BRITISH STANDARD

BS ISO 6980-3:2006

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

ICS 17.240

British Standards

National foreword

This British Standard was published by BSI. It is the UK implementation of ISO 6980-3:2006. Together with BS ISO 6980-1:2006 and BS ISO 6980-2:2004, it supersedes BS ISO 6980:1996 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee NCE/2, Radiation protection and measurement.

A list of organizations represented on NCE/2 can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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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

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 6980-3 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.

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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

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
$\overline{E}$
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$\overline{\varepsilon}$ by dm where d$\overline{\varepsilon}$ is the mean energy imparted by ionizing radiation to matter of mass, dm

$$D = \frac{\mathrm{d}\overline{\varepsilon}}{\mathrm{d}m} \tag{1}$$

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

$$H = D \cdot Q \tag{2}$$

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):

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

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, $h'_D(0{,}07;\mathit{source};\alpha)$ 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 $h'_D(0{,}07;\mathit{source};\alpha)$.

NOTE 2 The conversion coefficients, $h_{p,D}(0{,}07;\mathit{source};\alpha)$ and $h'_D(0{,}07;\mathit{source};\alpha)$ 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:

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

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, $h_{p,D}(0{,}07;\mathit{source},\alpha)$ 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 $h_{p,D}(0{,}07;\mathit{source};\alpha)$.

NOTE 2 The conversion coefficients, $h_{p,D}(0{,}07;\mathit{source};\alpha)$ and $h'_D(0{,}07;\mathit{source};\alpha)$, 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

$$h_D = \frac{H}{D_R} \tag{5}$$

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 $H_{t,0}/N_0$ (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

3.23
calibration factor
N
quotient of the conventional true value of a quantity, H_t, and the indicated value, M_r, at the point of test for a specified reference radiation under specified reference conditions:

$$N = \frac{H_t}{M_r} \quad (6)$$

NOTE 1 The calibration factor, *N*, is dimensionless when the instrument indicates the quantity to be measured. A dosemeter indicating the conventional true value correctly has the calibration factor of unity (see ISO 4037-3).

NOTE 2 The reciprocal of the calibration factor is equal to the response under reference conditions. In contrast to the calibration factor, which refers to the reference conditions only, the response refers to any condition prevailing at the time of measurement (see ISO 4037-3).

NOTE 3 The value of the calibration factor can vary with the magnitude of the quantity to be measured. In such case, a dosemeter is said to have a non-linear response (see ISO 4037-3).

3.24
reference calibration factor
N_0
calibration factor for a reference value, $H_{t,0}$, of the quantity to be measured. With $M_{r,0}$ being the indicated value:

$$N_0 = \frac{H_{t,0}}{M_{r,0}} \quad (7)$$

NOTE This definition is of special importance for dosemeters having a non-linear response (see 3.23, Note 3).

3.25
correction summand
A
additional indication caused by the zero indication or an influence quantity of type S

NOTE 1 See 3.14.

NOTE 2 The corrections of microphony and electromagnetic disturbance require correction summands. These influence quantities are (mainly) of type S.

3.26
correction factor for non-linear response
k_n
quotient of the calibration factor, *N*, and the reference calibration factor, N_0, for conditions where the quantity to be measured is varied:

$$k_n = \frac{N}{N_0} \quad (8)$$

NOTE For an instrument with linear response, k_n is equal to unity.

3.27
correction factor for an influence quantity
k_q
quotient of the conventional true value of a quantity, H_t, divided by the product of the indicated value, M, and calibration factor, N, at the point of test for conditions where the influence quantity under consideration is varied, but all other influence quantities have their reference values

NOTE 1 For an instrument with linear response, this correction factor is expressed as Equation (9)

$$k_q = \frac{H_t}{N \cdot M} \tag{9}$$

NOTE 2 For an instrument with non-linear response, the indicated value is expected to be the same as the value obtained when determining the reference calibration factor.

NOTE 3 The correction of radiation energy and direction of radiation incidence requires a correction factor; these influence quantities are of type F.

3.28
correction factor for beta-particle energy and angle of incidence
$k_{E,\alpha}$
correction factor for (mean) beta-particle energy, E and (mean) angle, α, of beta particle incidence

NOTE 1 See 3.20.

NOTE 2 α represents the angle of incidence from the source. Due to the scattering of the electrons, the electrons are incident at a wide variety of angles and α can be considered a mean representation of the angles of incidence of the electrons. α is the angle between the reference direction of the source and the direction of incidence of radiation from the source.

3.29
measured value
H_m
value determined from the indicated value, M, by applying the reference calibration factor, N_0, the correction factor k_n for non-linear response, the l correction summands, A_p, for the influence quantities of type S and the j correction factors, k_q, for the other influence quantities of type F as given in Equation (10):

$$H_m = N_0 \, k_n \left[M - \sum_{I=1}^{l} \left(A_p \right)_I \right] \prod_{J=1}^{j} \left(k_q \right)_J \tag{10}$$

NOTE 1 Equation (10) is the model function of the measurement necessary for any determination of the uncertainty according to *GUM* (see *GUM*:1995, 3.1.6, 3.4.1 and 4.1).

