) = h'_D(0{,}07; source; \alpha) D_R \quad (3)$$

with "*source*" denoting the reference radiation field of the source at the calibration distance (specific combination of isotope, distance and filtering) and α the angle of beta-particle incidence under calibration conditions

NOTE 1 Any statement of absorbed-dose-to-dose-equivalent conversion coefficient (see 3.12) requires the statement of the type of dose equivalent, e.g. directional or personal dose equivalent. The conversion coefficient, h_D, depends on the energy particle spectrum and, for the quantities $H'(0{,}07; \vec{\Omega})$ and $H_p(0{,}07)$, also on the direction distribution of the incident radiation (see ICRU Report 47:1992, Figure 2.1). Under calibration conditions, it is assumed that the direction, $\vec{\Omega}$, coincides with the direction of incidence. Therefore, any directional dependence of the directional and personal dose equivalent is given by the (mean) angle, α, between the (mean) direction of incidence and the normal on the phantom surface. It is, therefore, useful to consider the conversion coefficient, $h'_D(0{,}07; source; \alpha)$ as a function of the spectral fluence of the reference radiation field as impacted by the geometry (*source*), and the angle of incidence, α. The conversion coefficient for the directional dose equivalent is $h'_D(0{,}07; source; \alpha)$.

NOTE 2 The conversion coefficients, $h_{p,D}(0{,}07; source; \alpha)$ and $h'_D(0{,}07; source; \alpha)$ are approximately equal and no additional data are included.

NOTE 3 A conventional true value is, in general, regarded as being sufficiently close to the true value for the difference to be insignificant for the given purpose.

EXAMPLE Within an organization, the result of a measurement obtained with a secondary standard instrument may be taken as the conventional true value of the quantity to be measured.

3.11
conventional true value of personal dose equivalent
$H_{p,t}$
conventional true value, determined by a primary or secondary standard, or by a reference instrument which has previously been calibrated against a primary or secondary standard which, for the quantity personal dose equivalent at a depth of 0,07 mm is equal to Equation 4:

$$H_{p,t}(0{,}07) = h_{p,D}(0{,}07; source; \alpha)\, D_R \quad (4)$$

NOTE 1 Any statement of absorbed-dose-to-dose-equivalent conversion coefficient requires the statement of the type of dose equivalent, e.g. directional or personal dose equivalent. The conversion coefficient, h_D, depends on the energy particle spectrum and, for the quantities $H'(0{,}07; \vec{\Omega})$ and $H_p(0{,}07)$, also on the direction distribution of the incident radiation (see ICRU report 47, Figure 2.1). Under calibration conditions, it is assumed that the direction, $\vec{\Omega}$, coincides with the direction of incidence. Therefore, any directional dependence of the directional and personal dose equivalent is given by the (mean) angle, α, between the (mean) direction of incidence and the normal on the phantom surface. It is, therefore, useful to consider the conversion coefficient, $h_{p,D}(0{,}07; source, \alpha)$ as a function of the spectral fluence of the reference radiation field as impacted by the geometry (*source*), and the angle of incidence, α. The conversion coefficient for the personal dose equivalent is denoted as $h_{p,D}(0{,}07; source; \alpha)$.

NOTE 2 The conversion coefficients, $h_{p,D}(0{,}07; source; \alpha)$ and $h'_D(0{,}07; source; \alpha)$, are approximately equal and no additional data are included.

NOTE 3 A conventional true value is, in general, regarded as being sufficiently close to the true value for the difference to be insignificant for the given purpose.

EXAMPLE Within an organization, the result of a measurement obtained with a secondary standard instrument can be taken as the conventional true value of the quantity to be measured.

