SLOVENSKI STANDARD
SIST EN ISO 4037-3:2021

01-april-2021

Radiološka zaščita - Referenčno sevanje z rentgenskimi in gama žarki za kalibracijo dozimetrov in merilnikov doze sevanja ter za ugotavljanje njihovega odzivanja kot funkcije fotonske energije - 3. del: Kalibriranje zunanjih in osebnih dozimetrov ter merjenje njihovega odzivanja kot funkcije energije in vpadnega kota (ISO 4037-3:2019)

Radiological protection - X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy - Part 3: Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence (ISO 4037-3:2019)

Strahlenschutz - Röntgen- und Gamma-Referenzstrahlungsfelder zur Kalibrierung von Dosimetern und Dosisleistungsmessgeräten und zur Bestimmung ihres Ansprechvermögens als Funktion der Photonenenergie - Teil 3: Kalibrierung von Orts- und Personendosimetern und Messung ihres Ansprechvermögens als Funktion von Energie und Einfallswinkel (ISO 4037-3:2019)

Radioprotection - Rayonnements X et gamma de référence pour l'étalonnage des dosimètres et des débitmètres et pour la détermination de leur réponse en fonction de l'énergie des photons - Partie 3: Étalonnage des dosimètres de zone et individuels et mesurage de leur réponse en fonction de l'énergie et de l'angle d'incidence (ISO 4037-3:2019)

Ta slovenski standard je istoveten z: **EN ISO 4037-3:2021**

ICS:

13.280	Varstvo pred sevanjem	Radiation protection
17.240	Merjenje sevanja	Radiation measurements

SIST EN ISO 4037-3:2021 **en,fr,de**

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN ISO 4037-3

February 2021

ICS 17.240

English Version

Radiological protection - X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy - Part 3: Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence (ISO 4037-3:2019)

Radioprotection - Rayonnements X et gamma de référence pour l'étalonnage des dosimètres et des débitmètres et pour la détermination de leur réponse en fonction de l'énergie des photons - Partie 3: Étalonnage des dosimètres de zone et individuels et mesurage de leur réponse en fonction de l'énergie et de l'angle d'incidence (ISO 4037-3:2019)

Strahlenschutz - Röntgen- und Gamma-Referenzstrahlungsfelder zur Kalibrierung von Dosimetern und Dosisleistungsmessgeräten und zur Bestimmung ihres Ansprechvermögens als Funktion der Photonenenergie - Teil 3: Kalibrierung von Orts- und Personendosimetern und Messung ihres Ansprechvermögens als Funktion von Energie und Einfallswinkel (ISO 4037-3:2019)

This European Standard was approved by CEN on 18 January 2021.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

Ref. No. EN ISO 4037-3:2021 E

Contents

Page

European foreword **3**

European foreword

The text of ISO 4037-3:2019 has been prepared by Technical Committee ISO/TC 85 "Nuclear energy, nuclear technologies, and radiological protection” of the International Organization for Standardization (ISO) and has been taken over as EN ISO 4037-3:2021 by Technical Committee CEN/TC 430 “Nuclear energy, nuclear technologies, and radiological protection” the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2021, and conflicting national standards shall be withdrawn at the latest by August 2021.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Endorsement notice

The text of ISO 4037-3:2019 has been approved by CEN as EN ISO 4037-3:2021 without any modification.

INTERNATIONAL STANDARD

ISO 4037-3

Second edition
2019-01

Radiological protection — X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy —

Part 3: Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence

Radioprotection — Rayonnements X et gamma de référence pour l'étalonnage des dosimètres et des débitmètres et pour la détermination de leur réponse en fonction de l'énergie des photons —

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

Reference number
ISO 4037-3:2019(E)

