BS EN ISO 28057:2021

BSI Standards Publication

Clinical dosimetry — Dosimetry with solid thermoluminescence detectors for photon and electron radiations in radiotherapy

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National foreword

This British Standard is the UK implementation of EN ISO 28057:2021. It is identical to ISO 28057:2019. It supersedes BS EN ISO 28057:2018, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee NCE/2, Radiation protection and measurement.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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Clinical dosimetry - Dosimetry with solid thermoluminescence detectors for photon and electron radiations in radiotherapy (ISO 28057:2019)

Dosimétrie clinique - Dosimétrie avec détecteurs thermoluminescents solides pour les rayonnements de photons et d'électrons en radiothérapie (ISO 28057:2019)

Dosimetrie mit Festkörper - Thermolumineszenzdetektoren für Photonen- und Elektronenstrahlung in der Strahlentherapie (ISO 28057:2019)

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

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European foreword

The text of ISO 28057:2019 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 28057:2021 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of an identical text or by endorsement, at the latest by August 2021, and conflicting national standards shall be withdrawn at the latest by August 2021.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.

This document supersedes EN ISO 28057:2018.

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 28057:2019 has been approved by CEN as EN ISO 28057:2021 without any modification.

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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).

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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 28057:2014), which has been technically revised.

— The clause on terms and definitions and the clause on rules for TLD measurement procedures, including quality assurance measurements at clinical accelerators, have been complemented and sharpened to ensure the safe application of TL dosimetry in the radiation therapy of cancer.

— Batch dependent changes of the k_Q values have been correlated with the simultaneously occurring mass density variations of TL discs (see 4.4.5.5).

— The response of TL materials to the neutrons, occurring within and around photon beams in megavoltage radiotherapy due to the photonuclear effect and eventually generating considerable components of the indicated values, has been dealt with in more detail (see 4.4.5.5).

— It is high-lighted that the k_E values of clinical electron beams are energy independent (see 4.4.5.5).

— Recent experimental results concerning the contribution of “intrinsic effects” to the response of TL detectors have been considered (see 4.4.5.5).

— The French title and the numbering of some subclauses of 5.4 have been corrected; Table 9 has been equipped with a heading.

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Introduction

The thermoluminescence dosimetry (TLD) with lithium fluoride (LiF) detectors has several advantages, in particular:

— small volumes of the detectors;

— applicability to continuous and pulsed radiation;

— fair water equivalency of the detector material;

— few correction factors needed for absorbed dose determinations.

The main disadvantage of thermoluminescence (TL) detectors is that, prior to each dosimetry application, they have to be regenerated by a pre-irradiation annealing procedure. Unfortunately, it is not possible to restore the former response of the detectors perfectly by this annealing. Provided, however, that all detectors of a production batch always undergo the same thermal treatment, one can at least determine the mean alteration of the response of these detectors, with sufficiently small fluctuations of the individually indicated values. From this mean alteration, a correction factor can be derived.

The essential aim of this document is to specify the procedures and to carry out corrections which allow one to achieve

a) a repeatability of the indicated value within a fraction of a percent[17] and thus;

b) a total uncertainty of measurement (including the calibration steps tracing to the primary standards) of a few percent, as in ionization chamber dosimetry[18][31][25][61][62].

The specifications in this document comprise special terms used in TLD, rules for the measurement technique, and requirements for the measurement system. The defined requirements and the testing techniques can, in whole or in part, serve as a basis for stability checks and acceptance tests. The TLD procedures described in this document can be used for photon radiation within the energy range from 20 keV to 50 MeV, including photon brachytherapy, and for electron radiation within the energy range from 4 MeV to 25 MeV, excluding beta radiation brachytherapy. In order to achieve the repeatability and total uncertainty stated above, this document is applicable in the dose range above 1 mGy. The upper limit of the minimum measuring range is in the order of magnitude of 10 Gy to 100 Gy. In clinical dosimetry, TL detectors are applied taking into account the requirements of high spatial resolution, i.e. in the study of the dose distributions with high gradients occurring in small stereotactic radiation fields and around brachytherapy sources. The other common application is the measurement of dose distributions in large absorbers, e.g. geometrical or tissue equivalent phantoms, either within the radiation field or in its periphery. A further usage is the quality assurance of clinical dosimetry by postal dose intercomparison[1][2][10][12][20][22][26][27][55].