NOTE 2 With the calibration controls adjusted according to the manufacturer's instructions, the calibration factor and all correction factors are set to unity and the correction summands are set to zero. These settings cause an uncertainty of measurement that can be determined from the measured variation of the correction factors and the measured variation of the correction summands.

NOTE 3 Equation (10) is obtained from $H_m = N \left[M - \sum_{I=1}^{l} \left(A_p \right)_I \right] \prod_{J=1}^{j} \left(k_q \right)_J$ by substituting N with $N_0 k_n$.

NOTE 4 One of the correction factors k_q is the correction factor $k_{E,\alpha}$ for (mean) beta particle energy, $\bar{E}$, and (mean) angle, α, of beta-particle incidence.

3.30
response
R
quotient of the indicated value of a quantity, M, and the conventional true value of that quantity

NOTE 1 The type of response should be specified.

EXAMPLES The response with respect to the dose equivalent, H_t, at the point of test under specified conditions is given by Equation (11):

$$R_H = \frac{M}{H_t} \tag{11}$$

The response with respect to reference absorbed dose D_R is given by Equation (12):

$$R_D = \frac{M}{D_R} \tag{12}$$

NOTE 2 For the specified reference conditions, the response is the reciprocal of the calibration factor.

3.31
calibration
quantitative determination of the calibration factor, N, and the correction factor, k_n, under a controlled set of standard test conditions for which all the j correction factors, k_q, are unity

NOTE 1 The correction factor, k_n, is the conceptual equivalent to the function of the quantity to be measured mentioned in ISO 4037-3.

NOTE 2 The calibration of secondary standard instruments, in many cases, also comprises the determination of the correction factors, $k_{E,\alpha}$, for several reference radiation qualities.

NOTE 3 Normally, the calibration conditions are the full set of standard test conditions (Annex B). A routine calibration can be performed, under simplified conditions, to check the calibration carried out by the manufacturer or to check whether the calibration factor is sufficiently stable during a continued long-term use of the dosemeter. In general, the methods of a routine calibration are worked out on the basis of a type test. One of the objectives of a type test can be to establish the procedures for a routine calibration in a way that the result of a routine calibration approximates that of a calibration under standard test conditions as closely as possible (see also 6.3.1). A routine calibration is often used to provide batch or individual calibration factors.

4 Procedures applicable to all area and personal dosemeters

4.1 General principles

4.1.1 Radiation qualities

4.1.1.1 Selection of sources

Two series of reference radiation sources are specified in ISO 6980-1. The series 1 sources use beam-flattening filters to produce a uniform dose rate over an area of about 15 cm in diameter, e.g. for the calibration of an area monitor or a number of individual dosemeters simultaneously. The calibration distances, filter distances and filter types are specified in ISO 6980-1. Deviations from those specifications shall not be made.

Series 2 reference radiation may be produced without the use of beam-flattening filters and have the advantage of extending the energy and dose rate beyond those of series 1. Calibrations and response determinations shall specify the series of reference radiation used and the source-to-detector distance.

Although special sources and geometries may be established for beta calibrations, secondary laboratories shall, as a minimum, have available the series 1 sources. These standard sources provide consistent and reproducible results, permitting comparison of results from laboratory to laboratory.

The dosimetry in these radiation fields shall be conducted in accordance with ISO 6980-2.

The beta radiation field produced by all these radionuclides except ^{106}Ru + ^{106}Rh is practically free of photon radiation, apart from bremsstrahlung generated in the surrounding materials or in the beta particle source itself. ^{106}Ru + ^{106}Rh is used because of the high maximum energy of the emitted beta particles. Only beta-particle sources with small self-absorption and thin encapsulation can fulfil the specifications in ISO 6980-1, since it is necessary that the maximum energy of the beta particles at the calibration distance, E_{res} (residual maximum beta energy), be higher than a specified E_{res} value.

4.1.2 Conversion coefficients

4.1.2.1 General dose equivalent quantities

According to 3.10 and 3.11, it is necessary to calculate the dose equivalent, $H(0{,}07; source; \alpha)$, where H is equivalent to H' and H_p for beta radiation, from the reference absorbed dose, D_R (see 3.10), using the absorbed-dose-to-dose-equivalent conversion coefficient, $h'_D(0{,}07; source; \alpha)$, according to Equations (3) and (4). It is necessary to measure the reference absorbed dose, D_R, in a slab phantom at a depth of 0,07 mm and at an angle, α, of 0° between the source and the reference orientation of the slab phantom. It is necessary to measure D_R at the distance of the point of test. Due to the scatter of the beta particles in air and within optional beam flattening filters, all real beta fields are far from mono-directional. Therefore, the above-mentioned angle, α, is only the mean angle of an unknown distribution.

