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GUIDE

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Application of uncertainty of measurement to conformity assessment activities in the electrotechnical sector

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Application of uncertainty of measurement to conformity assessment activities in the electrotechnical sector

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

APPLICATION OF UNCERTAINTY OF MEASUREMENT TO CONFORMITY ASSESSMENT ACTIVITIES IN THE ELECTROTECHNICAL SECTOR

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition GUIDE 115:2007. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

This second edition of IEC Guide 115 has been prepared, in accordance with ISO/IEC Directives, Part 1, Annex A, by IECEE/CTL. This is a non-mandatory guide in accordance with SMB Decision 136/8.

This second edition cancels and replaces the first edition published in 2007.

The main changes with respect to the previous edition are as follows:

a) editorial alignment to ISO/IEC 17025:2017 without adapting the technical content;
b) references to ISO/IEC 17025:2005 and ISO/IEC 17025:2017 in order to help for the transition to the new edition of ISO/IEC 17025.

The text of this IEC Guide is based on the following documents:

Four months' vote	Report on voting
SMBNC/8/DV	SMBNC/14/RV

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 Guide is English.

This publication has been drafted in accordance with the 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/standardsdev/publications.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This document has been prepared by the IECEE Committee of Testing Laboratories (CTL) to provide guidance on the practical application of the measurement uncertainty requirements of ISO/IEC 17025 to the electrical safety testing conducted within the IECEE CB Scheme.

The IECEE CB Scheme is a multilateral, international agreement, among over 40 countries and some 60 national certification bodies, for the acceptance of test reports on electrical products tested to IEC standards.

The aim of the CTL is, among other tasks, to define a common understanding of the test methodology with regard to the IEC standards as well as to ensure and continually improve the repeatability and reproducibility of test results among the member laboratories.

The practical approach to measurement uncertainty outlined in this document has been adopted for use in the IECEE Schemes, and is also extensively used around the world by testing laboratories engaged in testing electrical products to national safety standards.

This document is of particular interest to the following IEC technical committees, which ~~may~~ can decide to make use of it if necessary:

TECHNICAL COMMITTEE 13:	~~EQUIPMENT FOR ELECTRICAL ENERGY MEASUREMENT, TARIFF AND LOAD CONTROL~~ ELECTRICAL ENERGY MEASUREMENT AND CONTROL
TECHNICAL COMMITTEE 17:	HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR
TECHNICAL COMMITTEE 18:	ELECTRICAL INSTALLATIONS OF SHIPS AND OF MOBILE AND FIXED OFFSHORE UNITS
TECHNICAL COMMITTEE 20:	ELECTRIC CABLES
TECHNICAL COMMITTEE 21:	SECONDARY CELLS AND BATTERIES
TECHNICAL COMMITTEE 22:	POWER ELECTRONIC SYSTEMS AND EQUIPMENT
TECHNICAL COMMITTEE 23:	ELECTRICAL ACCESSORIES
TECHNICAL COMMITTEE 32:	FUSES
TECHNICAL COMMITTEE 33:	POWER CAPACITORS AND THEIR APPLICATIONS
TECHNICAL COMMITTEE 34:	~~LAMPS AND RELATED EQUIPMENT~~ LIGHTING
TECHNICAL COMMITTEE 35:	PRIMARY CELLS AND BATTERIES
TECHNICAL COMMITTEE 38:	INSTRUMENT TRANSFORMERS
~~TECHNICAL COMMITTEE 39:~~	~~ELECTRONIC TUBES~~
TECHNICAL COMMITTEE 40:	CAPACITORS AND RESISTORS FOR ELECTRONIC EQUIPMENT
TECHNICAL COMMITTEE 47:	SEMICONDUCTOR DEVICES
TECHNICAL COMMITTEE 59:	PERFORMANCE OF HOUSEHOLD AND SIMILAR ELECTRICAL APPLIANCES
TECHNICAL COMMITTEE 61:	SAFETY OF HOUSEHOLD AND SIMILAR ELECTRICAL APPLIANCES
TECHNICAL COMMITTEE 62:	ELECTRICAL EQUIPMENT IN MEDICAL PRACTICE
TECHNICAL COMMITTEE 64:	ELECTRICAL INSTALLATIONS AND PROTECTION AGAINST ELECTRIC SHOCK
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TECHNICAL COMMITTEE 66:	SAFETY OF MEASURING, CONTROL AND LABORATORY EQUIPMENT
TECHNICAL COMMITTEE 76:	OPTICAL RADIATION SAFETY AND LASER EQUIPMENT
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TECHNICAL COMMITTEE 78:	LIVE WORKING
TECHNICAL COMMITTEE 80:	MARITIME NAVIGATION AND RADIOCOMMUNICATION EQUIPMENT AND SYSTEMS
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TECHNICAL COMMITTEE 110:	ELECTRONIC DISPLAYS

APPLICATION OF UNCERTAINTY OF MEASUREMENT TO CONFORMITY ASSESSMENT ACTIVITIES IN THE ELECTROTECHNICAL SECTOR

1 Scope

This Guide presents a practical approach to the application of uncertainty of measurement to conformity assessment activities in the electrotechnical sector. It is specifically conceived for use in IECEE Schemes as well as by testing laboratories engaged in testing electrical products to national safety standards. It describes the application of uncertainty of measurement principles and provides guidance on making uncertainty of measurement calculations. It also gives some examples relating to uncertainty of measurement calculations for product conformity assessment testing.

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/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

~~*Guide to the expression of uncertainty in measurement* (GUM) (1995) [BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML]~~

~~*International vocabulary of basic and general terms in metrology* (VIM) (1996) [BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML]~~

3 Terms and definitions

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

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
coverage factor
number that, when multiplied by the combined standard uncertainty, produces an interval (the expanded uncertainty) about the measurement result that ~~may~~ can be expected to encompass a large, specified fraction (e.g. 95 %) of the distribution of values that could be reasonably attributed to the measurand

3.2
combined standard uncertainty
result of the combination of standard uncertainty components

3.3
error of measurement
result of a measurement minus a true value of the measurand ~~(not precisely quantifiable because true value lies somewhere unknown within the range of uncertainty)~~

Note 1 to entry: The error of measurement is not precisely quantifiable because the true value lies somewhere unknown within the range of measurement uncertainty.

