

Protección radiológica. Aceleradores de electrones médicos.  
Requisitos y recomendaciones para el diseño y evaluación de  
blindajes (ISO 16645:2016) (Ratificada por la Asociación  
Española de Normalización en julio de 2019.)

UNE-EN ISO 16645:2019

Protección radiológica. Aceleradores de electrones médicos. Requisitos y recomendaciones para el diseño y evaluación de blindajes (ISO 16645:2016) (Ratificada por la Asociación Española de Normalización en julio de 2019.)

*Radiological protection - Medical electron accelerators - Requirements and recommendations for shielding design and evaluation (ISO 16645:2016) (Endorsed by Asociación Española de Normalización in July of 2019.)*

*Radioprotection - Accélérateurs médicaux d'électrons - Exigences et recommandations pour la conception et l'évaluation du blindage (ISO 16645:2016) (Entérinée par l'Asociación Española de Normalización en juillet 2019.)*

En cumplimiento del punto 11.2.5.4 de las Reglas Internas de CEN/CENELEC Parte 2, se ha otorgado el rango de documento normativo español UNE al documento normativo europeo EN ISO 16645:2019 (Fecha de disponibilidad 2019-06-12)

Este documento está disponible en los idiomas oficiales de CEN/CENELEC/ETSI.

Este anuncio causará efecto a partir del primer día del mes siguiente al de su publicación en la revista UNE.

La correspondiente versión oficial de este documento se encuentra disponible en la Asociación Española de Normalización (Génova 6 28004 MADRID, [www.une.org](http://www.une.org)).

Las observaciones a este documento han de dirigirse a:

## Asociación Española de Normalización

Génova, 6  
28004 MADRID-España  
Tel.: 915 294 900  
[info@une.org](mailto:info@une.org)  
[www.une.org](http://www.une.org)

© UNE 2019

Prohibida la reproducción sin el consentimiento de UNE.

Todos los derechos de propiedad intelectual de la presente norma son titularidad de UNE.

EUROPEAN STANDARD

**EN ISO 16645**

NORME EUROPÉENNE

EUROPÄISCHE NORM

June 2019

ICS 13.280

English Version

## Radiological protection - Medical electron accelerators - Requirements and recommendations for shielding design and evaluation (ISO 16645:2016)

Radioprotection - Accélérateurs médicaux d'électrons -  
Exigences et recommandations pour la conception et  
l'évaluation du blindage (ISO 16645:2016)

Strahlenschutz - Medizinische  
Elektronenbeschleuniger-Anlagen - Anforderungen  
und Empfehlungen an die Ausführung der  
Abschirmung und deren Bewertung (ISO 16645:2016)

This European Standard was approved by CEN on 8 March 2019.

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, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, 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**

<b>Contents</b>	<b>Page</b>
<b>European foreword.....</b>	<b>3</b>

## European foreword

The text of ISO 16645:2016 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 16645:2019 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 December 2019, and conflicting national standards shall be withdrawn at the latest by December 2019.

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, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

## Endorsement notice

The text of ISO 16645:2016 has been approved by CEN as EN ISO 16645:2019 without any modification.

