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Reference radiation fields for radiation protection — Definitions and fundamental concepts

Champs de rayonnement de référence pour la radioprotection — Défintions et concepts fondamentaux

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Foreword

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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.

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ISO 29661 was prepared by Technical Committee ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection*.

Introduction

International Standards ISO 4037, ISO 6980, ISO 8529 and ISO 12789[1]...[12], with focus on photon, beta and neutron reference radiation fields, are each divided into several parts: one part gives the methods of production and characterization of reference radiation fields, and others describe the dosimetry of the reference radiation qualities and the procedures for calibrating and determining the response of dosemeters and doserate meters in terms of the operational quantities of the International Commission on Radiation Units and Measurements (ICRU)[25] [26] [27] [28] [31].

The subject of these four International Standards is the same; they differ only in the kind of radiation each addresses. Their terms and definitions, and most of the descriptions of methods and procedures given are basically the same — whatever the radiation. Nevertheless, they do differ, more or less, from one to the other in detail. This International Standard brings together terms and definitions and fundamental concepts common to all of them. Thus, it serves to harmonize International Standards on radiation protection.

Besides definitions relating to calibration primary quantities, the operational quantities for area and individual monitoring are specified. For area monitoring, the operational quantities are ambient dose equivalent, $H^*(10)$, directional dose equivalents, $H'(0{,}07,\vec{\Omega})$ and $H'(3,\vec{\Omega})$, and the appropriate dose rates. For individual monitoring using personal dosemeters, the dose equivalent quantities, $H_\mathrm{p}(10)$, $H_\mathrm{p}(0{,}07)$ and $H_\mathrm{p}(3)$, and the respective dose rates are available.

The method used to represent these operational quantities is the following. First, a basic (primary) quantity, such as air kerma free-in-air, fluence or absorbed dose to soft tissue, is measured. Then the appropriate operational quantity is derived by the application of the conversion coefficient that relates the basic (primary) quantity to the selected operational quantity. The procedure for the calibration and the determination of the response of radiation protection dosemeters is described in general terms. Depending on the type of dosemeter under test, the position of the reference point is specified differently and the irradiation is either carried out on a phantom (for personal dosemeters) or free in air (for area dosemeters or area survey meters).

With the publication of this International Standard, it is intended that ISO 4037, ISO 6980, ISO 8529 and ISO 12789 be revised successively for further harmonization since, among other aspects, certain of their definitions differ from those published here and the symbols chosen for this International Standard are more consistent with ICRU reports and other International Standards used for radiation protection purposes.

Reference radiation fields for radiation protection — Definitions and fundamental concepts

1 Scope

This International Standard defines terms and fundamental concepts for the calibration of dosemeters and equipment used for the radiation protection dosimetry of external radiation — in particular, for beta, neutron and photon radiation. It defines the measurement quantities for radiation protection dosemeters and doserate meters and gives recommendations for establishing these quantities. For individual monitoring, it covers whole body and extremity dosemeters (including those for the skin and the eye lens), and for area monitoring, portable and installed dosemeters. Guidelines are given for the calibration of dosemeters and doserate meters used for individual and area monitoring in reference radiation fields. Recommendations are made for the position of the reference point and the phantom to be used for personal dosemeters.

This International Standard also deals with the determination of the response as a function of radiation quality and angle of radiation incidence.

It is intended to be used by calibration laboratories and manufacturers.

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.

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO/IEC 17025:2005, *General requirements for the competence of testing and calibration laboratories.* Corrected by ISO/IEC 17025:2005/Cor 1:2006

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE These terms and definitions are relevant for the calibration of dosemeters and for the quantities and conversion coefficients that are general to ISO 4037, ISO 6980, ISO 8529 and ISO 12789. Special terms and definitions can be found in those International Standards.

