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**Radiological protection — X and gamma reference radiation for calibrating dosimeters 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**

*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 2: Dosimétrie pour la radioprotection dans les gammes d'énergie de 8 keV à 1,3 MeV et de 4 MeV à 9 MeV*



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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.

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](http://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](http://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](http://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 4037-2:1997), which has been technically revised.

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](http://www.iso.org/members.html).

This corrected version of ISO 4037-2:2019 incorporates the following corrections:

- In 10.5.2.2, the subscripts to the values have been reapplied;
- In Table 5, the headers in columns 4 and 5 have been reinserted.

## 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<sup>[1]</sup>). 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)<sup>[2]</sup>. 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. This document 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)<sup>[2]</sup>. ISO 4037-3 describes the methods for calibrating and determining the response of dosimeters and doserate meters in terms of the phantom related operational quantities of the ICRU<sup>[2]</sup>. ISO 4037-4 gives special considerations and additional requirements for calibration of area and personal dosimeters in low energy X reference radiation fields, which are reference fields with generating potential lower or equal to 30 kV.

In this document, two methods are given to determine the phantom related operational quantities. Both methods need a reference field according to ISO 4037-1. The first method requires the dosimetry with respect to air kerma free-in-air and after that the selected operational quantity is derived by the application of a conversion coefficient that relates the air kerma free-in-air to the selected operational quantity. For matched reference fields, this conversion coefficient is taken from ISO 4037-3, for characterized reference fields the conversion coefficient is determined using spectrometry. The second method, applicable for characterized reference fields, requires the direct dosimetry with respect to the selected operational quantity. For all calibrations secondary standard instruments are required, which have a nearly constant energy dependence of the response to the selected quantity.

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

# Radiological protection — X and gamma reference radiation for calibrating dosimeters 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

### 1 Scope

This document specifies the procedures for the dosimetry of X and gamma reference radiation for the calibration of radiation protection instruments over the energy range from approximately 8 keV to 1,3 MeV and from 4 MeV to 9 MeV and for air kerma rates above 1  $\mu\text{Gy/h}$ . The considered measuring quantities are the air kerma free-in-air,  $K_a$ , and the phantom related operational quantities of the International Commission on Radiation Units and Measurements (ICRU)[2],  $H^*(10)$ ,  $H_p(10)$ ,  $H'(3)$ ,  $H_p(3)$ ,  $H'(0,07)$  and  $H_p(0,07)$ , together with the respective dose rates. The methods of production are given in ISO 4037-1.

This document can also be used for the radiation qualities specified in ISO 4037-1:2019, Annexes A, B and C, but this does not mean that a calibration certificate for radiation qualities described in these annexes is in conformity with the requirements of ISO 4037.

The requirements and methods given in this document are targeted at an overall uncertainty ( $k = 2$ ) of the dose(rate) of about 6 % to 10 % for the phantom related operational quantities in the reference fields. To achieve this, two production methods of the reference fields are proposed in ISO 4037-1.

The first is to produce “*matched reference fields*”, which follow the requirements so closely that recommended conversion coefficients can be used. 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 this document. For matched reference radiation fields, recommended conversion coefficients are given in ISO 4037-3 only for specified distances between source and dosimeter, e.g., 1,0 m and 2,5 m. For other distances, the user has to decide if these conversion coefficients can 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. The conversion coefficients can be determined for any distance, provided the air kerma rate is not below 1  $\mu\text{Gy/h}$ .

Both methods require charged particle equilibrium for the reference field. However this is not always established in the workplace field for which the dosimeter shall 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 is not applicable for the dosimetry of pulsed reference fields.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 radiation for calibrating dosimeters and dose-rate meters and for determining their response as a function of photon energy — Part 1: Radiation characteristics and production methods*

ISO 4037-3, *Radiological protection — X and gamma reference radiation for calibrating dosimeters and dose-rate meters and for determining their response as a function of photon energy — Part 3: Calibration of area and personal dosimeters and the measurement of their response as a function of energy and angle of incidence*

ISO 4037-4, *Radiological protection — X and gamma reference radiation for calibrating dosimeters and dose-rate meters and for determining their response as a function of photon energy — Part 4: Calibration of area and personal dosimeters 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*

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 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**  
**ionization chamber**  
ionization detector consisting of a chamber filled with a suitable gas, in which an electric field, insufficient to induce gas multiplication, is provided for the collection at the electrodes of charges associated with the ions and the electrons produced in the sensitive volume of the detector by the ionizing radiation<sup>[3]</sup>

Note 1 to entry: The ionization chamber includes the sensitive volume, the collecting and polarizing electrodes, the guard electrode, if any, the chamber wall, the parts of the insulator adjacent to the sensitive volume and any necessary caps to ensure electron equilibrium.

**3.2**  
**ionization chamber assembly**  
*ionization chamber* (3.1) and all other parts to which the chamber is permanently attached, except the measuring assembly

Note 1 to entry: For a cable-connected chamber, it includes the stem, the electrical fitting and any permanently attached cable or pre-amplifier. For a thin-window chamber, it includes any block of material in which the ionization chamber is permanently embedded.