KIIRGUSKAITSE
Dosimeetrite ja doosi kiiruse mõõteseadmete kalibreerimiseks ning nende footoni energiast sõltuva koste määramiseks kasutatav röntgeni- ja gammareferentskiirgus
Osa 1: Kiirgusparameetrid ja saamismeetodid

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 1: Radiation characteristics and production methods
(ISO 4037-1:2019, identical)

EESTI STANDARDIKESKUS
ESTONIAN CENTRE FOR STANDARDISATION

EESTI STANDARDI EESSÕNA	NATIONAL FOREWORD
See Eesti standard EVS-ISO 4037-1:2019 „Kiirguskaitse. Dosimeetrite ja doosi kiiruse mõõteseadmete kalibreerimiseks ning nende footoni energiast sõltuva koste määramiseks kasutatav röntgeni- ja gammareferentskiirgus. Osa 1: Kiirgusparameetrid ja saamismeetodid“ sisaldab rahvusvahelise standardi ISO 4037-1:2019 „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 1: Radiation characteristics and production methods“ identset ingliskeelset teksti.	This Estonian Standard EVS-ISO 4037-1:2019 consists of the identical English text of the International Standard ISO 4037-1:2019 „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 1: Radiation characteristics and production methods“.
Ettepaneku rahvusvahelise standardi ümbertrüki meetodil ülevõtuks on esitanud EVS/TK 28, standardi avaldamist on korraldanud Eesti Standardikeskus.	Proposal to adopt the International Standard by reprint method has been presented by EVS/TK 28, the Estonian Standard has been published by the Estonian Centre for Standardisation.
Standard EVS-ISO 4037-1:2019 on jõustunud sellekohase teate avaldamisega EVS Teataja 2019. aasta juunikuu numbris.	Standard EVS-ISO 4037-1:2019 has been endorsed with a notification published in the June 2019 issue of the official bulletin of the Estonian Centre for Standardisation.
Standard on kättesaadav Eesti Standardikeskusest.	The standard is available from the Estonian Centre for Standardisation.

Käsitlusala

See standard kirjeldab kaitsetaseme dosimeetrite ja doosi kiiruse mõõteseadmete kalibreerimiseks kasutatavaid röntgeni- ja gammareferentskiirguse parameetreid ning saamismeetodeid rahvusvahelise kiirgusühikute ja kiirgusmõõtmiste komisjoni (International Commission on Radiation Units and Measurement, ICRU[5]) fantoomiga seotud operatiivsuuruste suhtes. Kõige väiksem õhukerma kiirus, mille suhtes seda standardit kohaldatakse, on 1 $\mu Gy\ h^{-1}$. Allpool kõnealust õhukerma kiiruse väärtust nõuab (looduslik) taustkiirgus aga erilist tähelepanu ning seda selles dokumendis ei käsitleta.

Peatükkides 4 kuni 6 määratletud kiirgusparameetrite jaoks on avaldatud piisavalt teavet, et täpsustada nõudeid kõigile vastavuses olevate või kirjeldatud referentsväljade olulistele parameetritele, saavutamaks soovitud üldist määramatust ligikaudu 6 % kuni 10 % (k = 2) fantoomiga seotud operatiivsuuruste suhtes. Teatmelisades A kuni C kirjeldatud röntgenikiirguse väljad ei ole ette nähtud röntgenikiirguse referentsväljadeks.

MÄRKUS Standardi ISO 4037-1 1996. aastal välja antud esimene trükk sisaldas mõningaid täiendavaid kiirgusparameetreid, millede kohta selliselt avaldatud teave ei ole kättesaadav. Need on fluorestsentskiirgused, radionukliidi ^{241}Am, S-Am gammakiirgus ja suure energiaga footonkiirgused R-Ti ja R-Ni, mis on eemaldatud selle dokumendi põhiosast. Kõige sagedamini kasutatavad kiirgused, fluorestsentskiirgused ja radionukliidi ^{241}Am, S-Am gammakiirgus sisalduvad peaaegu muutmatul kujul teatmelisades A ja B. Teatmelisa C esitab täiendavaid röntgenikiirguse välju, mis on kirjeldatud kvaliteedinäitaja järgi.

Konkreetses footoni energia vahemikus referentskiirguste rühma saamiseks kasutatavad meetodid on kirjeldatud peatükkides 4 kuni 6, mis määravad ära ka nende kiirguste parameetrid. Need kolm referentskiirguse rühma on

a) energiavahemikus ligikaudu 8 keV kuni 330 keV pidev filtreeritud röntgenikiirgus,

b) energiavahemikus 600 keV kuni 1,3 MeV radionukliidide kiiratud gammakiirgus,

c) energiavahemikus 4 MeV kuni 9 MeV kiirendite toodetud footonkiirgus.