3.4
expanded uncertainty
value obtained by multiplying the combined standard uncertainty by a coverage factor

3.5
level of confidence
probability that the value of the measurand lies within the quoted range of uncertainty

3.6
measurand
quantity subjected to measurement, evaluated in the state assumed by the measured system during the measurement itself

[SOURCE: IEC 60359:2001, 3.1.1, modified – The NOTES have been deleted.]

3.7
quantity X_i
source of uncertainty

3.8
standard deviation
positive square root of the variance

3.9
standard uncertainty
estimated standard deviation

3.10
uncertainty of measurement
parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

[SOURCE: IEC 60359:2001, 3.1.4, modified – The NOTES have been deleted.]

3.11
Type A evaluation method
method of evaluation of uncertainty of measurement by the statistical analysis of a series of observations

3.12
Type B evaluation method
method of evaluation of uncertainty of measurement by means other than the statistical analysis of a series of observations

4 Application of uncertainty of measurement principles

4.1 General

4.1.1 ~~Qualification and acceptance of CB test laboratories (CBTL), e.g. in the IECEE, is performed according to IEC/ISO 17025, which states in 5.4.6.2:~~

Qualification and acceptance of Certification Body Testing Laboratories (CBTLs), e.g. in the IECEE, are performed according to ISO/IEC 17025.

> ISO/IEC 17025:2005, 5.4.6.2
>
> "Testing laboratories shall have and apply procedures for estimating uncertainty of measurement. In certain cases, the nature of the test method may preclude rigourous, metrologically and statistically valid, calculation of uncertainty of measurement. In these cases the laboratory shall at least attempt to identify all the components of uncertainty and make a reasonable estimation, and shall ensure that the form of reporting of the result does not give a wrong impression of the uncertainty. Reasonable estimation shall be based on knowledge of the performance of the method and on the measurement scope and shall make use of, for example, previous experience and validation data.
>
> NOTE 1 The degree of rigour needed in an estimation of uncertainty of measurement depends on factors such as:
>
> – the requirements of the test method;
>
> – the requirements of the client;
>
> – the existence of narrow limits on which decisions on conformance to a specification are based.
>
> NOTE 2 In those cases where a well-recognized test method specifies limits to the values of the major sources of uncertainty of measurement and specifies the form of presentation of calculated results, the laboratory is considered to have satisfied this clause by following the test method and reporting instructions (see 5.10)."

> ISO/IEC 17025:2017, 7.6
>
> **"7.6 Evaluation of measurement uncertainty**
>
> **7.6.1** Laboratories shall identify the contributions to measurement uncertainty. When evaluating measurement uncertainty, all contributions that are of significance, including those arising from sampling, shall be taken into account using appropriate methods of analysis.
>
> **7.6.2** A laboratory performing calibrations, including of its own equipment, shall evaluate the measurement uncertainty for all calibrations.
>
> **7.6.3** A laboratory performing testing shall evaluate measurement uncertainty. Where the test method precludes rigorous evaluation of measurement uncertainty, an estimation shall be made based on an understanding of the theoretical principles or practical experience of the performance of the method.
>
> NOTE 1 In those cases where a well-recognized test method specifies limits to the values of the major sources of measurement uncertainty and specifies the form of presentation of the calculated results, the laboratory is considered to have satisfied 7.6.3 by following the test method and reporting instructions.
>
> NOTE 2 For a particular method where the measurement uncertainty of the results has been established and verified, there is no need to evaluate measurement uncertainty for each result if the laboratory can demonstrate that the identified critical influencing factors are under control."

4.1.2 ~~IEC/ISO 17025~~ ISO/IEC 17025:2005, 5.10.3.1 c) states:

~~"Subclause 5.10.3.1 includes the following:~~

"c) where applicable, a statement on the estimated uncertainty of measurement; information on uncertainty is needed in test reports, when it is relevant to the validity ~~of~~ or application of the test results, when a ~~client's~~ customer's instruction so requires, or when the uncertainty affects compliance to a specification limit;".

ISO/IEC17025:2017, 7.8.3.1 c) states:

"c) where applicable, the measurement uncertainty presented in the same unit as that of the measurand or in a term relative to the measurand (e.g. percent) when:

- it is relevant to the validity or application of the test results;
- a customer's instruction so requires, or
- the measurement uncertainty affects conformity to a specification limit;".

4.1.3 ~~IEC/ISO 17025~~ ISO/IEC 17025 was written as a general use document, for all industries. Uncertainty of measurement principles are applied to laboratory testing and presentation of test results to provide a degree of assurance that decisions made about conformance of the products tested according to the relevant requirements are valid. Procedures and techniques for uncertainty of measurement calculations are well established. This ~~CB Testing Laboratory (CBTL) procedure~~ document is written to provide more specific guidance on the application of uncertainty of measurement principles to reporting of testing results under the CB Scheme.

4.1.4 Clause 4 of ~~CBTL procedure~~ this document focuses on the application of uncertainty of measurement principles under the CB Scheme, while Clause 5 ~~of CBTL procedure~~ provides guidance on making uncertainty of measurement calculations and includes examples.

4.2 Uncertainty of measurement principles

~~**4.2.1**~~ A challenge to applying uncertainty of measurement principles to conformity assessment activities is managing the cost, time and practical aspects of determining the relationships between various sources of uncertainty. Some relationships are either unknown or would take considerable effort, time and cost to establish. There are a number of proven techniques available to address this challenge. These techniques include eliminating from consideration those sources of variability which have little influence on the outcome and minimizing significant sources of variability by controlling them.

4.3 Background

4.3.1 Test methods used under the IECEE CB Scheme are in essence consensus standards. Criteria used to determine conformance with requirements are most often based on a consensus of judgment of what the limits of the test result should be. Exceeding the limit by a small amount does not result in an imminent hazard. Test methods used ~~may~~ can have a precision statement expressing the maximum permissible uncertainty expected to be achieved when the method is used. Historically, test laboratories have used state-of-the-art equipment and not considered uncertainty of measurement when comparing results to limits. Safety standards have been developed in this environment and the limits in the standards reflect this practice.

4.3.2 Test parameters that influence the results of tests can be numerous. Nominal variations in some test parameters have little effect on the uncertainty of the measurement result. Variations in other parameters ~~may~~ can have an effect. However, the degree of influence can be minimized by limiting the variability of the parameter when performing the test.