3.1 General

3.1.1
angle of radiation incidence
α
angle, in the coordinate system of the dosemeter, between the direction of radiation incidence and the reference direction of the dosemeter in unidirectional fields

3.1.2
area dosemeter
area survey meter
meter designed to measure the ambient dose equivalent (rate) or the directional dose equivalent (rate)

[SOURCE: IEV 394-22-08, modified.]

3.1.3
background indication
indication obtained from a phenomenon, body or substance similar to the one under investigation, but for which a quantity of interest is supposed not to be present, or is not contributing to the indication

[SOURCE: ISO/IEC Guide 99:2007, 4.2.]

3.1.4
calibration
operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and the corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication

[SOURCE: ISO/IEC Guide 99:2007, 2.39.]

Note 1 to entry: A calibration may be expressed by a statement, calibration function, calibration diagram, calibration curve, or calibration table. In some cases, it may consist of an additive or multiplicative correction of the indication with associated measurement uncertainty.

Note 2 to entry: The measurement standard can be a primary standard, a secondary standard or a working measurement standard.

Note 3 to entry: Often the first step alone in the above definition is perceived as being calibration.

3.1.5
calibration coefficient
$N(\mathrm{U},\alpha)$
quotient of the conventional quantity value to be measured and the corrected indication of the dosemeter normalized to reference conditions

Note 1 to entry: The calibration coefficient $N(\mathrm{U},\alpha)$ for the reference radiation quality U and the angle of incidence α is equivalent to the calibration factor multiplied by the instrument coefficient (see Annex B). It is given by

$$N(\mathrm{U},\alpha) = \frac{H_\mathrm{o}}{G_\mathrm{corr}} = C_\mathrm{f}(\mathrm{U},\alpha) \cdot c_\mathrm{i} \quad (1)$$

where

H_o	is the conventional quantity value;
G_corr	is the corrected indication;
$C_\mathrm{f}(\mathrm{U},\alpha)$	is the calibration factor for the radiation quality U and the angle of incidence α; and
c_i	is the instrument constant.

Concerning the dimension of the calibration factor and the calibration coefficient, see the Notes to 3.1.7 and 3.1.17.

Note 2 to entry: The reciprocal of the calibration coefficient is the response under reference conditions. The value of the calibration factor may vary with the magnitude of the quantity to be measured. In such cases a dosemeter is said to have a non-constant response (or a nonlinear indication).

Note 3 to entry: To distinguish between the indication of the standard and the dosemeter, subscripts 's' and 'd' are used and the respective coefficients are named $N(\mathrm{U},\alpha)_\mathrm{s}$ and $N(\mathrm{U},\alpha)_\mathrm{d}$.

[SOURCE: ICRU Report 76 modified.]

3.1.6
calibration conditions
conditions within the range of standard test conditions actually prevailing during the calibration measurement

3.1.7
calibration factor
$C_f(U,\alpha)$
factor by which the product of the corrected indication, G_{corr}, and the associated instrument constant, c_i, of the dosemeter is multiplied to obtain the conventional quantity value to be measured under reference conditions

Note to entry: The calibration factor is dimensionless.

[SOURCE: ICRU Report 76, modified.]

3.1.8
conventional quantity value
H_o
quantity value attributed by agreement to a quantity for a given purpose

Note to entry: The conventional quantity value H_o is the best estimate of the quantity to be measured, determined by a primary standard or a secondary or working measurement standard which are traceable to a primary standard.

[SOURCE: ISO/IEC Guide 99:2007, 2.39.]

3.1.9
correction factor
k
numerical value by which the indication is multiplied to compensate for the deviation of measurement conditions from reference conditions or for a systematic effect (e.g. ion recombination)

Note to entry: If the correction of the effect of an influence quantity requires a multiplicative factor, the influence quantity is of type F, see Note to entry 1 for 3.1.16.