The role of this document is not to anticipate national or international codes of practice in clinical dosimetry, neither for external beam therapy, brachytherapy, whole-body irradiation, mammography, nor dose measurements outside the treatment field or radiation protection of the staff. The authors of this document are well aware of the wide spectrum of the methods of clinical dosimetry, in which TL dosimetry is merely occupying a small sector. But within this framework, this document provides reliable concepts and rules for good practice for the application of TLD methods. The items covered include the terms and definitions, the rules for TLD measurement procedures, and the requirements on the TLD system; this document addresses medical physicists as well as instrument producers. Notably, the numerical examples given are valid for the TL detector materials and products stated in the publications referred to, and tests may be necessary to check whether they apply to TLD materials of other producers. The practical examples given, e.g. for the TL probe calibration conditions and for the numerical values of correction factor, k_Q, accounting for the dependence of the detector response on radiation quality, Q, are not conceived to be pre-emptive in relation to more general standards of the methods of clinical dosimetry or dose intercomparisons. Rather, this document provides access to the reliable application of TLD methods based upon the published results of worldwide development.

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The long-standing experience in the clinical usage of TLD, expressed in a set of valuable textbooks, protocols, and recommendations[6][13][25][28][29][42][43][61][62][54], has been accounted for.

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Clinical dosimetry — Dosimetry with solid thermoluminescence detectors for photon and electron radiations in radiotherapy

1 Scope

This document describes rules for the procedures, applications, and systems of thermoluminescence dosimetry (TLD) for dose measurements according to the probe method. It is particularly applicable to solid "TL detectors", i.e. rods, chips, and microcubes, made from LiF:Mg,Ti or LiF:Mg,Cu,P in crystalline or polycrystalline form. It is not applicable to LiF powders because their use requires special procedures. The probe method encompasses the arrangement, particularly in a water phantom or in a tissue-equivalent phantom, of single TL detectors or of "TL probes", i.e. sets of TL detectors arranged in thin-walled polymethyl methacrylate (PMMA) casings.

The purpose of these rules is to guarantee the reliability and the accuracy indispensable in clinical dosimetry when applied on or in the patient or phantom. This document applies to dosimetry in teletherapy with both photon radiation from 20 keV to 50 MeV and electron radiation from 4 MeV to 25 MeV, as well as in brachytherapy with photon-emitting radionuclides. These applications are complementary to the use of ionization chambers.

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.

IEC 60601-1, *Electromedical equipment — Part 1: General instructions pertaining to safety*

IEC 61000-4-2, *Electromagnetic compatibility (EMV) — Part 4-2: Test and measurement procedure — Test of immunity against static electric discharges*

IEC 61000-4-3, *Electromagnetic compatibility (EMC) — Part 4-3: Testing and measurement techniques — Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4, *Electromagnetic compatibility (EMC) — Part 4-4: Testing and measurement techniques — Electrical fast transient/burst immunity test*

IEC 61000-4-5, *Electromagnetic compatibility (EMC) — Part 4-5: Testing and measurement techniques — Surge immunity test*

IEC 61000-4-6, *Electromagnetic compatibility (EMC) — Part 4-6: Testing and measurement techniques — Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-8, *Electromagnetic compatibility (EMC) — Part 4-8: Testing and measurement techniques — Power frequency magnetic field immunity test*

IEC 61000-4-11, *Electromagnetic compatibility (EMC) — Part 4-11: Testing and measurement techniques — Voltage dips, short interruptions and voltage variations immunity tests*

IEC 61187, *Electrical and electronic measuring equipment — Documentation*

3 Terms and definitions

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

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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
absorbed dose
energy imparted to matter in a suitably small element of volume by ionizing radiation, divided by the mass of that element of volume

Note 1 to entry: All statements of absorbed dose need to be completed by a specification of the material for which the absorbed dose is stated, e.g. absorbed dose to air, D_a, or absorbed dose to water, D_w. In this document, the term absorbed dose, sometimes abbreviated as dose, means the absorbed dose to water, D_w, if not otherwise specified.