Contents

Page

Foreword v
Introduction vi
1 Scope 1
2 Normative references 2
3 Terms and definitions 2
4 Procedures applicable to all area and personal dosemeters 2
4.1 General principles 2
4.1.1 Radiation qualities 2
4.1.2 Recommended conversion coefficients 3
4.1.3 Point of test and reference point 4
4.1.4 Axes of rotation 4
4.1.5 Condition of the dosemeter to be calibrated 5
4.1.6 Effects associated with electron ranges 5
4.2 Methods for the determination of the calibration factor and of the response 6
4.2.1 Operation of the standard instrument 6
4.2.2 Measurements without a monitor for the source output 7
5 Particular procedures for area dosemeters 7
5.1 General principles 7
5.2 Quantities to be measured 7
6 Conversion coefficients for area dosimetry 7
6.1 Conversion coefficients from air kerma, K_a, to $H'(0,07)$ 7
6.1.1 Mono-energetic radiation 7
6.1.2 Low air kerma rate series 8
6.1.3 Narrow series 8
6.1.4 Wide series 8
6.1.5 High air kerma rate series 8
6.1.6 Radionuclides 8
6.2 Conversion coefficients from air kerma, K_a, to $H'(3)$ 15
6.2.1 Mono-energetic radiation 15
6.2.2 Low air kerma rate series 15
6.2.3 Narrow series 15
6.2.4 Wide series 15
6.2.5 High air kerma rate series 15
6.2.6 Radionuclides 15
6.2.7 High energy photon radiations 15
6.3 Conversion coefficient from air kerma, K_a, to $H^*(10)$ 23
6.3.1 Mono-energetic radiation 23
6.3.2 Low air kerma rate series 23
6.3.3 Narrow series 23
6.3.4 Wide series 23
6.3.5 High air kerma rate series 23
6.3.6 Radionuclides 23
6.3.7 High energy photon radiations 23
7 Particular procedures for personal dosemeters 27
7.1 General principles 27
7.2 Quantities to be measured 27
7.3 Experimental conditions 27
7.3.1 Use of phantoms 27
7.3.2 Geometrical considerations in divergent beams 28
7.3.3 Simultaneous irradiation of several dosemeters 28
7.3.4 Influence of the orientation on the values of $H_p(0,07)$ 29
7.3.5 Length of the rod phantom 30

8 Conversion coefficients for personal dosimetry **30**
8.1 General 30
8.2 Conversion coefficients from air kerma, K_a, to $H_p(0,07)$ in the rod phantom 30
8.2.1 Mono-energetic radiations 30
8.2.2 Low air kerma rate series 30
8.2.3 Narrow series 30
8.2.4 Wide series 30
8.2.5 High air kerma rate series 30
8.2.6 Radionuclides 31
8.3 Conversion coefficients from air kerma, K_a, to $H_p(0,07)$ in the pillar phantom 34
8.3.1 Mono-energetic radiations 34
8.3.2 Low air kerma rate series 34
8.3.3 Narrow series 34
8.3.4 Wide series 34
8.3.5 High air kerma rate series 34
8.3.6 Radionuclides 34
8.4 Conversion coefficients from air kerma, K_a, to $H_p(0,07)$ in the ICRU slab phantom 37
8.4.1 Mono-energetic radiations 37
8.4.2 Low air kerma rate series 37
8.4.3 Narrow series 37
8.4.4 Wide series 37
8.4.5 High air kerma rate series 38
8.4.6 Radionuclides 38
8.5 Conversion coefficients from air kerma, K_a, to $H_p(3)$ in the cylinder phantom 41
8.5.1 Mono-energetic radiations 41
8.5.2 Low air kerma rate series 41
8.5.3 Narrow series 41
8.5.4 Wide series 41
8.5.5 High air kerma rate series 41
8.5.6 Radionuclides 41
8.5.7 High energy photon radiations 41
8.6 Conversion coefficients from air kerma, K_a, to $H_p(10)$ in the ICRU slab phantom 44
8.6.1 Mono-energetic radiations 44
8.6.2 Low air kerma rate series 45
8.6.3 Narrow series 45
8.6.4 Wide series 45
8.6.5 High air kerma rate series 45
8.6.6 Radionuclides 45
8.6.7 High energy photon radiations 45

9 Uncertainties **53**
9.1 Statement of uncertainties 53

Annex A (informative) **Estimated conversion coefficients for fluorescence X radiation** **54**

Annex B (informative) **Estimated conversion coefficients for gamma radiation emitted by ^{241}Am radionuclide** **59**

Annex C (informative) **Estimated conversion coefficients for continuous filtered X radiation based on the quality index** **61**

Annex D (informative) **Additional information** **63**

Bibliography **67**

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www. iso. org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www. iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www. iso. org/iso/foreword.html.