It is necessary to determine $h'_D(0{,}07; source; \alpha)$ separately for any radiation field (given by the type of radiation sources, the holder and the surrounding structures) and for any distance. The value of $h'_D(0{,}07\ source; \alpha)$ depends in principle also on the phantom used (but see 4.1.2.3).

It is, therefore, not possible to give a generally applicable table of conversion coefficients. Measurements are necessary for any type of radiation field.

4.1.2.2 Determination of conversion coefficients

The determination of the conversion coefficients can be done with the same instrument used for the measurement of the reference absorbed dose, D_R. As an example, values of conversion coefficients determined for the beta-particle radiation field of a commercially available beta secondary standard [1] are given in Annex C.

4.1.2.3 Phantom dependence

ISO 4037-3 specifies three types of phantom: the ISO water-slab phantom, the ISO water-pillar phantom and the ISO PMMA-rod phantom. Contrary to photon and neutron radiation, the size and shape of the phantom has only a very small influence on the radiation field in front of the phantom. As noted in Reference [2], "… for normally incident electrons, dose conversion coefficients for the slab, pillar and rod phantoms are indistinguishable." At angles of incidence up to approximately 60°, the differences in the coefficients are negligible [2], [3]. At larger angles ($\alpha > 60°$) and higher energies ($E > 350$ keV for the rod), one begins to see differences in the coefficients between the phantoms and these can largely be attributed to direct penetration to the measurement point [2]. Therefore, the conversion coefficients measured for the slab phantom can, up to 60°, also be used for all other phantoms and consequently no distinction between different phantoms is made in this part of ISO 6980-3.

4.1.3 Standard test conditions

Calibrations and the determination of response shall be conducted under standard test conditions. 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.

4.1.4 Variation of influence quantities

For those measurements intended to determine the effects of variation of one influence quantity on the response, the other influence quantities should be maintained at fixed values within the standard test conditions unless otherwise specified.

NOTE There can be cases in which it is important that an influence quantity is varied in such a way that the indicated value, M, of the instrument under test is constant. For example, if the energy dependence of a dosemeter is to be examined in a doserate region where there is a substantial dead-time, it can be desirable that the measurements with the various radiation qualities are carried out at constant indication and not at constant dose rate. The same holds true for thermoluminescence dosemeters exhibiting a so-called supra-linearity. However, it should be added that it is usually advisable to carry out the examination of an instrument under conditions in which the response to dose or to doserate is essentially linear. See also 3.30.

4.1.5 Point of test and reference point

Measurements shall be carried out by positioning the reference point of the dosemeter at the point of test. In the absence of information on the reference point or on the reference direction of the dosemeter to be tested, these parameters shall be fixed by the testing laboratory. They shall be stated in the test certificate.

NOTE 1 Placing the reference point of the dosemeter at the point of test has two practical advantages. The first one is that the dose due to the primary radiation coming from the source is always measured correctly irrespective of the effect of the beam divergence on the backscattered radiation. For beta-particle radiation, this part of the dose always represents the majority contribution to the total dose, including the scattered radiation from the phantom. The convention adopted implies that the calibration factor of the dosemeter does not depend unnecessarily on the distance between the source and the point of test. The second advantage arises in an experimental determination of the angular response. If the reference point and the point of test coincide, the reading of the dosemeter under test does not have to be corrected for a variation of the distance between source and reference point with the angle of rotation.

NOTE 2 If portable area dosemeters are used under conditions where the distance from the source to the detector volume is small compared with the dimensions of the detector volume, the radiation fields in the detector are non-uniform. Portable area dosemeter readings under such conditions are an average of the energy deposition rate within the detector. The readings are significantly less than the actual dose equivalent rates existing at the surface of the entrance window [4].

4.1.6 Axes of rotation

For examining the effect of the direction of radiation incidence, a rotation of the dosemeter or of the combination of dosemeter and phantom can be required. The variation of response with direction of radiation incidence shall be examined by a rotation around at least two axes. The direction of the axes shall be mutually perpendicular. The axes of rotation shall pass through the reference point of the dosemeter.

4.1.7 Condition of the dosemeter to be calibrated

Before any calibration is made, the dosemeter shall be examined to confirm that it is in a good, serviceable condition and free from radioactive contamination. The set-up procedure and the mode of operation of the dosemeter shall be in accordance with its instruction manual.

4.1.8 Extraneous photons

Most beta-particle dosemeters respond to photons and the sensitivity to photon radiation should be estimated prior to the calibrations with beta-particle reference radiations. Corrections for the instrument response to photons should be made relative to the $H'(0{,}07;\ \vec{\Omega})$ response. The presence of photons may be determined by measuring dosemeter response with and without a 10 mm thick polymethylmethacrylate (PMMA) filter placed between the source and detector and approximately 10 cm in front of the detector. Photon absorption in the filter requires a correction that is small at higher energies ($E > 100$ keV). The 10 mm PMMA filter eliminates only electrons with energies below 2 MeV. However, additional information may be obtained by using additional PMMA filters.