3.2
background value
M_0
<clinical TL dosimetry> *indicated value* (3.16) of a *TLD system* (3.46) during evaluation of a non-irradiated *TL detector* (3.45) according to the operating instructions

Note 1 to entry: A change in the background value can be caused by a change in the *TL-indicating instrument* (3.47), by an insufficient *pre-irradiation annealing* (3.28), or by contamination of the *detector* (3.45).

Note 2 to entry: The background value may also be determined from the average of the individual values measured with a group of detectors.

3.3
batch
<clinical TL dosimetry> number of *TL detectors* (3.45) of the same type originating from the same manufacturing process and corresponding in their entirety both to the requirements defined in this document and to the quality properties guaranteed by the manufacturer with regard to their *response* (3.39), their *individual variation* (3.17), and their *nonlinearity* (3.24)

3.4
calibration
<clinical TL dosimetry> determination of the correlation between the *indicated value* (3.16) of a *TL detector* (3.45) and the conventional true value of the *measured quantity* (3.20), *absorbed dose* (3.1) to water, under *reference conditions* (3.32)

Note 1 to entry: Calibration serves to determine or check the *calibration coefficient* (3.5).

Note 2 to entry: The conventional true value of the *measured quantity* (3.20) by the *measured value* (3.21) determined directly or indirectly with a primary standard.

3.5
calibration coefficient
N_i
<clinical TL dosimetry> relation valid under *reference conditions* (3.32)

$$N_i = \frac{D}{M_i - M_0}$$

in this formula, D is the conventional true value of the *measured quantity* (3.20), $M_i - M_0$ is the difference resulting from the *indicated value* (3.16) of a single *TL detector* (3.45) i and the *background value* (3.2)

Note 1 to entry: Thus, the calibration coefficient is the reciprocal value of the *response* (3.39) under *reference conditions* (3.32).

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3.6
casing
capsule, usually made from PMMA of 1 mm front wall thickness and shaped as a flat circular cylinder, in which a small set of *TL detectors* (3.45) can be placed in the same plane

Note 1 to entry: The setup consisting of the *detectors* (3.45) and the casing is the *TL probe* (3.48).

Note 2 to entry: Other forms of the casing may be chosen to fit the respective application, e.g. for intracavitary measurements or measurements on the patient surface. Low-density materials such as PMMA are recommended for the construction of the casing.

3.7
conditioning of a batch
conditioning
multiple irradiation and *pre-irradiation annealing* (3.28) of a *batch* (3.3) of *TL detectors* (3.45)

Note 1 to entry: Whether conditioning is sufficient is examined by the *reusability* (3.40); test of reusability according to 5.3.3.

3.8
correction factor
<clinical TL dosimetry> factor applied to the *indicated value* (3.16) in order to compensate for the measurement deviation caused by an *influence quantity* (3.18) or by the *measured quantity* (3.20)

Note 1 to entry: Examples for using a correction factor are the corrections for *fading* (3.13), *energy dependence* (3.12), and *nonlinearity* (3.24) (see 4.4.5).

3.9
correction summand
summand added to the *indicated value* (3.16) in order to compensate for the measurement deviation caused by an *influence quantity* (3.18)

Note 1 to entry: The *background value* (3.2) is an example for corrections using a correction summand (see 4.4.2).

3.10
directional dependence of response
directional dependence
<clinical TL dosimetry> dependence of the *response* (3.39) of a *TL detector* (3.45) on the direction of radiation incidence

3.11
direction of preference
direction referring to the *TL detector* (3.45) or *TL probe* (3.48) that is considered as a reference value for the direction of radiation incidence as an *influence quantity* (3.18)

3.12
energy dependence of response
energy dependence
dependence of the *response* (3.39) of a *TL detector* (3.45) on *radiation quality* (3.30)

3.13
fading
F
quotient of the alteration of the *measured value* (3.21) of the *absorbed dose* (3.1) during the time interval between the end of the irradiation and the evaluation, e.g. caused by the influence of the ambient temperature, and the value of the *absorbed dose* (3.1) measured immediately after irradiation

Note 1 to entry: Fading is expressed as a percentage.