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

This second edition cancels and replaces the first edition (ISO 4037-3:1999), which has been technically revised.

A list of all the parts in the ISO 4037 series can be found on the ISO website.

Introduction

The maintenance release of this document incorporates the improvements to high voltage generators from 1996 to 2017 (e.g., the use of high frequency switching supplies providing nearly constant potential), and the spectral measurements at irradiation facilities equipped with such generators (e.g., the catalogue of X-ray spectra by Ankerhold[1]). It also incorporates all published information with the aim to adjust the requirements for the technical parameters of the reference fields to the targeted overall uncertainty of about 6 % to 10 % for the phantom related operational quantities of the International Commission on Radiation Units and Measurements (ICRU)[2]. It does not change the general concept of the existing ISO 4037.

ISO 4037, focusing on photon reference radiation fields, is divided into four parts. ISO 4037-1 gives the methods of production and characterization of reference radiation fields in terms of the quantities spectral photon fluence and air kerma free-in-air. ISO 4037-2 describes the dosimetry of the reference radiation qualities in terms of air kerma and in terms of the phantom related operational quantities of the International Commission on Radiation Units and Measurements (ICRU)[2]. This document describes the methods for calibrating and determining the response of dosemeters and doserate meters in terms of the phantom related operational quantities of the ICRU[2]. ISO 4037-4 gives special considerations and additional requirements for calibration of area and personal dosemeters in low energy X reference radiation fields, which are reference fields with generating potential ≤30 kV.

The determination of the response of dosemeters and doserate meters is essentially a three-step or two-step process. First, a basic quantity such as air kerma is measured free-in-air at the point of test. Then the appropriate operational quantity is derived by the application of the conversion coefficient that relates the quantity measured to the selected operational quantity. These two steps may be merged into a single-step if a standard for the phantom related quantities is used. Finally, the device under test is placed at the point of test for the determination of its response. 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 area and individual monitoring this document describes details of the methods and provides, if applicable, the recommended conversion coefficients to be used for the determination of the response of dosemeters and doserate meters in terms of the phantom related operational quantities of the ICRU for photons. The use of these recommended conversion coefficients requires that the corresponding radiation quality of the reference field used for the irradiation is validated. For all non-validated radiation qualities, the recommended conversion coefficients cannot be used. For these radiation qualities, the dosimetry with respect to the phantom related operational quantities of the ICRU – see ISO 4037-2:2019, Clause 6 – or the spectrometry – see ISO 4037-2:2019, Annex B – should be performed. For tube potentials of 30 kV and below ISO 4037-4 gives special requirements.

The general procedures described in ISO 29661 are used as far as possible in this document. In addition, the symbols used are in line with ISO 29661.

Radiological protection — X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy —

Part 3: Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence

1 Scope

This document specifies additional procedures and data for the calibration of dosemeters and doserate meters used for individual and area monitoring in radiation protection. The general procedure for the calibration and the determination of the response of radiation protection dose(rate)meters is described in ISO 29661 and is followed as far as possible. For this purpose, the photon reference radiation fields with mean energies between 8 keV and 9 MeV, as specified in ISO 4037-1, are used. In Annex D some additional information on reference conditions, required standard test conditions and effects associated with electron ranges are given. For individual monitoring, both whole body and extremity dosemeters are covered and for area monitoring, both portable and installed dose(rate)meters are covered.

