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TECHNICAL SPECIFICATION

Radiation protection instrumentation - Determination of uncertainty in measurement

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Radiation protection instrumentation - Determination of uncertainty in measurement

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IEC TS 62461, which previously was a Technical Report, has been prepared by subcommittee 45B: Radiation protection instrumentation, of IEC technical committee 45: Nuclear instrumentation. It is a Technical Specification.

This first edition of IEC TS 62461 cancels and replaces the second edition of IEC TR 62461 published in 2015. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) several minor corrections;
b) the addition of an example of the determination of the decision threshold and detection limit in accordance with ISO 11929.

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The text of this Technical Specification is based on the following documents:

Draft	Report on voting
45B/1115/DTS	45B/1126/RVDTS

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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INTRODUCTION

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)* as well as its Supplement 1:2008, *Propagation of distributions using a Monte Carlo method* (GUM S1), are general guides to assess uncertainty in measurement. Furthermore, ISO 11929 is a general guide to assess the decision threshold and detection limit, as well as coverage interval for measurements of ionizing radiation. This Technical Specification lays emphasis on the application of these documents in the area of radiation protection and serves as a practical introduction to ISO/IEC Guide 98-3:2008 and its Supplement 1:2008 as well as ISO 11929.

The process of determining uncertainty delivers not only a numerical value of uncertainty; in addition, it produces the best estimate of the quantity to be measured, which can differ from the indication of the instrument. Thus, it can also improve the result of the measurement by using information beyond the indicated value of the instrument, e.g., the energy dependence of the instrument. Furthermore, measurement uncertainties and characteristic values, such as the decision threshold, the detection limit and limits of the coverage interval for measurements, as well as the best estimate and its associated standard measurement uncertainty, are of importance in metrology in general and for radiation detection and radiological protection in particular. The quantification of the uncertainty associated with a measurement result provides a basis for the trust an individual can have in a measurement result. Conformity with regulatory limits, constraints or reference values can only be demonstrated by taking into account and quantifying all sources of uncertainty. Characteristic limits provide the basis for deciding if a measurement method is suitable and reliable for the proposed measuring task.

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1 Scope

This Technical Specification gives guidelines for the application of the uncertainty analysis according to ISO/IEC Guide 98-3:2008 (GUM describing an analytical method for the uncertainty determination) and its Supplement 1:2008 (GUM S1 describing a Monte Carlo method for the uncertainty determination) for measurements of ionizing radiation. It does not include the uncertainty associated with the concept of the measuring quantity, e.g., the difference between $H_p(10)$ on the ISO water slab phantom and on the person.

This document explains the principles of ISO/IEC Guide 98-3:2008, its Supplement 1:2008 and the special considerations necessary for radiation protection at an example taken from individual dosimetry of external radiation. In the informative annexes, several examples are given for the application on instruments measuring ionizing radiation, for several of which the IEC has developed standards.

This document is intended to assist the understanding of ISO/IEC Guide 98-3:2008, ISO/IEC Guide 98-3-SP1:2008 and other papers on uncertainty analysis. It cannot replace these papers, nor can it provide the background and justification of the arguments leading to the concept of ISO/IEC Guide 98-3:2008 and ISO/IEC Guide 98-3-SP1:2008.

Finally, this document gives a very simple method to judge whether a measured result is significantly different from zero or not based on ISO 11929.

NOTE For a better readability the correct terms are not always used throughout this document. For example, instead of "random variables of a quantity" only the "quantity" itself is stated.

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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 60050-311:—[1], *International Electrotechnical Vocabulary (IEV) - Part 311: Electrical and electronic measurements - General terms relating to measurements*

IEC 60050-151, *International Electrotechnical Vocabulary (IEV) - Part 151: Electrical and magnetic devices*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO/IEC Guide 98-3-SP1:2008, *Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM:1995) - Propagation of distributions using a Monte Carlo method*

ISO 11929-1:2019, *Determination of the characteristic limits (decision threshold, detection limit and limits of the coverage interval) for measurements of ionizing radiation - Fundamentals and application - Part 1: Elementary applications*

ISO 11929-3:2019, *Determination of the characteristic limits (decision threshold, detection limit and limits of the coverage interval) for measurements of ionizing radiation - Fundamentals and application - Part 3: Applications to unfolding methods*

[1] Under consideration. Stage at the time of publication: IEC/CDV 60050-311:2026.

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ISO 11929-4:2022, *Determination of the characteristic limits (decision threshold, detection limit and limits of the coverage interval) for measurements of ionizing radiation - Fundamentals and application - Part 4: Guidelines to applications*

3 Terms and definitions

For the purposes of this document, the technical terms of IEC 60050-151, and IEC 60050-311 as well as the following definitions taken from ISO/IEC Guide 98-3:2008, and ISO/IEC Guide 98-3-SP1:2008 apply.