Note 2 to entry: The alteration of the measured value of the *absorbed dose* (3.1) may be positive (increment) or negative (decrement).

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3.14
fading rate

$\dot{F}$

fading (3.13) in a time interval, divided by this time interval

Note 1 to entry: The fading rate is expressed as a percentage per day.

3.15
glow curve
<clinical TL dosimetry> *measured value* (3.21) of the light emission of the *TL detector* (3.45) as a function of the temperature or time during the evaluation process

3.16
indicated value
M
<clinical TL dosimetry> numerical value of a parameter displayed by a *TL-indicating instrument* (3.47)

Note 1 to entry: The indicated value, *M*, for a *TL detector* (3.45) is assessed from the *glow curve* (3.15) by the *TL-indicating instrument* (3.47) (see 4.3.8.3). The *measured value* (3.21) of the dose is determined from the indicated value by applying the *calibration coefficient* (3.5), the *correction factors* (3.8), and the *correction summands* (3.9) (see 4.4).

Note 2 to entry: The indicated value is also termed the reading of the *TL-indicating instrument* (3.47).

3.17
individual variation of the response
individual variation
deviation of the *response* (3.39) of single *TL detectors* (3.45) from the mean *response* (3.39) of a *batch* (3.3) of *TL detectors* (3.45) under identical irradiation and evaluation conditions

3.18
influence quantity
<clinical TL dosimetry> a quantity which is not a *measured quantity* (3.20) but nevertheless influences the result of a measurement

Note 1 to entry: Influence quantities can develop influences as external disturbances (temperature, humidity, line voltage, etc.), as properties inherent to the instrument, i.e. caused by the instrument itself (zero drift, aging of the system components, post-irradiation stabilization, etc.), or as adjustable quantities affecting the result of the measurement [e.g. *radiation quality* (3.30) or direction of radiation incidence during dose measurement].

Note 2 to entry: The correction of the impact of an influence quantity may require the application to the *indicated value* (3.16) of a *correction factor* (3.8) [multiplicative influence quantity, e.g. *fading* (3.13)] or of a *correction summand* (3.9) [additive influence quantity, e.g. *background value* (3.2)].

Note 3 to entry: If an influence quantity is not taken into account by applying a *correction factor* (3.8) or a *correction summand* (3.9), the *correction factor* (3.8) is set equal to one or the *correction summand* (3.9) is set equal to zero, respectively.

3.19
linear energy transfer
LET
average energy locally imparted to a medium by a charged particle of a specified energy along a suitably small element of its path, divided by the length of that element

Note 1 to entry: The value of LET (in keV/μm) is usually stated for water as the medium traversed by the charged particle.

Note 2 to entry: In ICRU 85a, this quantity is called the „unrestricted linear energy transfer" and denoted as L_∞ or simply L.

[SOURCE: ICRU 85a[81]]

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3.20
measured quantity
<clinical TL dosimetry> physical quantity to be determined by the measuring system

Note 1 to entry: According to ICRU 62[82], the measured quantity in clinical dosimetry is the *absorbed dose* (3.1) to water at the *point of measurement* (3.26).

Note 2 to entry: The measured quantity is a variable which can adopt various values. These are denoted as *measured values* (3.21).

3.21
measured value of a TLD system
measured value
<clinical TL dosimetry> value of the *measured quantity* (3.20), *absorbed dose* (3.1) to water, determined with a *TLD system* (3.46) at the *point of measurement* (3.26)

Note 1 to entry: According to Formula (1), the measured value is determined from the individual *indicated values* (3.16), the *background value* (3.2) the individual *calibration coefficients* (3.5) and the *correction factors* (3.8).

3.22
measurement cycle
sequence of working steps in TL dosimetry consisting of *pre-irradiation annealing* (3.28), irradiation, *post-irradiation annealing* (3.27), and evaluation of *TL detectors* (3.45)

3.23
measuring range
<clinical TL dosimetry> range of measured values (3.21) in which the *TLD system* (3.46) meets the requirements for the operation characteristics

Note 1 to entry: The measuring range of a *TLD system* (3.46) is always part of and within the interval spanned by the smallest and the highest *measured value* (3.21).