Plaanitava rakenduse jaoks kõige sobivama referentskiirguse välja saab valida tabelist 1, mis annab ülevaate kõigist peatükkides 4 kuni 6 kirjeldatud referentskiirguse parameetritest. See ei hõlma lisades A, B ja C kirjeldatud kiirgusi.

Peatükkides 4 kuni 6 esitatud nõuded ja meetodid on suunatud doosi (kiiruse) väärtuse ligikaudu 6 % kuni 10 % (k = 2) üldise määramatuse saavutamiseks fantoomiga seotud operatiivsuuruste suhtes referentsväljas. Selle saavutamiseks pakutakse välja kaks saamismeetodit.

Esimene neist on piisavalt hästi kirjeldatud omadustega „vastavuses olevate referentsväljade“ tekitamine, et oleks võimalik kasutada standardis ISO 4037-3 soovitatud teisendustegureid. „Vastavuses olevate referentsväljade“ spektraaljaotuste ainult väikeste erinevuste, võrreldes nominaalsete referentsväljadega, olemasolu on kinnitatud toimingutega, mis on üksikasjalikult kirjeldatud standardis ISO 4037-2. Vastavuses olevate kiirguse referentsväljade jaoks on toodud standardis ISO 4037-3 soovitatavad teisendustegurid ainult kindlate allika ja dosimeetri vahekauguste, nt 1,0 m ja 2,5 m jaoks. Teiste vahekauguste korral peab kasutaja otsustama, kas neid teisendustegureid saab kasutada. Kui mõlemad väärtused on väga lähedased, nt erinevad ainult 2 % või vähem, võib kasutada lineaarset interpolatsiooni.

Teine meetod on tekitada „kirjeldatud referentsvälju“. Seda tehakse kas teisendustegurite määramisel spektromeetria abil või mõõdetakse vajalik väärtus vahetult sekundaarsete standardsete dosimeetrite abil. Kõnealust meetodit rakendatakse mis tahes kiirgusparameetri korral, mis tahes mõõdetavale suurusele ja kui see on rakendatav, siis ka iga fantoomi ja kiirguse vahelisele langemisnurgale. Lisaks sõltuvad referentskiirgust iseloomustavatele parameetritele esitatud nõuded fantoomis määratud sügavusest, s.o kas 0,07 mm, 3 mm või 10 mm, kusjuures eri sügavuste jaoks kehtivad eri nõuded. Seega võib antud kiirgusväli olla 0,07 mm sügavuse jaoks „vastavuses olev referentsväli“, aga seda mitte 10 mm sügavuse jaoks, mille puhul võib see olla „kirjeldatud referentsväli“. Teisendustegureid saab määrata mis tahes kauguste jaoks, kui õhukerma kiirus ei jää alla 1 µGy/h.

Mõlemad meetodid vajavad referentsvälja jaoks laetud osakeste tasakaalu. Kusjuures see pole alati tuvastatud töökohal olevas väljas, mille jaoks dosimeeter on kalibreeritud. See kehtib eriti footoni energia kohta referentssügavusel d ilma laetud osakestele omase tasakaaluta, mis sõltub energia ja referentssügavuse d tegelikust kombinatsioonist. Elektronid, mille energia on üle 65 keV, 0,75 MeV ja 2,1 MeV, võivad läbida vastavalt 0,07 mm, 3 mm ja 10 mm ICRU kudet ja nendest väärtustest suuremate footoni energiate korral loetakse kiirgusparameetrid sellel sügavusel defineeritud suuruste jaoks sisemise tasakaaluta laetud osakeste kiirgusparameetriteks.

Doosi (kiiruse) väärtuse ja sellega seotud üldise määramatuse määramiseks peavad kõik mõõtevahendid, mida kasutatakse nende suuruste väärtuse määramisel, olema rahvuslike standarditeni jälgitavalt kalibreeritud.

See dokument ei kirjelda pulseerivaid referentskiirguse välju.