Charged particle equilibrium is needed for the reference fields although this is not always established in the workplace fields for which the dosemeter should be calibrated. This is especially true at photon energies without inherent charged particle equilibrium at the reference depth *d*, which depends on the actual combination of energy and reference depth *d*. Electrons of energies above 65 keV, 0,75 MeV and 2,1 MeV can just penetrate 0,07 mm, 3 mm and 10 mm of ICRU tissue, respectively, and the radiation qualities with photon energies above these values are considered as radiation qualities without inherent charged particle equilibrium for the quantities defined at these depths. This document also deals with the determination of the response as a function of photon energy and angle of radiation incidence. Such measurements can represent part of a type test in the course of which the effect of further influence quantities on the response is examined.

This document is only applicable for air kerma rates above 1 µGy/h.

This document does not cover the in-situ calibration of fixed installed area dosemeters.

The procedures to be followed for the different types of dosemeters are described. Recommendations are given on the phantom to be used and on the conversion coefficients to be applied. Recommended conversion coefficients are only given for matched reference radiation fields, which are specified in ISO 4037-1:2019, Clauses 4 to 6. ISO 4037-1:2019, Annexes A and B, both informative, include fluorescent radiations, the gamma radiation of the radionuclide ^{241}Am, S-Am, for which detailed published information is not available. ISO 4037-1:2019, Annex C, gives additional X radiation fields, which are specified by the quality index. For all these radiation qualities, conversion coefficients are given in Annexes A to C, but only as a rough estimate as the overall uncertainty of these conversion coefficients in practical reference radiation fields is not known.

NOTE The term dosemeter is used as a generic term denoting any dose or doserate meter for individual or area monitoring.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 4037-1, *Radiological protection — X and gamma reference radiations for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy — Part 1: Radiation characteristics and production methods*

ISO 4037-2:2019, *Radiological protection — X and gamma reference radiations for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy — Part 2: Dosimetry for radiation protection over the energy ranges from 8 keV to 1,3 MeV and 4 MeV to 9 MeV*

ISO 4037-4:2019, *Radiological protection — X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy — Part 4: Calibration of area and personal dosemeters in low energy X reference radiation fields*

ISO 29661, *Reference radiation fields for radiation protection — Definitions and fundamental concepts*

ISO 80000-10, *Quantities and units — Part 10: Atomic and nuclear physics*[1)]

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

ISO/IEC Guide 99, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4037-1, ISO 4037-2, ISO 29661, ISO 80000-10, ISO/IEC Guide 99 and the following apply:

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
back-scatter factor
ratio of air kerma in front of a phantom to the air kerma at the same position free-in-air without the phantom. The field is considered to be unidirectional with a direction of incidence perpendicular to the phantom surface

Note 1 to entry: The value of the back-scatter factor depends on the point of test (distance from the surface and from the beam axis), beam diameter, phantom size and material and radiation energy.

4 Procedures applicable to all area and personal dosemeters

4.1 General principles

4.1.1 Radiation qualities

All radiation qualities shall be chosen from, and produced in accordance to, ISO 4037-1. In general, it is useful to select an appropriate validated radiation quality taking into account the specified energy and dose or dose rate range of the dosemeter to be tested.

1) Under preparation. Stage at the time of publication ISO/Guide 80000-10:2019.

4.1.2 Recommended conversion coefficients

If only a standard instrument for the air kerma, K_a, free-in-air is used for dosimetric measurements, then for all the other phantom related operational quantities $H^*(10)$, $H_p(10)$, $H'(3)$, $H_p(3)$, $H'(0{,}07)$ and $H_p(0{,}07)$, appropriate conversion coefficients shall be applied to the measured air kerma values. These conversion coefficients shall, in principle, be determined by spectrometry for any reference field, any measuring quantity and, if applicable, for any phantom and angle of radiation incidence.