4.2 Determination of the calibration factor and of the correction factor

4.2.1 Determination of the reference dose rate by a standard instrument

Dosimetry of beta-particle reference fields is described in ISO 6980-2. In general, the reference doserate, $\dot{D}_R$, is determined with an extrapolation chamber. Corrections for source decay shall be performed.

4.2.2 Determination of reference calibration factor and correction factor for non-linear response

The reference calibration factor, N_0, is obtained for the reference value, $H_{t,0}$, of the quantity to be measured and the correction factor for non-linear response is given by $k_n = N / N_0$.

4.2.2.1 Calibration factor for personal dosemeters

The calibration factor, N, for a personal dosemeter mounted on a specified phantom (slab, rod, pillar) at an angle of incidence of 0°, is obtained from Equation (13):

$$N = \frac{H_{p,t}(0{,}07)}{M_r} \tag{13}$$

where

M_r is the indicated value of the dosemeter on the specified phantom under reference conditions;

$$H_{p,t}(0{,}07) = h_{p,D}(0{,}07; source; 0°)\ D_R \tag{14}$$

where

D_R is the reference absorbed dose;

$h_{p,D}(0{,}07; source; 0°)$ is the conversion coefficient (see 3.11 and 4.1.2) for the source and conditions used.

For the sources and phantoms used in this part of ISO 6980, $h_{p,D}(0{,}07; source; 0°)$ can be considered to be 1 $Sv \cdot Gy^{-1}$.

4.2.2.2 Calibration factor for area dosemeters

The calibration factor, N, for an area dosemeter at an angle of incidence of 0°, is obtained from Equation (15):

$$N = \frac{H'_t(0{,}07; 0°)}{M_r} \tag{15}$$

where

M_r is the indicated value of the dosemeter under reference conditions;

$$H_t'(0{,}07; 0°) = h'_D(0{,}07; source; 0°)\ D_R \tag{16}$$

where

$h'_D(0{,}07; source; 0°)$ is the conversion coefficient (see 3.10) for the source and conditions used.

D_R is the reference absorbed dose.

For the sources used in this part of ISO 6980, $h'_D(0{,}07; source; 0°)$ can be considered to be 1 $Sv \cdot Gy^{-1}$.

4.2.3 Determination of the correction factor, $k_{E,\alpha}$

The correction factor $k_{E,\alpha}$ for (mean) beta-particle energy, E, and (mean) angle, α, of beta-particle incidence is determined by means of D_R for the various reference fields given in ISO 6980-1.

For personal dosemeters:

$$k_{E,\alpha} = \frac{h_{p,D}(0{,}07; source; \alpha)\, D_R}{N \times M(0{,}07; E; \alpha)} \tag{17}$$

For area dosemeters:

$$k'_{E,\alpha} = \frac{h'_D(0{,}07; source; \alpha)\, D_R}{N \times M(0{,}07; E; \alpha)} \tag{18}$$

Deviations from reference conditions shall be considered by proper correction factors k_q; see Equation (10).

NOTE The relative response of the dosemeter with respect to its response under reference conditions is the inverse of the correction factor $k_{E,\alpha}$. The relative response can be a useful quantity for describing the variation of response as a function of beta-particle energy, E, or angle of incidence, α, as it easily visualizes such variation.

5 Particular procedures for area dosemeters

5.1 General principles

These principles apply to the calibration of portable and installed area dosemeters in reference radiations, where the term “area dosemeter” comprises both active and passive devices. It does not apply to *in-situ* calibrations of installed area dosemeters. Dosemeters for area monitoring shall be irradiated in free air (without a phantom).

5.2 Quantities to be measured

For area dosemeters, the quantity to be measured shall be the directional dose equivalent, $H'(0{,}07; \vec{\Omega})$.

6 Particular procedures for personal dosemeters

6.1 General principles

These principles apply to the calibration of personal dosemeters, i.e. whole-body and extremity dosemeters. The irradiation should be performed on a phantom.

6.2 Quantity to be measured

The quantity to be measured for individual monitoring is the personal dose equivalent, $H_p(0{,}07)$.

6.3 Experimental conditions

6.3.1 Use of phantoms

Calibrations of personal dosemeters, measurements of the correction factor $k_{E,\alpha}$ and the response as a function of radiation energy and angle of radiation incidence should be carried out on an appropriate phantom.

Calibrations should be carried out on the ISO water-slab phantom for whole body dosemeters and on the ISO rod or pillar phantom for extremity dosemeters. The ISO water-slab phantom has outer dimensions of 30 cm × 30 cm × 15 cm with PMMA walls (front wall, 2,5 mm thick; other walls, 10 mm thick) filled with water. For beta radiations only, a PMMA slab of at least 10 cm × 10 cm × 1 cm may be substituted for this phantom. The ISO rod phantom is a 19 mm diameter PMMA rod for calibration of finger dosemeters while the ISO pillar phantom is a 73 mm diameter cylinder of PMMA (2,5 mm thick side walls, 10 mm thick end walls) filled with water for the calibration of wrist (or leg) dosemeters. Dosemeters for environmental monitoring are irradiated free-in-air.