Tabel 1 — Röntgeni- ja gammareferentskiirgused, nende keskmised energiad $\bar{E}(\Phi)$ 1 m kaugusel ja nende lühendid

Kiirgus-parameeter	$\bar{E}(\Phi)$ keV	Kiirgus-parameeter	$\bar{E}(\Phi)$ keV	Kiirgus-parameeter	$\bar{E}(\Phi)$ keV	Kiirgus-parameeter	$\bar{E}(\Phi)$ keV
L-10	9,0	N-10	8,5	W-30	22,9	H-10	8,0
L-20	17,3	N-15	12,4	W-40	29,8	H-20	13,1
L-30	26,7	N-20	16,3	W-60	44,8	H-30	19,7
L-35	30,4	N-25	20,3	W-80	56,5	H-40	25,4
L-55	47,8	N-30	24,6	W-110	79,1	H-60	38,0
L-70	60,6	N-40	33,3	W-150	104	H-80	48,8
L-100	86,8	N-60	47,9	W-200	138	H-100	57,3
L-125	109	N-80	65,2	W-250	172	H-150	78,0
L-170	149	N-100	83,3	W-300	205	H-200	99,3
L-210	185	N-120	100			H-250	122
L-240	211	N-150	118			H-280	145
		N-200	165			H-300	143
		N-250	207			H-350	167
		N-300	248			H-400	190
		N-350	288				
		N-400	328				

Radionukliidid			Suure energiaga footonkiirgus		
Kiirgus-parameeter	Radionukliid	$\bar{E}(\Phi)$ keV	Kiirgus-parameeter	Reaktsioon	$\bar{E}(\Phi)$; $\bar{E}[H^*(10)]$ [a] MeV
S-Cs	^{137}Cs	662	R-C	^{12}C (p,p'γ) ^{12}C	4,2; 4,4
S-Co	^{60}Co	1250	R-F	^{19}F (p,αγ) ^{16}O	4,4; 6,5

MÄRKUS Teatmelisades A kuni C on toodud veel kiirguse parameetreid. Need hõlmavad keskmist footoni energiat 8 keV kuni 270 keV.

[a] Keskmine footoni energia, mis on kaalutud ambientse doosiekvivalendi $H^*(10)$ jaotusega footoni energia E suhtes.

Tagasisidet standardi sisu kohta on võimalik edastada, kasutades EVS-i veebilehel asuvat tagasiside vormi või saates e-kirja meiliaadressile standardiosakond@evs.ee.

ICS 17.240

Contents

Page

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 4037-1:1996), which has been technically revised. The main changes are:

— introduction of two types of reference fields, matched reference fields and characterized reference fields;

— introduction of validation for matched reference fields;

— introduction of limits for the allowed deviation of parameters like high voltage, filter purity and filter thickness from their nominal values. These limits now depend on the definition depth of the phantom related quantity. This is done to achieve an overall uncertainty ($k = 2$) of about 6 % to 10 % for the phantom related operational quantities.

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This 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[4]). 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)[5]. 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)[5]. ISO 4037-3 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[5]. 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 lower or equal to 30 kV.

The general procedures described in ISO 29661 are used as far as possible in this document. Also, 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 1: Radiation characteristics and production methods

1 Scope

This document specifies the characteristics and production methods of X and gamma reference radiation for calibrating protection-level dosemeters and doserate meters with respect to the phantom related operational quantities of the International Commission on Radiation Units and Measurements (ICRU)[5]. The lowest air kerma rate for which this standard is applicable is 1 µGy h^{-1}. Below this air kerma rate the (natural) background radiation needs special consideration and this is not included in this document.

For the radiation qualities specified in Clauses 4 to 6, sufficient published information is available to specify the requirements for all relevant parameters of the matched or characterized reference fields in order to achieve the targeted overall uncertainty (k = 2) of about 6 % to 10 % for the phantom related operational quantities. The X ray radiation fields described in the informative Annexes A to C are not designated as reference X-radiation fields.

NOTE The first edition of ISO 4037-1, issued in 1996, included some additional radiation qualities for which such published information is not available. These are fluorescent radiations, the gamma radiation of the radionuclide ^{241}Am, S-Am, and the high energy photon radiations R-Ti and R-Ni, which have been removed from the main part of this document. The most widely used radiations, the fluorescent radiations and the gamma radiation of the radionuclide ^{241}Am, S-Am, are included nearly unchanged in the informative Annexes A and B. The informative Annex C gives additional X radiation fields, which are specified by the quality index.

The methods for producing a group of reference radiations for a particular photon-energy range are described in Clauses 4 to 6, which define the characteristics of these radiations. The three groups of reference radiation are:

a) in the energy range from about 8 keV to 330 keV, continuous filtered X radiation;

b) in the energy range 600 keV to 1,3 MeV, gamma radiation emitted by radionuclides;

c) in the energy range 4 MeV to 9 MeV, photon radiation produced by accelerators.

The reference radiation field most suitable for the intended application can be selected from Table 1, which gives an overview of all reference radiation qualities specified in Clauses 4 to 6. It does not include the radiations specified in the Annexes A, B and C.