4.3.3 A frequent way of accounting for the effects of test parameters on test results is to define the acceptable limits of variability of test parameters. When this is done, any variability in measurement results obtained due to changes in the controlled parameters is not considered significant if the parameters are controlled within the limits. Examples of the application of this technique require:

a) input power source to be maintained: voltage ±2 %, frequency ±0,5 %, total harmonic distortion maximum 3 %;

b) ambient temperature: 23 °C ± 2 °C;

c) relative humidity: 93 % ± 2 % (RH);

d) personnel: documented technical competency requirements for the test;

e) procedures: documented laboratory procedures;

f) equipment accuracy: instrumentation with accuracy according to CTL ~~decision 251A~~ OD-5014.

NOTE The acceptable limits in items a) through c) are given as examples and do not necessarily represent actual limits established.

4.3.4 The end result of controlling sources of variability within prescribed limits is that the measurement result can be used as the best estimate of the measurand. In effect, the uncertainty of measurement about the measured result is negligible with regard to the final pass/fail decision.

4.4 Uncertainty of measurement principles – Application of procedures

4.4.1 When a test results in measurement of a variable, there is uncertainty associated with the test result obtained.

4.4.2 Procedure 1, see Figure 1, is used when calculation of uncertainty of measurement is required by ~~IEC /ISO 17025, 5.4.6.2 and 5.10.3.1 item c)~~ ISO/IEC 17025:2017, 7.6.3 and 7.8.3.1 c). Calculate the uncertainty for measurement (see Clause 5) and compare the measured result with the uncertainty band to a defined acceptable limit. The measurement complies with the requirement if the probability of its being within the limit is at least 50 %.

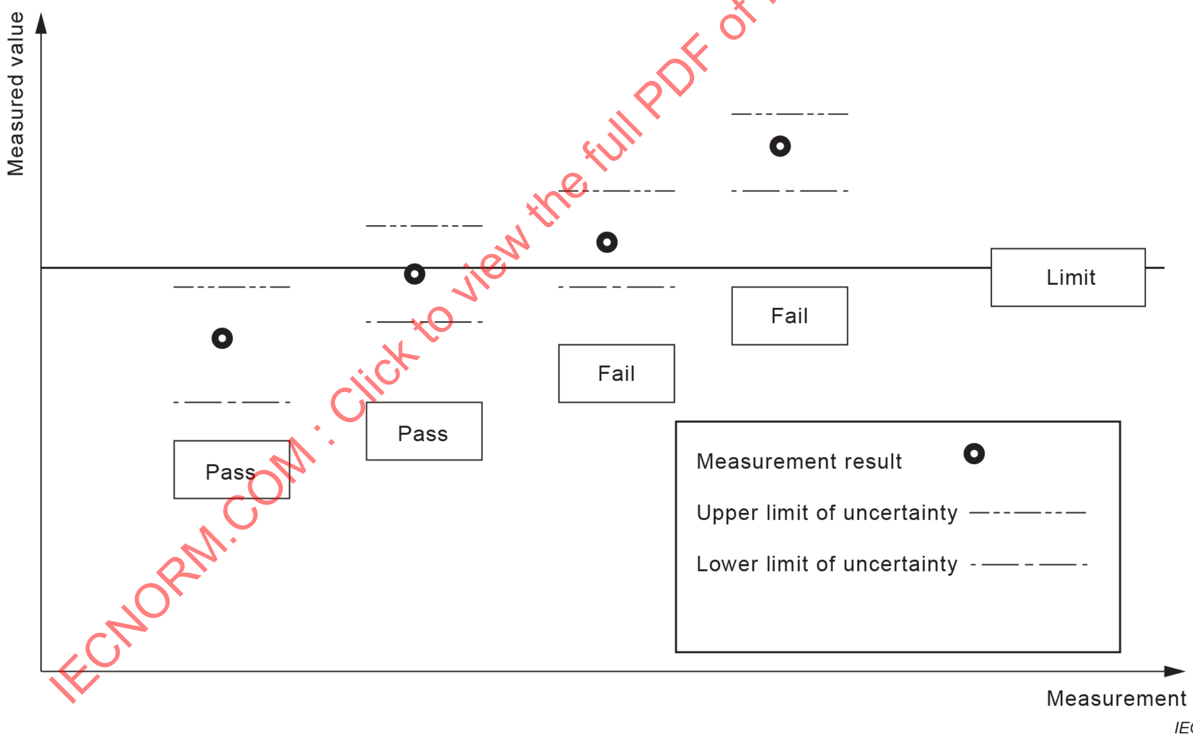

Figure 1 – Procedure 1: uncertainty of measurement calculated

4.4.3 Procedure 2, see Figure 2, is used when ~~IEC /ISO 17025, 5.4.6.2~~ ISO/IEC 17025:2017, 7.6.3, Note 2, applies. Procedure 2 is the traditional method used under the CB Scheme and has been referred to as the "accuracy method". The test performed is routine. Sources of uncertainty are minimized so that the uncertainty of the measurement need not be calculated to determine conformance with the limit. Variability in test parameters is within acceptable limits. Test parameters such as power source voltage, ambient temperature and ambient humidity are maintained within the defined acceptable limits for the test. Personnel training and laboratory procedures minimize uncertainty of measurement due to human factors. Instrumentation used has an uncertainty within prescribed limits.

NOTE The name, accuracy method, comes from the concept of limiting uncertainty due to instrumentation by using instruments within prescribed accuracy limits. For this purpose, the accuracy specification for an instrument is considered the maximum uncertainty of measurement attributable to the instrument.