3.1.10
correction factor for non-constant response
k_n
numerical value by which the indication is multiplied to compensate for the non-constant response (or non-linear indication) of the dosemeter, i.e. for the variation of the calibration factor or calibration coefficient with the variation of the magnitude of the quantity to be measured

Note to entry: For a dosemeter with constant response with respect to the selected measuring quantity, k_n is equal to unity.

3.1.11
corrected indication
G_{corr}
indication of a dosemeter corrected for any differences of the values of the influence quantities from reference conditions

Note 1 to entry: The corrected indication, G_{corr}, can be calculated with the correction factor, k_n, for non-constant response, the q correction factors, k_f, for the influence quantities of type F and the p correction summands, G_w, for the influence quantities of type S. It is given by

$$G_{corr} = k_n \cdot (G - \sum_{w=1}^{p} G_w) \cdot \prod_{f=1}^{q} k_f \quad (2)$$

which is a model function of the measurement necessary for any determination of the uncertainty according to ISO/IEC Guide 98-3.

Note 2 to entry: To distinguish between the indication of the standard and the dosemeter, Subscripts ‘s’ and ‘d’ are used and the respective indications are named $G_{s,corr}$ and $G_{d,corr}$.

3.1.12
correction summand
G_w
value added to the indication to compensate the deviation of measurement conditions from reference conditions or for a systematic error (e.g. zero indication)

Note to entry: If the correction of the effect of an influence quantity requires a summand, the influence quantity is of type S, see Note 1 to entry 3.1.16.

3.1.13
ICRU tissue
material equivalent to the human soft tissue with a density of 1 g·cm^{-3} and a mass composition of 76,2 % oxygen, 11,1 % carbon, 10,1 % hydrogen and 2,6 % nitrogen

[SOURCE: ICRU Report 33.]

3.1.14
ICRU sphere
spherical phantom of 30 cm in diameter made of ICRU tissue

Note to entry: This phantom is only used for the calculation of conversion coefficients to ambient or directional dose equivalent and not for dosemeter calibration.

[SOURCE: ICRU Report 33, modified.]

3.1.15
indication
G
quantity value provided by a measuring instrument or a measuring system

Note 1 to entry: A measuring instrument or a measuring system may consist of several parts, e.g. the ionisation chamber plus the electrometer, or the complete instrument in one housing, but always without the phantom (if used). In this International Standard it is always termed a *dosemeter*.

Note 2 to entry: The units of the indication of the dosemeter are not necessarily the same as that of the measurand. For example, for measurements with ionisation chambers the instrument indication is, in general, the value of the current I or of the charge Q. It is necessary to document whether the indication is normalized to the reference conditions to account for influence quantities and is corrected for intrinsic background and other influences. The corrected indication is named G_{corr}.

Note 3 to entry: To distinguish between the indication of the standard and the dosemeter, subscripts 's' and 'd' are used and the respective indications are named G_{s} and G_{d}.

[SOURCE: ISO/IEC Guide 99:2007, 4.1.]

3.1.16
influence quantity
quantity that, in a direct measurement, does not affect the quantity that is actually measured, but affects the relation between the indication and the measurement result

Note 1 to entry: The correction of the effect of the influence quantity can require a correction factor (influence quantity of type F) and/or a correction summand (influence quantity of type S) to be applied to the indication of the dosemeter, e.g. energy for type F and microphony or electromagnetic disturbance for type S, see 3.1.9 and 3.1.12.

Note 2 to entry: The dose rate is an influence quantity when measuring the dose.

[SOURCE: ISO/IEC Guide 99:2007, 2.52.]

3.1.17
instrument constant
c_i
constant by which the indication of the dosemeter, G, or — if corrections or a normalization were applied — the corrected indication, G_{corr}, is multiplied to convert it to the same unit as the measurand

Note to entry: If the instrument's indication is already expressed in the same unit as the measurand, c_i is unnecessary.

[SOURCE: ICRU Report 76.]

3.1.18
measurand
quantity intended to be measured

[SOURCE: ISO/IEC Guide 99:2007, 2.3.]