3.12
absorbed-dose-to-dose-equivalent conversion coefficient
h_D
quotient of the dose equivalent, H, and the reference absorbed dose, D_R

$$h_D = \frac{H}{D_\mathrm{R}} \tag{5}$$

3.13
phantom
object constructed to simulate the scattering and attenuation properties of the human body

NOTE In principle, the ISO water slab phantom, ISO rod phantom or the ISO pillar phantom should be used. For the purposes of this part of ISO 6980, however, a polymethylmethacrylate (PMMA) slab 10 cm × 10 cm in cross-sectional area by 1 cm thick is sufficient to simulate the backscattering properties of the trunk of the human body, while tissue-equivalent materials such as polyethylene terephthalate (PET) are sufficient to simulate the attenuation properties of human tissue (see 4.1.2.3).

3.14
influence quantity
quantity that can have a bearing on the result of a measurement without being the subject of the measurement

NOTE 1 The correction of the effect of the influence quantity on the indicated value can require a correction factor to be applied to the indication (influence quantity of type F), e. g. radiation energy and angle of radiation incidence (3.28), and/or a correction summand to be applied to the indication (influence quantity of type S), e.g. microphony or electromagnetic disturbance.

NOTE 2 A given influence quantity can be of both types S and F.

NOTE 3 Depending on the design of the dosemeter, an influence quantity can be of type S or F.

NOTE 4 The dose rate is an influence quantity when measuring the dose.

EXAMPLE The reading of a dosemeter with an unsealed ionization chamber is influenced by the temperature and the pressure of the surrounding atmosphere. Although needed for determining the value of the dose, the measurement of these two quantities is not the primary objective.

3.15
reference conditions
conditions which represent the set of influence quantities for which the calibration factor is valid without any correction

NOTE 1 See also Note 1 3.14.

NOTE 2 For an instrument with linear response, the value for the quantity to be measured may be chosen freely in agreement with the properties of the instrument to be calibrated. For an instrument with non-linear response the indicated value, M, (3.22) should be equal to $H_{\mathrm{t},0}/N_0$ (3.24). The quantity to be measured is not an influence quantity (3.14).

NOTE 3 The reference conditions are subdivided into reference conditions for radiological influence quantities (given in Table B.1) and reference conditions for other influence quantities (given in Table B.2).

3.16
standard test conditions
range of values of a set of influence quantities under which a calibration or a determination of response is carried out

NOTE Ideally, calibrations should be carried out under reference conditions. As this is not always achievable (e.g. for ambient air pressure) or convenient (e.g. for ambient temperature), a (small) interval around the reference values may be used. The deviations of the calibration factor from its value under reference conditions caused by these deviations should, in principle, be corrected for. In practice, the target uncertainty serves as a criterion to determine if it is necessary to take an influence quantity into account by an explicit correction or whether its effect may be incorporated into the uncertainty. During type tests, all values of influence quantities that are not the subject of the test are fixed within the interval of the standard test conditions. The standard test conditions, together with the reference conditions applicable to this part of ISO 6980, are given in Tables B.1 and B.2.

3.17
calibration conditions
conditions within the range of standard test conditions actually prevailing during the calibration

3.18
point of test
point in the radiation field at which the conventional true value of the quantity to be measured is known

NOTE The reference point of a dosemeter is placed at the point of test for calibration or testing purposes.

3.19
reference direction
direction in the coordinate system of a dosemeter with respect to which the angle to the direction of radiation incidence is measured in unidirectional fields

NOTE At 0° incidence, the reference direction (axis) of the dosemeter coincides with the direction of radiation incidence, but is directly opposed.

3.20
reference point
⟨dosemeter⟩ point which is placed at the point of test for calibrating or testing purposes

NOTE 1 The reference point and the reference direction of the dosemeter to be tested should be stated by the manufacturer.

NOTE 2 The reference point and the reference direction should be marked on the outside of a dosemeter. If this proves impossible, they should be indicated in the accompanying documents supplied with the instrument.

NOTE 3 The distance of measurement refers to the distance between the radiation source and the reference point of the dosemeter, even if it is attached to a phantom.

3.21
reference orientation
⟨dosemeter⟩ orientation for which the direction of incident radiation coincides with the reference direction of the dosemeter

3.22
indicated value
M
value given by the reading of the dosemeter