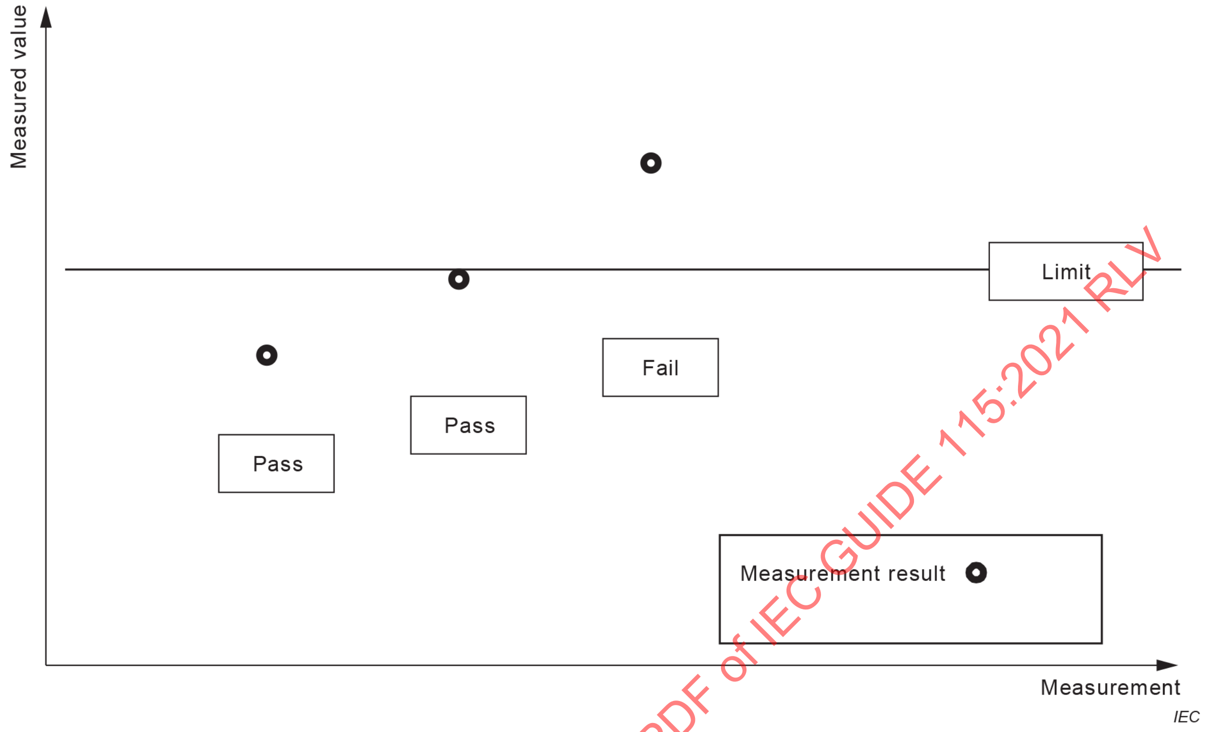

Figure 2 – Procedure 2: accuracy method

4.4.4 The measurement result is considered in conformance with the requirement if it is within the prescribed limit. It is not necessary to calculate the uncertainty associated with the measurement result.

4.4.5 Example – Procedure 2

- Power supply output voltage measurement test

  a) Method

  Connect the power supply to a mains source of rated voltage, ±2 %, and rated frequency. Measure output voltage from power supply while loaded to rated current, ±2 %, with a non-inductive resistive load. The test is to be performed in an ambient temperature of 23 °C ± 2 °C.

  Use meters having an accuracy conforming to CTL ~~decision 251A~~ OD-5014.

  The power supply conforms to the requirements if the output voltage is ±5 % of rated value.

  b) Results

  Power supply rating: 240 V, 50 Hz input; 5 V d.c., 2 A output. See Table 1.

Table 1

Input		Output	
U V	**Frequency** Hz	*I* A	*U* V
242	50	2,01	5,1

Test ambient temperature: 24 °C.

The accuracy of the instruments used is shown in ~~the following table~~ Table 2.

Table 2

Meter	Calibrated accuracy for scale used for measurement	CTL decision 251A, max.
Thermometer	±1,0 °C	±2,0 °C
Voltmeter	±0,5 %	±1,5 %
Frequency meter	±0,2 %	±0,2 %
Current meter	±0,5 %	±1,5 %

The conclusion of the test is that the power supply conforms to the requirement.

4.5 Conclusion

4.5.1 The traditional approach to addressing uncertainty of measurement for conformity assessment activities under the CB Scheme has been the application of the accuracy method. This method minimizes sources of uncertainty associated with the performance of routine tests so that the measurement result can be directly compared with the test limit to determine conformance with the requirement. This method conforms to the requirements in ~~IEC/ISO 17025~~ ISO/IEC 17025. The accuracy method takes less time and costs less to implement than detailed uncertainty of measurement calculations and the conclusions reached are valid with regard to the final pass/fail decision.

4.5.2 In situations where the traditional, accuracy method does not apply, uncertainty of measurement values are calculated and reported along with the variables results obtained during testing.

5 Guidance on making uncertainty of measurement calculations including examples of how to perform the calculations

5.1 General principles

5.1.1 Clause 5 is meant to be a short and simplified summary of the steps to be taken by a CBTL when the need to estimate uncertainties arises. It also includes examples of how to perform the calculations.

5.1.2 It is by no means a comprehensive paper about measurement uncertainty (MU), its sources and estimation in general, but is supposed to offer a practical approach for most applicable circumstances within a CBTL in the IECEE CB Scheme.

5.1.3 No measurement is perfect and the imperfections give rise to error of measurement in the result. Consequently, the result of a measurement is only an approximation to the measured value (measurand) and is only complete when accompanied by a statement of the uncertainty of that approximation. Indeed, because of measurement uncertainty, a true value can never be known.

5.1.4 The total uncertainty of a measurement is a combination of a number of component uncertainties. Even a single instrument reading may be influenced by several factors. Careful consideration of each measurement involved in the test is required to identify and list all the factors that contribute to the overall uncertainty. This is a very important step and requires a good understanding of the measuring equipment, the principles and practice of the test and the influence of environment.

5.1.5 ~~The Guide to the expression of uncertainty in measurement (GUM)~~ ISO/IEC GUIDE 98-3:2008 has adopted the approach of grouping uncertainty components into two categories based on their method of evaluation: Type A and Type B. This categorization of the methods of evaluation, rather than of the components themselves, avoids certain ambiguities.

5.1.6 Type A evaluation is carried out by calculation from a series of repeated observations, using statistical methods.

5.1.7 Type B evaluation is carried out by means other than that used for Type A. For example, by judgment based on ~~the following table~~ Table 3.

Table 3

Data in calibration certificates	This enables corrections to be made and Type B uncertainties to be assigned
Previous measurement data	For example, history graphs can be constructed and yield useful information about changes with time
Experience or general knowledge	Behaviour and properties of similar materials and equipment
Accepted values of constants	Associated with materials and quantities
Manufacturers' specifications	
All other relevant information	

5.1.8 Individual uncertainties are evaluated by the appropriate method and each is expressed as a standard deviation and is referred to as a standard uncertainty.