The air kerma is given by the sum of the air collision kerma, $K_{a,coll}$, and the air radiative kerma, $K_{a,rad}$: $K_a = K_{a,coll} + K_{a,rad}$. The air collision kerma, $K_{a,coll}$, is related to the air kerma by the equation $K_{a,coll} = K_a \cdot (1 - g_a)$, where g_a is the fraction of the energy of the electrons liberated by photons that is lost by radiative processes (bremsstrahlung, fluorescence radiation or annihilation radiation of positrons). Values of $(1–g_a)$ for mono-energetic radiation are given in ISO 4037-2, upper part of Table 2. In the lower part of that Table 2, values for the reference radiations S-Cs, S-Co, R-C and R-F are given. Values are interpolated for S-Cs or taken from Roos and Grosswendt[8] for S-Co and from PTB-Dos-32 for R-C and R-F. For water or air and for energies lower than 1,3 MeV, g_a is less than 0,003 and below 1,5 MeV the values of $(1–g_a)$ can be considered to be unity, see ICRU Report 47[9], A.2.1.

The air collision kerma is the part that leads to the production of electrons that dissipate their energy as ionization in or near the electron tracks in the medium – and is obtained in some Monte Carlo calculations as the energy deposited. The interpretation that was made in ISO 29661 was that the original conversion coefficients which were derived from ICRU Report 57 actually refer to air collision kerma. This approach is adopted in ISO 4037 in the following way: for energies up to and including that of the S-Co reference field the original values are used, as the application of the factor $(1 – g_a)$ does not change numerical values truncated to three significant digits. Conversion coefficients for the R-C and R-F given in ISO 4037-3 differ from those given in ICRU and the previous edition of 4037-3 (1999) by the factor $(1 - g_a) = 0{,}987$ and $(1 - g_a) = 0{,}978$, respectively.

For the tables in Clauses 6 and 8, the irradiation distance is measured from the focal spot of the X-ray tube (or from the geometrical centre of the radio nuclide source) to the point of test, at which the reference point of the dosemeter shall be located. For the R-C and R-F radiations, the irradiation distance shall be measured from the centre of the target surface from which the radiation emerges to the point of test. For the X-radiation qualities, recommended conversion coefficients are given, if available, for two distances of 1,0 m and 2,5 m in separate columns, even if they differ only by the last digit. This shall avoid the introduction of additional uncertainties. If these recommended conversion coefficients are identical for both distances, then the two table cells are merged and only one recommended conversion coefficient is given. This indicates that the recommended conversion coefficient can be used at least for distances from 1 m to 2,5 m. If the recommended conversion coefficients are different for the distances of 1 m and 2,5 m and a recommended conversion coefficient is required for other distances, then the given values of the recommended conversion coefficients shall be interpolated or extrapolated accordingly. If both values are very similar, e.g., only different by 2 % or less, then a linear interpolation may be used. If a range is given for the distance, then the values of the recommended conversion coefficients may be used without modification over this range of distances. From the available data in the Tables, it can be concluded that for collimated beams with mean energies above about 40 keV there is no difference in the recommended conversion coefficients for both distances. The difference increases with decreasing photon energy, increasing definition depth, increasing width of the spectra and increasing angle of radiation incidence.

In Clauses 6 and 8 and in Annexes A to C, a notation is used for the presentation of recommended conversion coefficients which is explained in the following: The example of $h'_K(0{,}07; E, \alpha)$ refers to the conversion coefficient from air kerma K_a to directional dose equivalent in a depth of 0,07 mm for mono-energetic and unidirectional photon radiation of energy E, with an angle α between the reference direction of the dosemeter and the direction of radiation incidence. The prime is replaced by an asterisk for ambient dose equivalent or by the letter p as a subscript for personal dose equivalent. For personal dose equivalent, the type of the phantom is indicated by a subscript at the end. The subscripts rod, pill, cyl and slab stand for rod phantom, pillar phantom, cylinder phantom and slab phantom, respectively. Similar to the above example this would be for the rod phantom $h_{pK}(0{,}07; E, \alpha)_{rod}$. For radiation qualities, U, of finite spectral width the symbol E is replaced by the letter U to represent any radiation