When these phantoms are used as described above, no correction factors shall be applied to the indication of the dosemeter under test, due to possible differences in backscatter properties between these phantoms and the ICRU tissue slab.

It has become established practice to routinely calibrate individual dosimetry systems by irradiating the dosemeters on the surface of an appropriate phantom, such as a solid polymethylmethacrylate (PMMA) slab with a side length of greater than or equal to 300 mm and a thickness of greater than or equal to 150 mm for calibrating planar dosemeters, or a PMMA rod greater than or equal to 300 mm in length and 19 mm in diameter for calibrating finger dosemeters, or a PMMA cylinder greater than or equal to 300 mm in length and 73 mm in diameter for calibrating arm and leg dosemeters. For beta radiations, the solid polymethylmethacrylate phantoms are equivalent to the ISO phantoms.

In a simplified procedure, it is not always necessary to perform routine calibrations on a phantom but they may sometimes be done more simply, free-in-air or with another type of radiation than that which the dosemeter is intended to measure. Such simplifications, if they are to be applied, shall be justified prior to their adoption by demonstrating that they lead to results identical to those from procedures described in this part of ISO 6980 or that reliable corrections can be made for any differences. This may be done on the basis of the results of a type test and production checks on the consistency of important components of the dosemeter, for example the film covering a thermoluminescent chip and the dimensions of that chip.

6.3.2 Geometrical considerations in divergent beams

The point of test shall be chosen at a distance from the source such that the field size in the plane of measurement is sufficiently large to allow the irradiation of the entire front face of the phantom. The value of the quantity to be measured shall be determined by positioning the reference point of the standard instrument at the point of test or by using a pre-calibrated test point provided for the source. Then the reference point of the dosemeter under test shall be positioned at the point of test with its reference direction oriented at the required angle, α, to the direction of radiation incidence. Extremity dosemeters should be attached to the phantom in the way they are attached to the body during normal use. The slab phantom shall be positioned in such a way that its front surface is in contact with the rear side of the dosemeter and is at the required angle, α, to the beam axis. The irradiation of the dosemeter under test shall be made under conditions identical to those prevailing during the irradiation of the standard instrument, but now with the phantom present. The calibration factor or the value of the energy or angular response shall be obtained with the equations in 4.2.2 and 4.2.3.

NOTE 1 In this part of ISO 6980, the entity of the personal dosemeter and phantom is considered as the dosemeter to be tested. The reference point of the entity is the reference point of the dosemeter. The value of the quantity to be measured pertains to the value of the dose equivalent at a depth of 0,07 mm inside the reference phantom in the absence of the dosemeter.

NOTE 2 This concept is consistent with the definition of H_p, which, at least in principle, requires the determination of the dose equivalent at a non-accessible point inside the body. Placing the reference point of the dosemeter at the point of test has two practical advantages. The first one is that the dose due to the primary radiation coming from the source is always measured correctly, irrespective of the extent of beam divergence. For beta particle radiation, this part of the dose always represents the majority contribution to the total dose, including the scattered radiation from the phantom. The convention adopted implies that the calibration factor of the dosemeter does not depend unnecessarily on the distance between the source and the point of test. The second advantage arises in an experimental determination of the angular response. If the reference point and the point of test coincide, it is not necessary that the reading of the dosemeter under test be corrected for a variation of the distance between source and reference point with the angle of rotation.

NOTE 3 For an irradiation on the slab phantom, it can be practical to rotate the phantom around only one axis and to locate the dosemeter in two mutually perpendicular orientations on the surface of the phantom.

6.3.3 Simultaneous irradiation of several dosemeters

If more than one dosemeter is irradiated simultaneously, two effects require additional attention.

a) By positioning several dosemeters on the phantom surface, the backscatter can be reduced due to the attenuation of the primary radiation passing through the dosemeters.

b) It is necessary to consider possibly different distances of the reference points from the radiation source.

Before such a practice is adopted, it shall be verified that it leads to results identical to within 2 % of those obtained when one dosemeter alone is irradiated in the centred position of the phantom. Use of the appropriate filters as described for series 1 sources in ISO 6980-1 serves to provide homogenous fields over the phantom surface.

For a simultaneous determination of the response of several dosemeters as a function of the direction of radiation incidence, the reference points of the dosemeters shall be positioned on the axis of rotation.

7 Presentation of results

7.1 Records and certificates

National regulations often specify details and format of both calibration records and certificates as well as the frequency of calibration and the length of time for which calibration records should be kept.

The records or certificates shall include at least the following:

a) date and place of calibration;

b) description of dosemeter, its type and serial number;

c) owner of the dosemeter;

d) details of the radiation sources and secondary standard instruments used;

e) reference conditions, calibration conditions and/or standard test conditions;

f) equation for the measured value, see Equation (10), with all numerical values of the correction factors;

g) results;

h) name of person carrying out the calibration;

i) any special observations;

j) statement of uncertainties.