5.2 Summary of steps when estimating uncertainty

5.2.1 Identify the factors that ~~may~~ can significantly influence the measured values and review their applicability. There are many possible sources in practice, mainly including the following.

a) Contribution from calibration of the measuring instruments, including contribution from reference or working standards.

b) Temperature error at the beginning and end of a test (e.g. winding resistance method).

c) Uncertainty related to the loading applied and the measurement of it.

d) Velocity of air flow over the test sample and uncertainty in measuring it.

e) For digital instruments, there are the number of displayed digits and the stability of the display at the time the reading is taken. In addition, the reported uncertainty of an instrument does not necessarily include the display.

f) Instrument resolution, limits in graduation of a scale.

g) Approximations and assumptions incorporated in the measurement method.

h) Uncertainty due to the procedures used to prepare the sample for test and actually testing it.

i) If a computer is used to acquire the readings from the instrument, there is uncertainty associated with the processing of the data due to calculations or other manipulations within the computer such as analogue-to-digital conversions, and conversions between floating point and integer numbers.

k) Rounded values of constants and other parameters used for calculations.

m) Effects of environmental conditions (e.g. variation in ambient temperature) or measurement of these on the measurement.

NOTE 1 Negligible in case environmental conditions are stable (which is assumed and expected from a CBTL).

n) Variability of the power supply source (voltage, current, frequency) the sample is connected to and the uncertainty in measuring it.

NOTE 2 Negligible in case stabilized supply sources are used (which is assumed and expected from a CBTL).

o) Personal bias in reading analogue instruments (e.g. parallax error or the number of significant figures that can be interpolated).

NOTE 3 Negligible in case of digital displays or in case of appropriate training (which is assumed and expected from a CBTL).

p) Variation between test samples and in case the samples are not fully representative.

Unless the IEC standard specifies tests on multiple samples, only one sample is tested.

NOTE 4 The variation between test samples is assumed to be negligible by CBTLs.

NOTE 5 This list does not state all of the items that can contribute to MU. It is possible that other factors ~~may have~~ will need to be identified and considered by each individual laboratory ~~respectively~~.

5.2.2 Transform influencing factors x_i to the unit of the measured value (quantity), for which you are going to estimate the uncertainty, if not already given in that unit (e.g. if the unit of the measured value is the volt (V) and a resistor's tolerance in ohms (Ω) is one of the influencing factors, transform the change of resistance to the resulting contribution in volts).

Once the uncertainty contributions associated with a measurement process have been identified and quantified, ~~it is necessary to combine~~ a combination of them in some manner ~~in order to provide~~ provides a single value of uncertainty that can be associated with the measurement result.

5.2.3 Determine the probability distribution

The probability distribution of the measured quantity describes the variation in probability of the true value lying at any particular difference from the measured or assigned result. The form of the probability distribution will often not be known, and an assumption ~~has to~~ shall be made, based on prior knowledge or theory, that it approximates to one of the common forms. It is then possible to calculate the standard uncertainty, $U(x_i)$, for the assigned form from simple expressions. The four main distributions of interest are

– normal,
– rectangular,
– triangular, and
– U-shaped.

5.2.4 Normal distribution is assigned when the uncertainty is taken from, for example, a calibration certificate/report where the coverage factor, *k*, is stated. The standard uncertainty is found by dividing the stated uncertainty from the calibration certificate by its coverage factor *k*, which is $k = 2$ for a level of confidence of approximately 95 % (recommended for CBTLs in the IECEE CB Scheme). It ~~may be necessary~~ is possible that *k* will need to ~~confirm *k*~~ be confirmed with the calibration laboratory in case it is not stated on the certificate.

$$\text{Normal: } u(x_i) = \frac{U}{k}$$

where *U* is the expanded uncertainty stated on the certificate.

5.2.5 Rectangular distribution means that the probability density is constant within the prescribed limits. A rectangular distribution should be assigned where a manufacturer's specification limits are used as the uncertainty, unless there is a statement of confidence associated with the specification, in which case a normal distribution can be assumed.

$$\text{Rectangular: } u(x_i) = \frac{a_i}{\sqrt{3}}$$

where a_i is the half width of the rectangular distribution.

5.2.6 U-shaped distribution is applicable to mismatch uncertainty. The value of the limit for the mismatch uncertainty, *M*, associated with the power transfer at a junction is obtained from

$$100\,((1 \pm |\Gamma_G||\Gamma_L|)^2 - 1)\,\% \text{ or } 20\log_{10}(1 \pm |\Gamma_G||\Gamma_L|)\text{ dB (logarithmic units)}$$

where Γ_G and Γ_L are the reflection coefficients for the source and load.

The mismatch uncertainty is asymmetric about the measured result; however, the difference this makes to the total uncertainty is often insignificant, and it is acceptable to use the larger of the two limits.

U-shaped distribution is used for ~~EMC~~ electromagnetic compatibility purposes but also for climatic control of temperature and humidity.

U-shaped: $u(x_i) = \dfrac{M}{\sqrt{2}}$

5.2.7 Triangular distribution means that the probability of the true value lying at a point between two prescribed limits increases uniformly from zero at the extremities to the maximum at the centre. A triangular distribution should be assigned where the contribution has a distribution with defined limits and where the majority of the values between the limits lie around the central point.

Triangular: $u(x_i) = \dfrac{a_i}{\sqrt{6}}$

5.2.8 A detailed approach to the determination of probability distribution can be found in ~~the Guide to the expression of uncertainty in measurement (GUM)~~ ISO/IEC GUIDE 98-3:2008.

5.2.9 Correlation: For the statistical approach to the combination of individual uncertainty contributions to be valid, it is assumed that there ~~shall be~~ are no common factors associated with these contributions.

5.2.10 The effect of correlated input quantities ~~may~~ can be to increase or decrease the combined standard uncertainty. For example, if the area of a rectangle is determined by measurement of its width and height using the same measuring implement the correlation will increase the uncertainty. On the other hand, if a gauge block were to be measured by comparison with another of identical material, the effect of uncertainty due to temperature will depend on the difference in temperature between the two blocks and will therefore tend to cancel.

5.2.11 If the correlation is such that the combined standard uncertainty is increased, the most straightforward approach is to add the standard uncertainties for these quantities before combining the result statistically with other contributions.

5.2.12 If, however, the correlation is such that the combined standard uncertainty will be decreased, as in the gauge-block comparison above, the difference in standard uncertainty would be used as the input quantity.

5.2.13 A detailed approach to the treatment of correlated input quantities can be found in ~~the GUM~~ ISO/IEC GUIDE 98-3:2008.