The requirements and methods given in Clauses 4 to 6 are targeted at an overall uncertainty (k = 2) of the dose(rate) value of about 6 % to 10 % for the phantom related operational quantities in the reference fields. To achieve this, two production methods are proposed:

The first one is to produce "*matched reference fields*", whose properties are sufficiently well-characterized so as to allow the use of the conversion coefficients recommended in ISO 4037-3. The existence of only a small difference in the spectral distribution of the "matched reference field" compared to the nominal reference field is validated by procedures, which are given and described in detail in ISO 4037-2. For matched reference radiation fields, recommended conversion coefficients are given in ISO 4037-3 only for specified distances between source and dosemeter, e.g., 1,0 m and 2,5 m.

For other distances, the user has to decide if these conversion coefficients can be used. If both values are very similar, e.g., differ only by 2 % or less, then a linear interpolation may be used.

The second method is to produce "characterized reference fields". Either this is done by determining the conversion coefficients using spectrometry, or the required value is measured directly using secondary standard dosimeters. This method applies to any radiation quality, for any measuring quantity and, if applicable, for any phantom and angle of radiation incidence. In addition, the requirements on the parameters specifying the reference radiations depend on the definition depth in the phantom, i.e., 0,07 mm, 3 mm and 10 mm, therefore, the requirements are different for the different depths. Thus, a given radiation field can be a "matched reference field" for the depth of 0,07 mm but not for the depth of 10 mm, for which it can then be a "characterized reference field". The conversion coefficients can be determined for any distance, provided the air kerma rate is not below 1 μGy/h.

Both methods need charged particle equilibrium for the reference field. However, this is not always established in the workplace field for which the dosemeter is 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.

To determine the dose(rate) value and the associated overall uncertainty of it, a calibration of all measuring instruments used for the determination of the quantity value is needed which is traceable to national standards.

This document does not specify pulsed reference radiation fields.

Table 1 — List of X and gamma reference radiation, their mean energies, $\bar{E}(\Phi)$, for 1 m distance and their short names

Radiation quality	$\bar{E}(\Phi)$ keV	Radiation quality	$\bar{E}(\Phi)$ keV	Radiation quality	$\bar{E}(\Phi)$ keV	Radiation quality	$\bar{E}(\Phi)$ keV
L-10	9,0	N-10	8,5	W-30	22,9	H-10	8,0
L-20	17,3	N-15	12,4	W-40	29,8	H-20	13,1
L-30	26,7	N-20	16,3	W-60	44,8	H-30	19,7
L-35	30,4	N-25	20,3	W-80	56,5	H-40	25,4
L-55	47,8	N-30	24,6	W-110	79,1	H-60	38,0
L-70	60,6	N-40	33,3	W-150	104	H-80	48,8
L-100	86,8	N-60	47,9	W-200	138	H-100	57,3
L-125	109	N-80	65,2	W-250	172	H-150	78,0
L-170	149	N-100	83,3	W-300	205	H-200	99,3
L-210	185	N-120	100			H-250	122
L-240	211	N-150	118			H-280	145
		N-200	165			H-300	143
		N-250	207			H-350	167
		N-300	248			H-400	190
		N-350	288				
		N-400	328				

Table 1 *(continued)*

Radionuclides			High energy photon radiations		
Radiation quality	**Radionuclide**	$\bar{E}(\Phi)$ keV	**Radiation quality**	**Reaction**	$\bar{E}(\Phi)$; $\bar{E}[H^*(10)]_a$ MeV
S-Cs	^{137}Cs	662	R-C	^{12}C (p,p'γ) ^{12}C	4,2; 4,4
S-Co	^{60}Co	1250	R-F	^{19}F (p,αγ) ^{16}O	4,4; 6,5

NOTE In the informative Annexes A to C, further radiation qualities are given. These cover the mean photon energies from 8 keV up to 270 keV.

a Mean photon energy weighted by distribution of ambient dose equivalent, $H^*(10)$, with respect to photon energy E.

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 2919, *Radiological protection — Sealed radioactive sources — General requirements and classification*

ISO 4037-2:2018, *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 2: Dosimetry for radiological protection over the energy ranges 8 keV to 1,3 MeV and 4 MeV to 9 MeV*

ISO 4037-3, *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 29661, *Reference radiation fields for radiation protection — Definitions and fundamental concepts*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 29661 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
air kerma-to-dose-equivalent conversion coefficient
h_K
quotient of the dose equivalent, H, and the air kerma free-in-air, K_a, at a point in the photon radiation field

$$h_K = \frac{H}{K_a}$$

Note 1 to entry: The unit of the air kerma-to-dose-equivalent conversion coefficient is sievert per gray ($Sv \cdot Gy^{-1}$).

Note 2 to entry: This definition differs from the one given by ISO 29661:2012, 3.2.4, as it uses the air kerma instead of the air collision kerma. See also 4.1.2.