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

– IEC Electropedia: available at https://www.electropedia.org/

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

3.1
calibration factor
N
quotient of the conventional true value of a quantity, i.e., the conventional quantity value, and the indicated value for a specified reference radiation under specified reference conditions

3.2
complete result of the measurement
set of values attributed to a measurand, including a value, its uncertainty, coverage interval, coverage probability, and the unit

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Note 1 to entry: The central value of the whole (set of values) can be selected as *measured value* and a parameter characterising the dispersion as *uncertainty*.

Note 2 to entry: The result of a measurement is related to the *indication given by the instrument* and to the values of correction obtained by calibration and by the use of a *model*.

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Note 3 to entry: In this Technical Specification, the "measured value", see Note 1, is abbreviated by M.

Note 4 to entry: In this Technical Specification, the "indication given by the instrument", see Note 2, is abbreviated by G, and called "indicated value".

Note 5 to entry: In this Technical Specification, the "model", see Note 2, is called "model function", see 3.15 and 5.2.

3.3
conformity test
test for conformity evaluation

[SOURCE: IEC 60050-151:2001,151-16-15]

3.4
correction factor
K
factor to the indicated value to correct for deviation of measurement conditions from calibration conditions

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3.5
coverage interval
interval containing the set of true quantity values of a measurand with a stated probability, based on the information available

Note 1 to entry: A coverage interval does not need to be centred on the chosen measured quantity value.

Note 2 to entry: A coverage interval should not be termed "confidence interval" to avoid confusion with the statistical concept.

[SOURCE: ISO 11929-1:2019]

3.6
coverage factor
$\boldsymbol{k}_{\mathbf{cov}}$
numerical factor used as a multiplier of the (combined) standard uncertainty in order to obtain an expanded uncertainty

Note 1 to entry: A coverage factor k_{cov} is typically in the range of 2 to 3.

[SOURCE: ISO/IEC Guide 98-3:2008, 2.3.6]

3.7
decision threshold
$\boldsymbol{m}^*$
value of the estimator of the measurand, which, when exceeded by the result of an actual measurement using a given measurement procedure of a measurand quantifying a physical effect, is used to decide that the physical effect is present

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Note 1 to entry: The decision threshold is defined such that in cases where the measurement result, m, exceeds the decision threshold, m^*, the probability of a wrong decision, namely that the true value of the measurand is not zero if in fact it is zero, is less or equal to a chosen probability, α.

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Note 2 to entry: If the result, m, is below the decision threshold, m^*, it is decided to conclude that the result cannot be attributed to the physical effect; nevertheless, it cannot be concluded that it is absent.

Note 3 to entry: In other words: the probability α is the probability that a measured value exceeds the decision threshold and is accepted as indicator for a non-zero true value although it is, in fact, zero. In this case, the conclusion $\tilde{m} > 0$ would be a wrong decision.

[SOURCE: ISO 11929-1:2019, 3.12, modified – addition of Note 3 to entry]

3.8
detection limit
$\boldsymbol{m}^{\#}$
smallest true value of the measurand which ensures a specified probability of being detectable by the measurement procedure

Note 1 to entry: With the decision threshold according to 3.7, the detection limit is the smallest true value of the measurand for which the probability of wrongly deciding that the true value of the measurand is zero is equal to a specified value, β, when, in fact, the true value of the measurand is not zero. The probability of being detectable is consequently (1-β).

Note 2 to entry: The terms detection limit and decision threshold are used in an ambiguous way in different standards (e.g., standards related to chemical analysis or quality assurance). If these terms are referred to one has to state according to which standard they are used.

Note 3 to entry: In other words: the probability β is the probability that a measured value lies below the decision threshold and the result is therefore not attributed to the physical effect although the true value equals $m^{\#}$. In this case, the conclusion $\tilde{m} = 0$ would be a wrong decision.

[SOURCE: ISO 11929-1:2019, 3.13, modified – addition of Note 3 to entry]

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3.9
deviation
D
difference between the indicated values for the same value of the measurand of an indicating measuring instrument, or the values of a material measure, when an influence quantity assumes, successively, two different values

Note 1 to entry: This definition is applicable to all measuring instruments and influence quantities, but it should mainly be used in those cases, where this deviation is independent of the indicated value.

[SOURCE: IEC 60050-311:2001, 311-07-03, modified – renaming of the term from "variation (due to an influence quantity)" to "deviation"]

3.10
distribution function
$\boldsymbol{F(x)}$
function giving, for every value x, the probability that the random variable X be less than or equal to x: $F(x) = \Pr(X \leq x)$

[SOURCE: ISO/IEC Guide 98-3:2008, C.2.4; ISO/IEC Guide 98-3:2008-SP1:2008, 3.2]

3.11
evaluator
person performing the measurement and uncertainty analysis

3.12
expanded uncertainty
U
quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand

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Note 1 to entry: The expanded uncertainty is obtained by multiplying the (combined) standard uncertainty by a coverage factor.