7.2 Statement of uncertainties

The statement of uncertainty shall be consistent with the approaches recommended by *GUM*, e.g. using an uncertainty budget (see Table 4.1 of Reference [5]; see also 3.30, Notes).

The following component uncertainties shall be taken into account:

a) uncertainty of the conventional true value as taken from the calibration certificate;

b) uncertainty in the exact positioning of standard and test instrument;

c) uncertainty due to field inhomogeneities over the cross-sectional area of the beam in the plane of measurement owing to beam divergence and the effect of beam-flattening filters, if any;

d) uncertainties due to simultaneous irradiation of several dosemeters;

e) uncertainties due to simplified procedures (see e.g. 6.3.3), where applicable;

f) uncertainty due to corrections for source decay;

g) uncertainty due to long-term variation of response of standard instrument;

h) uncertainty due to temperature/pressure/humidity corrections or lack thereof;

i) uncertainty introduced by contaminating radiations;

j) uncertainties introduced by the instruments calibrated due to non-linearity, instrument geotropism, instrument precision, etc;

k) uncertainties in dose determinations introduced by timing errors.

Annex A
(normative)

Symbols and abbreviated terms

See Table A.1.

Table A.1 — Symbols and abbreviated terms

Symbol	Meaning	Unit
α	(mean) angle of beta-particle incidence under calibration conditions	deg
$\vec{\Omega}$	direction of the radius vector of the ICRU sphere	deg
A	correction summand	Sv
A_p	correction summand for influence quantity, p	Sv
D	absorbed dose	Gy
$D_\mathrm{p}(0{,}07)$	personal absorbed dose in 0,07 mm depth	Gy
D_R	reference absorbed dose	Gy
$\dot{D}_\mathrm{R}$	rate of reference dose	$\mathrm{Sv \cdot h^{-1}}$
$\mathrm{d}\bar{\varepsilon}$	mean energy imparted by the ionizing radiation to the material in a volume	keV
$\overline{E}$	mean energy of a beta-particle spectrum	keV
E	(mean) beta-particle energy	keV
E_max	maximum energy of a beta-particle spectrum	keV
E_res	residual maximum energy of a beta-particle spectrum	keV
F	letter indicating an multiplicative influence quantity	—
H	dose equivalent	Sv
$H^*(10)$	ambient dose equivalent	Sv
$\dot{H}^*(10)$	rate of ambient dose equivalent	$\mathrm{Sv \cdot h^{-1}}$
$H'(0{,}07;\vec{\Omega})$	directional dose equivalent at 0,07 mm depth measured in the direction $\vec{\Omega}$	Sv
$\dot{H}'\left(0{,}07;\vec{\Omega}\right)$	rate of directional dose equivalent at 0,07 mm depth measured in the direction $\vec{\Omega}$	$\mathrm{Sv \cdot h^{-1}}$
H_m	measured value	Sv
$H_\mathrm{p}(0{,}07)$	personal dose equivalent at 0,07 mm depth	Sv
h_D	absorbed-dose-to-dose-equivalent conversion coefficient from D_R to H	$\mathrm{Sv \cdot Gy^{-1}}$
$h'_D(0{,}07;E,\alpha)$	conversion coefficient from D_R to $H'(0{,}07)$ for angle, α, and energy, E	$\mathrm{Sv \cdot Gy^{-1}}$
$h_{\mathrm{p},D}(0{,}07;E,\alpha)$	conversion coefficient from D_R to $H_\mathrm{p}(0{,}07)$ for angle α and energy E	$\mathrm{Sv \cdot Gy^{-1}}$
H_t	conventional true value of H	Sv
$H_{\mathrm{t},0}$	conventional true value in the reference conditions	Sv
H'_t	conventional true value of directional dose equivalent	Sv

Table A.1 (*continued*)

Symbol	Meaning	Unit
$H'_t(0{,}07;\vec{\Omega})$	conventional true value of directional dose equivalent at 0,07 mm depth measured in the direction $\vec{\Omega}$	Sv
$H_{p,t}$	conventional true value of the personal dose equivalent	Sv
$H_{p,t}(0{,}07)$	conventional true value of the personal dose equivalent at 0,07 mm depth	Sv
j	number of influence quantities of type F	—
k_n	correction factor for non-linear response	—
k_q	correction factor for the influence quantity q	—
$k_{E,\alpha}$	correction factor for beta-particle energy and angle of incidence	—
l	number of influence quantities of type S	—
m	mass	kg
M	indicated value	Sv
M_r	indicated value under reference conditions	Sv
$M_{r,0}$	indicated value under reference conditions for a reference value of H	Sv
N	calibration factor	—
N_0	reference calibration factor	—
Q	quality factor	$Sv \cdot Gy^{-1}$
R	response	—
S	letter indicating an additive influence quantity	—

Annex B
(normative)

Reference conditions

B.1 Statement of reference conditions and required standard test conditions

B.1.1 Radiological parameters

See Table B.1.