3.1.19
measured quantity value
measured value
M
quantity value representing a measurement result

Note to entry: See 6.2.4.

[SOURCE: ISO/IEC Guide 99:2007, 2.10.]

3.1.20
monitor device
device installed in an irradiation facility to monitor the fluence or dose (rate) of the irradiation field

3.1.21
personal dosemeter
meter designed to measure the personal dose equivalent (rate)

Note to entry: A personal dosemeter can be worn on the trunk (whole-body personal dosemeter), at the extremities (extremity personal dosemeter) or close to the eye lens (eye lens dosemeter).

[SOURCE: IEV 394-22-08, modified.]

3.1.22
phantom
artefact constructed to simulate the scattering properties of the human body or parts of the human body such as the extremities

Note to entry: A phantom can be used for the definition of a quantity and made of artificial material, e.g. ICRU tissue, or for the calibration and then be made of physically existing material, see 6.6.2 for details.

3.1.23
point of test
point in the radiation field at which the conventional quantity value is known

[SOURCE: ICRU Report 76.]

3.1.24
primary measurement standard
primary standard
measurement standard established using a primary reference measurement procedure, or created as an artefact, chosen by convention

EXAMPLE Free-air chambers as primary measurement standards of the measurand air kerma free-in-air.

Note 1 to entry: A primary standard has the highest metrological quality in a given field of metrology.

Note 2 to entry: The quantity value of the primary standard is equated to the best estimate of the quantity to be measured, i.e. the conventional quantity value.

[SOURCE: ISO/IEC Guide 99:2007, 5.4.]

3.1.25
quantity
property of a phenomenon, body or substance, where the property has a magnitude that can be expressed as a number and a reference

[SOURCE: ISO/IEC Guide 99:2007, 1.1.]

Note to entry: The quantities considered in the scope of this International Standard are the operational quantities for radiation protection purposes (ambient dose equivalent, directional dose equivalent, personal dose equivalent and the respective dose rates) and the basic quantities such as air kerma free-in-air, fluence and absorbed dose to soft tissue.

3.1.26
quantity value
number and reference together expressing magnitude of a quantity

EXAMPLE 1,52 μGy h^{-1} as the dose rate in a given radiation field.

Note to entry: A quantity value is a product of a number and a measurement unit (the unit one is generally not indicated for quantities of dimension one).

[SOURCE: ISO/IEC Guide 99:2007, 1.19.]

3.1.27
radiation detector
apparatus or substance used to convert incident ionizing radiation energy into a signal suitable for indication and/or measurement

[SOURCE: IEV 394-24-01.]

3.1.28
radiation quality
U
characteristic of ionizing radiation determined by the spectral distribution of radiation with respect to energy

Note to entry: The characteristic is expressed by parameters which are given together with their values in ISO 4037, ISO 6980, ISO 8529 and ISO 12789. Examples of the parameters are effective energy, half-value layer, X-ray tube voltage and filtration.

[SOURCE: IEV 881-02-22, modified.]

3.1.29
reference direction
direction, in the coordinate system of the dosemeter, with respect to which the angle of radiation incidence is measured in reference fields

Note 1 to entry: At the angle of incidence of 0° the reference direction of the dosemeter is parallel to the direction of radiation incidence. At the angle of 180° the reference direction of the dosemeter is anti-parallel to the direction of radiation incidence.

Note 2 to entry: The reference direction, in the coordinate system of the dosemeter, points into the dosemeter (see Figure 1). For parts to be irradiated consisting of a personal dosemeter and a cylindrical phantom such as a pillar or rod phantom the reference direction points into the phantom and is perpendicular to the centre line of the phantom.

3.1.30
reference operating condition
reference condition
operating condition prescribed for evaluating the performance of a measuring instrument or measuring system or for comparison of measurement results

[SOURCE: ISO/IEC Guide 99:2007, 4.11.]