# Contents

	Page
<b>Foreword</b> .....	<b>v</b>
<b>Introduction</b> .....	<b>vi</b>
<b>1 Scope</b> .....	<b>1</b>
<b>2 Normative references</b> .....	<b>1</b>
<b>3 Terms and definitions</b> .....	<b>1</b>
3.1 Quantities.....	1
3.2 Definitions.....	4
<b>4 Shielding design goals and other design criteria</b> .....	<b>6</b>
4.1 Shielding design goals.....	6
4.2 Shielding design assumptions.....	7
<b>5 Role of the manufacturers, of the radiation protection officer or qualified expert and interactions between stakeholders</b> .....	<b>8</b>
5.1 General.....	8
5.2 Linear accelerator manufacturer.....	8
5.3 Shielding material vendor.....	9
5.4 Architectural firm/general contractor.....	10
5.5 Radiation protection officer or qualified expert.....	10
5.6 The licensee.....	11
<b>6 Radiation fields around a linear electron accelerator</b> .....	<b>11</b>
6.1 General.....	11
6.2 X-ray radiation.....	11
6.2.1 Primary X-ray beam.....	11
6.2.2 Primary electron beam bremsstrahlung.....	12
6.2.3 Secondary X-ray radiation.....	12
6.2.4 Tertiary X-ray radiation.....	13
6.3 Neutron radiation.....	13
6.3.1 General.....	13
6.3.2 Direct neutron radiation.....	14
6.3.3 Scattered and thermal neutron radiation.....	14
6.3.4 Primary barrier neutron radiation.....	15
6.4 $\gamma$ radiation.....	15
6.4.1 General.....	15
6.4.2 Maze $\gamma$ radiation.....	15
6.4.3 Door $\gamma$ radiation.....	15
6.4.4 Primary barrier $\gamma$ radiation.....	15
6.4.5 Air $\gamma$ radiation.....	16
<b>7 Shielding materials and transmission values</b> .....	<b>16</b>
<b>8 General formalism for shielding calculation</b> .....	<b>18</b>
<b>9 Shielding calculation for conventional devices</b> .....	<b>20</b>
9.1 General.....	20
9.2 Primary barriers.....	20
9.2.1 Radiation components.....	20
9.2.2 Barrier with a unique material.....	21
9.2.3 Barrier with multiple layers.....	21
9.3 Secondary barriers.....	22
9.3.1 Radiation components.....	22
9.3.2 Barrier with a unique material.....	23
9.3.3 Barriers with multiple layers.....	24
<b>10 Doors and mazes</b> .....	<b>24</b>
10.1 General.....	24

10.2	Radiation components .....	25
10.3	Standard maze.....	25
10.3.1	Maze X-ray scatter calculations.....	25
10.3.2	X-ray direct Leakage.....	30
10.3.3	Maze neutron and capture gamma calculations.....	31
10.4	Two legged maze.....	33
10.5	No maze - Direct-shielded doors.....	34
10.5.1	General.....	34
10.5.2	Shielding at the far side of a direct-shielded door entrance.....	35
10.5.3	Shielding at the near side of a direct-shielded door entrance.....	37
10.6	No door at maze entrance.....	39
10.7	Door Calculations.....	40
10.7.1	General.....	40
10.7.2	Maze door calculations.....	40
10.7.3	Direct Shielded Door Calculations.....	41
<b>11</b>	<b>Shielding calculations for special devices.....</b>	<b>41</b>
11.1	General.....	41
11.2	Robotic arm accelerator.....	41
11.3	Helical intensity modulated radiotherapy.....	42
11.4	Dedicated device for intra operative radiotherapy with electrons.....	42
<b>12</b>	<b>Ducts.....</b>	<b>43</b>
12.1	Duct impact on radiation protection.....	43
12.2	Recommended location and geometry.....	43
12.3	Additional shielding.....	44
12.3.1	General.....	44
12.3.2	Neutron and capture gamma radiation passing through the interior of the shielded duct.....	44
12.3.3	X scattered radiation passing through the interior of the shielded duct.....	45
12.3.4	Scattered radiation passing through the walls of the duct shielding.....	46
12.3.5	Dose equivalent at HVAC duct exterior opening.....	46
<b>13</b>	<b>Special considerations.....</b>	<b>46</b>
13.1	Skyshine.....	46
13.1.1	General.....	46
13.1.2	X-ray skyshine radiation.....	46
13.1.3	Neutron skyshine radiation.....	48
13.2	Groundshine radiations.....	49
13.3	Joints and junctions.....	49
<b>14</b>	<b>Shielding evaluation (experimental verification).....</b>	<b>49</b>
14.1	General.....	49
14.2	Measuring equipment and methodology.....	50
14.3	Evaluation.....	50
<b>15</b>	<b>Indication, warning signs, interlocks.....</b>	<b>52</b>
<b>Annex A (informative) Tenth value layers for the most common shielding materials.....</b>		<b>53</b>
<b>Annex B (informative) Supporting data for shielding calculations.....</b>		<b>66</b>
<b>Annex C (informative) Example of calculation for conventional device and standard maze.....</b>		<b>68</b>
<b>Bibliography.....</b>		<b>75</b>

## 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. [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. [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 meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: [Foreword - Supplementary information](#)

The committee responsible for this document is ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection*.

This corrected version of ISO 16645:2016 incorporates the correction of [Tables A.9](#) and [C.6](#).