Table B.1 — Reference conditions and standard test conditions for radiological parameters

Influence quantities	Reference conditions	Standard test conditions (unless otherwise indicated)
Beta-particle radiation reference field	$^{90}Sr + ^{90}Y$ [a]	$^{90}Sr + ^{90}Y$ [a]
Phantom (only in the case of personal dosemeters)	Slab of ICRU tissue 30 cm × 30 cm × 15 cm (for whole body dosemeters)	ISO slab phantom: 30 cm × 30 cm × 15 cm water phantom with 2,5 mm front plate (irradiation side) of PMMA and other walls of 10 mm PMMA
	Straight circular cylinder of ICRU tissue with 73 mm diameter and 300 mm length (for wrist or ankle dosemeters)	ISO pillar phantom: straight circular cylinder 73 mm diameter filled with water; 300 mm length walls of PMMA; side walls 2,5 mm thick and end walls of 10 mm thickness
	Straight circular cylinder of ICRU tissue with 19 mm diameter and 300 mm length (for ring dosemeters)	ISO rod phantom: straight circular cylinder of PMMA; 19 mm diameter, 300 mm length
Angle of radiation incidence	Reference orientation	Reference orientation ± 5°
Contamination by radioactive elements	Negligible [b]	Negligible [b]
Radiation background	Ambient dose equivalent rate $\dot{H}^*(10) \leqslant 0,1$ µSv h^{-1} and directional dose equivalent rate $\dot{H}'(0,07;\vec{\Omega}) \leqslant 0,1$ µSv h^{-1}	Ambient dose equivalent rate $\dot{H}^*(10) < 0,25$ µSv h^{-1} and directional dose equivalent rate $\dot{H}'(0,07;\vec{\Omega}) < 0,25$ µSv h^{-1}

[a] Another radiation quality can be used if this is more appropriate.

[b] Allowable limits on surface contamination are established by local governments. “Negligible” indicates levels of contamination that do not affect the accuracy of the calibration nor pose a risk to the calibration personnel or facility.

B.1.2 Other parameters

See Table B.2.

Table B.2 — Reference conditions and standard test conditions for other parameters

Influence Quantities	Reference conditions	Standard test conditions (unless otherwise indicated)
Ambient temperature	20 °C	18 °C to 22 °C [b, c]
Relative humidity	65 %	50 % to 75 % [b, c]
Atmospheric pressure	101,3 kPa	86 kPa to 106 kPa [b, c]
Stabilization time	15 min	> 15 min
Power supply voltage	Nominal power supply voltage	Nominal power supply voltage ± 3 %
Frequency [a]	Nominal frequency	Nominal frequency ± 1 %
AC power supply [a]	Sinusoidal	Sinusoidal with total wave-form harmonic distortion less than 5 % [a]
Electromagnetic field of external origin	Negligible	Less than the lowest value that causes interference
Magnetic induction of external origin	Negligible	Less than twice the value of the induction due to the earth's magnetic field
Assembly controls	Set up for normal operation	Set up for normal operation

[a] Only for assemblies that are operated from a mains voltage supply.

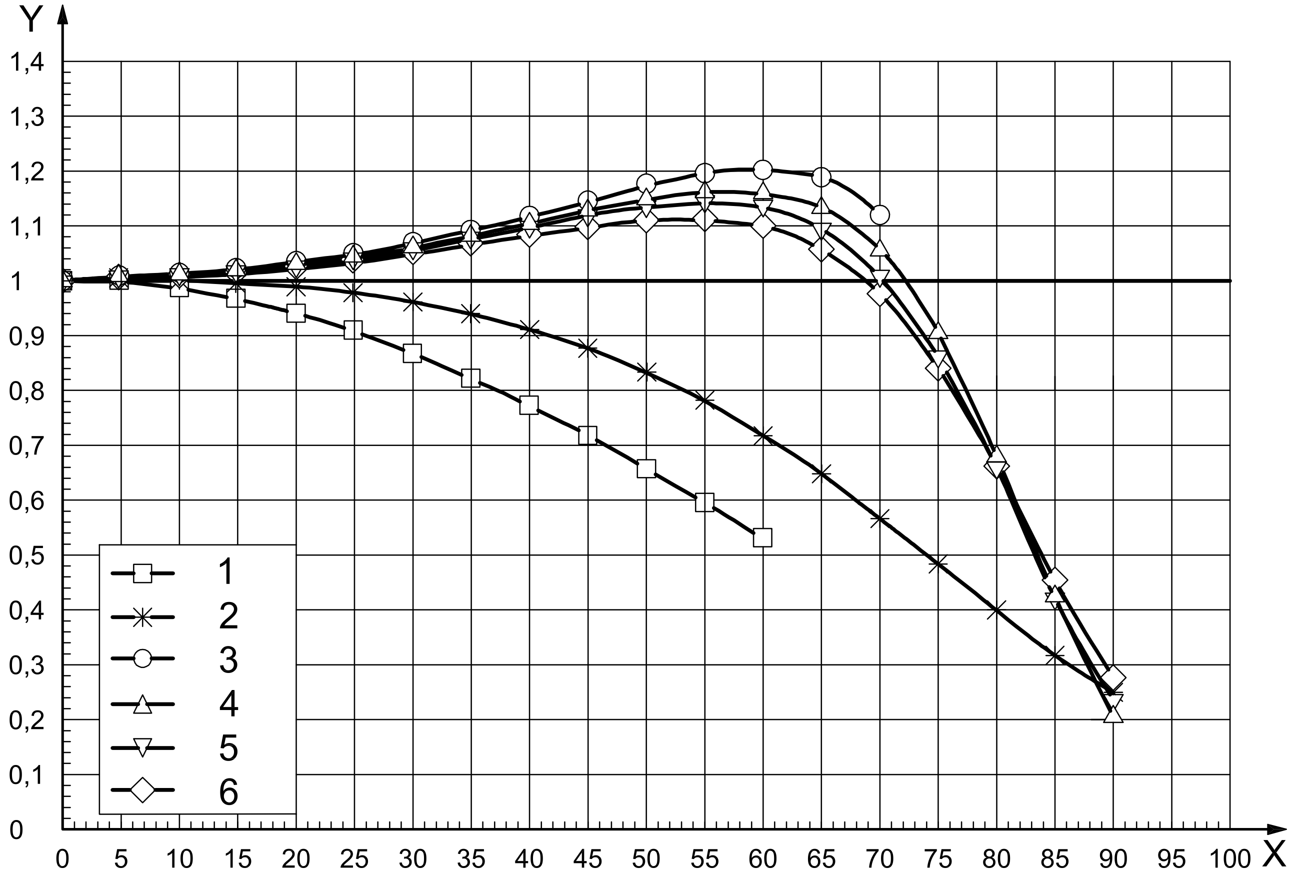
[b] The actual values of these quantities at the time of test shall be stated.