5.2.14 Establish the uncertainty budget m_x, containing the standard uncertainties of each influencing factor (quantity) $u(x_i)$. Usually $u(x_i)$ will already represent the uncertainty contribution $u_i(y)$ of each factor. A convenient way to do that is to write the identified and potential contributing factors and their estimates into a table (see examples). The uncertainty contribution $u(m_x)$ is calculated by the formula:

~~$u(m_x) = SQRT (u_1(y)^2 + u_2(y)^2 + ... + u_i(y)^2)$~~

$$u(m_x) = \sqrt{\left(u_1(y)^2 + u_2(y)^2 + \ldots + u_i(y)^2\right)}$$

5.2.15 Calculate the expanded uncertainty *U*, considering your level of confidence. The expanded uncertainty is calculated by multiplying the standard uncertainty with the coverage factor *k*, which is $k = 2$ for a level of confidence of approximately 95 % (recommended for CBTLs in the IECEE CB Scheme), or $k = 3$ for approximately 99,7 % level of confidence.

$$u = k \times u(m_x)$$

5.2.16 Report the result of the measurement comprising the measured value, the associated expanded uncertainty *U* and the coverage factor *k*.

EXAMPLE 10,5 V ± 0,4 V (coverage factor $k = 2$, for a level of confidence of approximately 95 %).

5.3 Simple example – Estimation of measurement uncertainty for a temperature-rise test with thermocouples

The following example has been chosen to demonstrate the basic method of evaluating the uncertainty of measurement. It has been simplified in order to provide transparency for the reader and intended to be general guidance on how to proceed. The contributions and values are not intended to imply mandatory or preferred requirements. The input quantities are regarded as being not correlated.

a) Identification of significant influencing factors

See Table 4.

Table 4

Quantity X_i	Source of uncertainty	Source of error quantity $s_p (x_i)$
δ_{TC}	Uncertainty of thermocouple	For example, from specifications
δ_{HR}	Uncertainty of hybrid recorder	For example, from the calibration certificate of a calibration laboratory, including their inherited uncertainty and the listed coverage factor of $k = 3$
δ_{Fixing}	Influence of fixing method of thermocouples	For example, from the laboratory's own investigation campaign
$\delta_{ambient}$	Uncertainty of ambient temperature measurement	For example, measured by a separate instrument, data taken from the manufacturer's specifications

b) Relating influencing factors to the measured value

The relationship between the influencing factor and the measured value evaluated at the point of measurement is known as the sensitivity coefficient. In this simple example, there is a 1-to-1 relationship between the influencing factors and the measured value. Therefore, the sensitivity coefficient is 1. For more complex relationships, the sensitivity coefficient can take on other values. See Table 5.

Table 5

Quantity X_i	Estimate x_i	Sensitivity coefficient	Error quantity $s_p(x_i)$
δ_{TC}	−40 °C to +350 °C	1	0,5 °C
δ_{HR}	Worst case of calibrated items, e.g. −25 °C to +250 °C	1	1,8 °C
δ_{Fixing}	Worst case of investigated temperatures, e.g. 25 °C, 85 °C, 150 °C	1	2,4 °C
$\delta_{ambient}$	Usually used in the vicinity of 25 °C	1	1,25 °C

c) Uncertainty budget, m_x

See Table 6.

Table 6

Quantity X_i	Estimate x_i	Error quantity $s_p(x_i)$	Probability distribution	Standard uncertainty $u(x_i)$	Sensitivity coefficient	Uncertainty contribution $u_i(y)$
δ_{TC}	−40 °C to +350 °C	0,5 °C	Rectangular	0,29 °C	1	0,29 °C
δ_{HR}	−25 °C to +250 °C	1,8 °C	Normal	0,6 °C	1	0,6 °C
δ_{Fixing}	25 °C, 85 °C, 150 °C	2,4 °C	Normal	2,4 °C	1	2,4 °C
$\delta_{ambient}$	–	1,25 °C	Rectangular	0,72 °C	1	0,72 °C
m_x	25 °C to 150 °C	–				$u(m_x)$ = 2,63 °C

$$u(m_x) = \sqrt{\left(u_1^2 + u_2^2 + u_3^2 + \ldots\right)}$$

$\sqrt{3}$ = 1,73, $\sqrt{6}$ = 2,45

d) Expanded uncertainty, U

$U = k \times u(m_x)$ = 2 × 2,63 °C = 5,27 °C = approximately 5,3 °C

e) Reported result

The measured temperature rise is xx,x K ± 5,3 °C

The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k = 2, which for a normal distribution corresponds to a coverage probability of approximately 95 %.

Annex A
(informative)

Uncertainty of measurement calculations for product conformity assessment testing – Examples 1 to 6

IECEE CTL WG 1 provides the following set of examples of calculations to illustrate the application of uncertainty of measurement to conformity assessment activities carried out under the IECEE CB Scheme.

Example 1 – Input test

Example 2 – Input power test

Example 3 – Leakage current measurement test

Example 4 – Distance measurement using calliper gauge

Example 5 – Torque measurement

Example 6 – Pre-conditioning for ball pressure test

These examples have been simplified to illustrate various steps of the process for performing uncertainty of measurement calculations.

Example 1: Input test

Result: uncertainty of input current expressed as a percentage of reading in amperes.

Description: Input current is measured to product connected to mains power source. Input current to product is proportional to voltage applied.

See Table A.1.

Table A.1 – Input test

Quantity X_i	Source of uncertainty	X_i	Type	Relative error quantity, $S_p(X_i)$	Probability shape	Distribution division factor, k	Relative standard uncertainty, $u(X_i)$	Sensitivity coefficient, C_i	Relative uncertainty contribution, $u_i(y)$
δ_R	Repeatability of measurement	X_R	A		Normal		0,2 %	1	0,2 %
δ_{instr}	Specification for instrument	X_{instr}	B	0,5 %	Rectangular	$\sqrt{3}$	0,3%	1	0,3 %
$\delta_{reading}$	Reading error	$X_{reading}$	B	0,3 %	Rectangular	$\sqrt{3}$	0,17 %	1	0,17 %
δ_{power}	Specification for power mains fluctuation	X_{power}	B	0,17 %	Rectangular	$\sqrt{3}$	0,1 %	1	0,1 %
					Relative combined standard uncertainty, u_c				0,41 %
					Coverage factor k_p = 2; confidence level: 95 %				–
					Relative expanded uncertainty, $U = u_c \times k_P$				0,81 %

Reported result – The measured input current is m_x (1 ± 0,008 1) A, k = 2,95 % confidence level.