3.24
nonlinearity of response
nonlinearity
<clinical TL dosimetry> change in dose dependence of the *response* (3.39)

Note 1 to entry: Linearity means constant *response* (3.39), supralinearity denotes an increase in *response* (3.39), and sublinearity denotes a decrease in *response* (3.39) with increasing dose.

3.25
parameters for tests
values of *influence quantities* (3.18) agreed upon for testing the impact of other *influence quantities* (3.18)

3.26
point of measurement
<clinical TL dosimetry> the point on or in the patient's body or water phantom at which the *absorbed dose* (3.1) to water is measured

Note 1 to entry: See also References [13], [39], [40] and ICRU 35[69].

Note 2 to entry: The point of measurement defined in the coordinate system of a phantom or patient is distinguished from the *reference point of a TL probe* (3.34) defined in the coordinate system of the TL probe. The *reference point of the probe* is usually positioned at the point of measurement in or on the phantom or patient.

3.27
post-irradiation annealing
<clinical TL dosimetry> controlled heat treatment (annealing) of a *TL detector* (3.45) after irradiation and before evaluation

Note 1 to entry: Post-irradiation annealing serves to reduce the *fading* (3.13).

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3.28
pre-irradiation annealing
<clinical TL dosimetry> controlled heat treatment of already evaluated *TL detectors* (3.45) before reuse

Note 1 to entry: Pre-irradiation annealing serves to delete the radiation-induced TL signal remaining after evaluation and approximately restores the original response.

3.29
radiation damage
<clinical TL dosimetry> permanent alteration of the *response* (3.39) of a *TL detector* (3.45) due to pre-irradiation beyond a detector-specific dose

Note 1 to entry: The value of this dose may depend on the temporal pattern of pre-irradiations (dose fractionation, dose protraction) and on the radiation type and quality of the pre-irradiations.

3.30
radiation quality
Q
parameter for the classification of the relative spectral particle fluence of a radiation type at a specified location

Note 1 to entry: In clinical dosimetry, simply measurable parameters such as the quality index of a photon radiation or the 50 % range of an electron radiation are used for the characterization of radiation quality (see ICRU 35[69], ICRU 62[82], ICRU 83[80] and Reference [25]).

3.31
rated range of use
variation range of an *influence quantity* (3.18) causing a change in *response* (3.39) that does not lead to a transgression of agreed upon values of the measurement deviation or to a transgression of defined values of the correction of its influence

3.32
reference conditions
<clinical TL dosimetry> set of reference values of all *influence quantities* (3.18) and of the *measured quantity* (3.20)

Note 1 to entry: If one or more *influence quantities* (3.18) or the *measured quantity* (3.20) deviate from their *reference values* (3.35, 3.36) (Table 2), the conditions of measurement are denoted as non-reference conditions, see 4.4.5.5, note 1. The correction for use of *detectors* (3.45) under non-reference conditions is dealt with in the context of Table 4.

3.33
reference detector
<clinical TL dosimetry> *TL detector* (3.45) used to determine the *correction factor* (3.8) for the change in *response* (3.39) during successive *measurement cycles* (3.22)

Note 1 to entry: See 4.4.5.3.

Note 2 to entry: The average change of the response during successive measurement cycles can be determined by accompanying measurements performed with a group of reference detectors, see 4.4.5.3.

3.34
reference point of a TL probe
point defined within or on the surface of the *TL probe* (3.48) whose spatial coordinates serve to specify the position of the *TL probe* (3.48) in its surroundings

Note 1 to entry: The position of the reference point within or on the *TL probe* (3.48) is defined by the manufacturer. In clinical dose measurements, the reference point of a *TL probe* (3.48) is placed at the *point of measurement* (3.26) either on or in the phantom or the patient's body. For *calibration* (3.4), the reference point of a *TL probe* (3.48) is placed at the point at which the *absorbed dose* (3.1) to water under *reference conditions* (3.32) is known.

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