[c] The values in the table are intended for calibrations performed in temperate climates. In other climates, the actual values of the quantities at the time of calibration shall be stated. Similarly, a lower limit of pressure of 70 kPa may be permitted where instruments are to be used at higher altitudes.

Annex C
(informative)

Conversion coefficients for some beta reference radiation fields

For some beta reference radiation fields [1] the conversion coefficients for the slab phantom were measured at the calibration distances in steps of 5°. The standard uncertainty of the measured values is of the order of 2 % to 4 %. In Figure C.1 and Table C.1 these measured coefficients are shown.



Key

X angle of radiation incidence, °

Y $h_{p,D}(0{,}07; \mathit{source}; \alpha)$, Sv·Gy^{-1}

1 ^{147}Pm; 20 cm with filter

2 ^{85}Kr; 30 cm with filter

3 ^{90}Sr + ^{90}Y; 20 cm

4 ^{90}Sr + ^{90}Y; 30 cm

5 ^{90}Sr + ^{90}Y; 30 cm with filter

6 ^{90}Sr + ^{90}Y; 50 cm

Figure C.1 — Measured conversion coefficients for the slab phantom as a function of the angle of incidence for some beta reference radiation fields
(see also Table C.1)

Table C.1 — Measured conversion coefficients $h_{\mathrm{p},D}(0{,}07; source; \alpha) = h'_D(0{,}07; source; \alpha)$ for the slab phantom dependent on the angle of incidence for commercial beta sources (see also Figure C.1)

Values in Sv·Gy^{-1}

Source			Conversion coefficient, $h_{\mathrm{p},D}(0{,}07; source; \alpha)$, for a value of α of															
Nuclide	**Beam-flattening filter**	**Dis-tance**																
		cm	**0°**	**5°**	**10°**	**15°**	**20°**	**25°**	**30°**	**35°**	**40°**	**45°**	**50°**	**55°**	**60°**	**65°**	**70°**	**75°**
^{90}Sr + ^{90}Y	yes	30	1,00	1,00	1,01	1,01	1,02	1,04	1,06	1,08	1,10	1,12	1,14	1,15	1,14	1,10	1,01	0,86
^{90}Sr + ^{90}Y	no	20	1,00	1,00	1,01	1,02	1,03	1,04	1,06	1,09	1,11	1,14	1,17	1,20	1,21	1,19	1,12	
^{90}Sr + ^{90}Y	no	30	1,00	1,00	1,01	1,01	1,03	1,04	1,06	1,08	1,10	1,13	1,15	1,16	1,16	1,14	1,06	0,91
^{90}Sr + ^{90}Y	no	50	1,00	1,00	1,00	1,01	1,02	1,03	1,05	1,07	1,08	1,10	1,11	1,11	1,10	1,06	0,98	0,84
^{85}Kr	yes	30	1,00	1,00	1,00	0,99	0,98	0,97	0,96	0,94	0,91	0,88	0,83	0,78	0,72	0,65	0,57	0,49
^{147}Pm	yes	20	1,00	1,00	0,98	0,96	0,94	0,91	0,87	0,82	0,77	0,72	0,66	0,59	0,53	—	—	—

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1) This document can be downloaded from http://www.european-accreditation.org, then go to documents, then to EA-4/02 (rev.00).

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