[SOURCE: ISO/IEC Guide 98-3:2008, 2.3.5]

3.13
indicated value
G
quantity value provided by a measuring instrument or a measuring system

Note 1 to entry: An indication is often given by the position of a pointer on the display for analogue outputs, a displayed or printed number for digital outputs, a code pattern for code outputs, or an assigned quantity value for material measures.

3.14
influence quantity
quantity that is not the measurand but that effects the result of the measurement

Note 1 to entry: For example, temperature of a micrometer used to measure length.

[SOURCE: ISO/IEC Guide 98-3:2008, B.2.10]

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3.15
measured value
M
value determined from the indicated value, G, by applying the model function for the measurement

Note 1 to entry: An example of a model function is given below. The calibration factor N, a deviation D, and a correction factor K are applied:

$$M = N \times K \times (G - D)$$

The calculations according to this model function are not always performed. One main purpose of this model function of the measurement is, that it is necessary for any determination of the uncertainty according to ISO/IEC Guide 98-3:2008 (see ISO/IEC Guide 98-3:2008, 3.1.6, 3.4.1 and 4.1; see also 5.2 of this document).

Note 2 to entry: In ISO/IEC Guide 98-3:2008 the "measured value" is called "value of the measurand".

3.16
probability density function
$\boldsymbol{f(x)}$
<for a continuous random variable> derivative (when it exists) of the distribution function: $f(x) = \mathrm{d}F(x)/\mathrm{d}x$

Note 1 to entry: $f(x) \times \mathrm{d}x$ is the "probability element": $f(x) \times \mathrm{d}x = \Pr(x<X<x + \mathrm{d}x)$; in general: $\Pr(a<X<b) = \int_a^b f(x)\,\mathrm{d}x$.

[SOURCE: ISO/IEC Guide 98-3:2008, C.2.5; ISO/IEC Guide 98-3-SP1:2008, 3.3, modified by adding "in general"]

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3.17
reference conditions
set of specified values and/or ranges of values of influence quantities under which the uncertainties, or limits of error, admissible for a measuring instrument are the smallest

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[SOURCE: IEC 60050-311:2001, 311-06-02]

3.18
reference response
$\boldsymbol{R}_{\mathbf{ref}}$
response of the assembly under reference conditions to unit reference dose (rate) or activity which is expressed as:

$$R_{\mathrm{ref}} = \frac{G}{M_{\mathrm{c}}}$$

where G_{ref} is the indicated value of the equipment or assembly under test at reference conditions, G_0 is the zero reading (indicated value without additional radiation) and $M_{\mathrm{c,ref}}$ is the conventional true value of the reference source, i.e., the conventional quantity value

3.19
relative response
$\boldsymbol{R}_{\mathbf{rel}}$
quotient of the response and the reference response under specified conditions

Note 1 to entry: For the specified reference conditions, the response is the reciprocal of the calibration factor.

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3.20
response
R
quotient of the indicated value measured under specified conditions by the equipment or assembly under test, G, minus the indicated value without additional radiation, G_0, and the conventional true value of this quantity, i.e., the conventional quantity value, M_c:

$$R = \frac{G - G_0}{M_c}$$

3.21
standard uncertainty
standard deviation associated with the measurement result or an input quantity value

Note 1 to entry: See ISO/IEC Guide 98-3:2008, 2.3.4.

Note 2 to entry: The standard uncertainty of the measurement result is sometimes called "combined standard uncertainty".

Note 3 to entry: The quotient of the standard uncertainty and the measurement result is called "relative standard uncertainty" and sometimes given as percentage.

3.22
true quantity value
true value of a quantity
true value
quantity value consistent with the definition of a quantity

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Note 1 to entry: In the Error Approach to describing measurement, a true quantity value is considered unique and, in practice, unknowable. The Uncertainty Approach is to recognize that, owing to the inherently incomplete amount of detail in the definition of a quantity, there is not a single true quantity value but rather a set of true quantity values consistent with the definition. However, this set of values is, in principle and in practice, unknowable. Other approaches dispense altogether with the concept of true quantity value and rely on the concept of metrological compatibility of measurement results for assessing their validity.

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Note 2 to entry: When the definitional uncertainty associated with the measurand is considered to be negligible compared to the other components of the measurement uncertainty, the measurand may be considered to have an "essentially unique" true quantity value. This is the approach taken by ISO/IEC Guide 98-3:2008 and associated documents, where the word "true" is considered to be redundant.

[SOURCE: ISO 11929-1:2019]

3.23
type test
conformity test made on one or more items representative of the production

[SOURCE: IEC 60050-151:2001, 151-16-16]

3.24
uncertainty
uncertainty of measurement
parameter, associated with the result of a measurement, that characterises the dispersion of the values that could reasonably be attributed to the measurand

Note 1 to entry: The parameter may be, for example, a standard deviation (or a given multiple of it), or the half-width of an interval having a stated level of confidence (coverage probability).

[SOURCE: ISO/IEC Guide 98-3:2008, 2.2.3]

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