δ_R repeatability of measurement – uncertainty due to repeatedly making the same measurement – Type A with normal distribution

$$u_1 = \bar{\sigma}_{n-1} = \sqrt{\frac{\sum\left(x_i - \bar{x}\right)^2}{n(n-1)}} = 0{,}2\ \%$$

NOTE This formula is used to estimate the standard deviation of the sampling distribution of the mean (i.e. to estimate the standard error of the mean). This estimate is represented by the symbol u_1 in the equation for δ_R.

δ_{instr} specification for instrument – uncertainty due to instrument used for measurements. Determined from specifications in instrument manual (MPE). Meter is 0,5 class. Error is ±0,5 %. Rectangular distribution, $k = \sqrt{3}$.

$u_2 = 0{,}5 / \sqrt{3} = 0{,}3\ \%$

$\delta_{reading}$ reading of instrument – uncertainty due to technician reading the instrument. When testing meter is 0,5 A per graduation and 100 graduations, estimating reading error is 1/10 graduation. In the practice testing, reading value is 34,8 line. Rectangular distribution, $k = \sqrt{3}$.

$u_3 = [(0{,}1)(0{,}5)]/[(34{,}5)(0{,}5)\ \sqrt{3}\,] \times 100 = 0{,}17\ \%$

δ_{power} power mains fluctuation – uncertainty due to fluctuations in power mains voltage. Uncertainty of the regulator is 0,2%. Rectangular distribution, $k = \sqrt{3}$. Sensitivity coefficient = 1.

$u_4 = 0,2 / \sqrt{3} = 0,1$ %

Example 2: Input power test

Result: uncertainties expressed as a percentage of input power in watts.

Description: input power is measured to product operating in stable condition while connected to regulated mains power source. Input power is measured by analogue or digital power meter.

See Table A.2.

Table A.2 – Input power test

Quantity X_i	Source of uncertainty	X_i	Type	Relative error quantity, $S_p(X_i)$	Probability shape	Distribution division factor, k	Relative standard uncertainty, $u(X_i)$	Sensitivity coefficient, c_i	Relative uncertainty contribution, $u_i(y)$
δ_R	Repeatability of measurement	X_R	A		Normal		0,2 %	1	0,2 %
δ_{instr}	Specification for instrument	X_{instr}	A	0,2 %	Normal	2	0,1 %	1	0,1 %
$\delta_{reading}$	Reading error	$X_{reading}$	B	0,45 %	Rectangular	$\sqrt{3}$	0,26 %	1	0,26 %
δ_{power}	Specification for power mains fluctuation	X_{power}	B	0,35 %	Rectangular	$\sqrt{3}$	0,2 %	1	0,20 %
					Relative combined standard uncertainty, u_c				0,40 %
					Coverage factor k_p = 2; confidence level: 95 %				–
					Relative expanded uncertainty, $U = u_c \times k_p$				0,80 %

Reported result – The measured input power is m_x (1 ± 0,008) W, k = 2, 95 % confidence level.

δ_R repeating error repeatability of measurement – uncertainty due to repeatedly making the same measurement – Type A with normal distribution

$$u_1 = \bar{\sigma}_{n-1} = \sqrt{\frac{\sum\left(x_i - \bar{x}\right)^2}{n(n-1)}} = 0{,}2\ \%$$

δ_{instr} specification for instrument – uncertainty due to instrument used for measurements. Determined from calibration laboratory report. Expanded uncertainty reported is ±0,2. Distribution is normal, k = 2.

u_2 = 0,2/2 = 0,1 %

$\delta_{reading}$ reading of instrument – uncertainty due to technician reading instrument – estimated.

δ_{power} specification of power mains fluctuation – uncertainty due to fluctuations in power mains voltage.

Example 3: Leakage current measurement test

Result: uncertainties of leakage current expressed in micro-amperes.

Description: leakage current is measured with product operating under normal working conditions. Leakage current is measured directly by a leakage current meter. The measurement is carried out under the following conditions.

a) Between any pole of the power source and metal parts that can be easily touched or the metal foil on the insulating materials that can be easily touched, not exceeding 20 cm by 10 cm.
b) Between any pole of the power source and the metal parts only using basic insulation to separate live parts of one stage apparatus.
c) Before and after humidity conditioning.

Tested parts are:

– between live parts and the enclosure isolated from the live part by only basic insulation;
– between the live parts and the shell with reinforced insulation.

See Table A.3.

Table A.3 – Leakage current measurement test

Quantity X_i	Source of uncertainty	X_i	Type	Error quantity, $S_p(X_i)$ µA	Probability shape	Distribution division factor, k	Standard uncertainty, $u(X_i)$ µA	Sensitivity coefficient, C_i	Uncertainty contribution, $u_i(y)$ µA
δ_R	Repeatability of measurement	X_R	A		Normal		1	1	1
δ_{inher}	Calibration of instrument	X_{inher}	A	15 normal 18 after	Normal	3	5 normal 6 after	1	5 normal 6 after
δ_{instr}	Quantum error of instrument	X_{instr}	B	0,5	Rectangular	$\sqrt{3}$	0,3	1	0,3
δ_{range}	Range of measurement	X_{range}	B	0,0	Rectangular	$\sqrt{3}$	0,0	1	0,0
δ_{temp}	Ambient temperature fluctuation	X_{temp}	A	3,2 normal 3,7 after	Normal	3	1 normal 1,2 after	1	1 normal 1,2 after
$\delta_{humidity}$	Relative humidity	$X_{humidity}$	B	3,7	Rectangular	$\sqrt{3}$	2 after	1	2,1 after
δ_{power}	Specification of power mains fluctuation	X_{power}	B	2	Rectangular	$\sqrt{3}$	1,2	1	1
					Combined standard uncertainty, u_c				5,3 normal 6,6 after
					Coverage factor k_p = 2; confidence level: 95 %				–
					Expanded uncertainty, $U = u_c \times k_p$				11 normal 13 after

Reported result – The measured leakage current is 320 µA ± 11 µA and 370 µA ± 13 µA after humidity, k = 2,95 % confidence level.

δ_R repeating error repeatability of measurement – uncertainty due to repeatedly making the same measurement – Type A with a normal distribution:

$$u_1 = \bar{\sigma}_{n-1} = \sqrt{\frac{\sum\left(x_i - \bar{x}\right)^2}{n(n-1)}} = 1\ \mu A$$

δ_{inher} calibration of instrument – leakage current of basic insulation is 320 µA under operating condition and 370 µA under humidity conditioning. According to the certificate of calibration, the system error of the measured instrument is ±5 %, normal, k = 3.

u_2 = 0,05 × 320/3 = 5 µA normal condition

u_2 = 0,05 × 370/3 = 6 µA humidity condition

δ_{instr} quantum error of instrument – uncertainty due to instrument used for measurements (MPE). When testing, used 2 mA measuring range, resolution is 0,001 mA, quantization error of instrument is in the same probability distribution in the 0,001/2 mA range.

$$u_3 = \frac{0{,}001/2}{\sqrt{3}}\ \text{mA} = 0{,}3\ \mu A$$

NOTE MPE is the maximum permissible error given by the manufacturer.

δ_{range} range of measurement – can be ignored because of its small value.

u_4 = 0

δ_{temp} ambient temperature fluctuation – for each 10 °C in environmental temperature, the variation of the indicated value is no more than ±1,5 % when testing. For common electronic and electro-mechanical and assembled apparatus, the temperature should be kept 20 °C ± 5 °C, we can consider that limit of variation of the indicated value is ±1 %. Normal distribution: k = 3.

u_5 = (320 µA × 0,01)/3 = 1,1 µA normal

u_5 = (370 µA × 0,01)/3 = 1,2 µA after

$\delta_{humidity}$ relative humidity – when tested under normal operation , it can be ignored. During humidity testing, the relative humidity should be kept 93 % ± 2 % (RH). If it varies, each 1 % of leakage current of basic insulation changes ±1 %. Rectangular distribution: $k = \sqrt{3}$.

u_6 = 0 normal

u_6 = (370 µA × 0,01)/ $\sqrt{3}$ = 2,1 µA

δ_{power} power mains fluctuation – the u_7 reflects the influence of output power and voltage. For the electric heating apparatus and microwave oven, $\Delta P = (0{,}25\ \% \times$ measuring range + $0{,}25\ \% \times$ reading values$) \leq 10\ W$. Leakage current variation does not go over 2 µA. Rectangular distribution: $k = \sqrt{3}$.

$$u_7 = \frac{2}{\sqrt{3}} = 1{,}2\ \mu A$$

Example 4: Distance measurement using calliper gauge ~~(analog)~~

Result: budget of uncertainty of distance for a calliper gauge (analogue).

Description: distance measurement is with a calliper gauge by an expert.

See Table A.4.

Table A.4 – Distance measurement using calliper gauge

Quantity X_i	Source of uncertainty	X_i	Type	Error quantity, $S_p(X_i)$	Probability shape	Distribution division factor, k	Standard uncertainty, $u(X_i)$	Sensitivity coefficient, c_i	Uncertainty contribution, $u_i(y)$
δ_{inst}	Specification for instrument	X_{inst}	B	50 µm	Rectangular	$\sqrt{3}$	29 µm	1	29 µm
δ_{read}	Reading of instrument (e.g. because of parallax)	X_{read}	B	5 µm	Rectangular	$\sqrt{3}$	2,89 µm	1	2,89 µm
δ_{temp}	Ambient temperature fluctuation	X_{temp}	B	0,1 µm	Rectangular	$\sqrt{3}$	0,057 7 µm	1	0,057 7 µm
δ_{calibr}	Calibration of gauge	X_{calibr}	B	0,5 µm	Rectangular	$\sqrt{3}$	2,89 µm	1	1,89 µm
δ_{abbe}	Canting of position of the measuring surface	X_{abbe}	B	60 µm	Rectangular	$\sqrt{3}$	35 µm	1	35 µm
δ_{user}	Difference in contact pressure by user	X_{user}	B	100 µm	Rectangular	$\sqrt{3}$	60 µm	1	60 µm
					Combined standard uncertainty, u_c				75 µm
					Coverage factor k_p = 2; confidence level: 95 %				–
					Expanded uncertainty, $U = u_c \times k_p$				150 µm

Reported result – The measured distance is m_x µm ± 150 µm, k = 2, 95 % confidence level.

δ_{inst} MPE is the maximum permissible error given by the manufacturer. According to the technical information of the manufacturer, MPE = 0,05 mm.

Distribution is rectangular, $k = \sqrt{3}$, u_1 = 0,05 mm/$\sqrt{3}$ = 29 µm.

δ_{read} reading error – depends on human influences and practical experience. Estimated as ±0,005 mm.

Distribution is rectangular, $k = \sqrt{3}$, u_2 = 0,005 mm/$\sqrt{3}$ = 2,89 µm.

δ_{temp} temperature error – because of the specific range of the calliper, influence of temperature can be neglected.

Distribution is rectangular, $k = \sqrt{3}$, u_3 = 0,000 1 mm/$\sqrt{3}$ = 0,057 7 µm.

δ_{calibr} calibration of gauge – according to calibration certificate.

Distribution is rectangular, $k = \sqrt{3}$, u_4 = 0,005 mm/$\sqrt{3}$ = 2,89 µm.

δ_{abbe} canting – because of the position of the measuring surface.

Distribution is rectangular, $k = \sqrt{3}$, u_5 = 0,06 mm/$\sqrt{3}$ = 35 µm.

δ_{user} contact pressure – influence of user, depends on the practical experience of the expert.

Distribution is rectangular, $k = \sqrt{3}$, u_6 = 0,1 mm/ $\sqrt{3}$ = 60 µm.

Example 5: Torque measurement

Result: uncertainty of torque measured.

Description: the complete measurement chain consists of a torque/speed sensor with uncertainty contributions due to eccentricity, internal friction (bearings), repeatability, influence of measuring amplifier and plotting unit (computer).

See Table A.5.

Table A.5 – Torque measurement

Quantity X_i	Source of uncertainty	X_i	Type	Relative error quantity, $S_p(X_i)$	Probability shape	Distribution division factor, k	Relative standard uncertainty, $u(X_i)$	Sensitivity coefficient, C_i	Relative uncertainty contribution, $u_i(y)$
$\delta_{friction}$	Internal friction	$X_{friction}$	B	0,05 %	Rectangular	$\sqrt{3}$	0,028 9 %	1	0,028 9 %
δ_{MPE}	Measurement amplifier	X_{MPE}	B	0,1 %	Rectangular	$\sqrt{3}$	0,057 7 %	1	0,057 7 %
$\delta_{plotter}$	Plotting unit	$X_{plotter}$	B	0,1 %	Rectangular	$\sqrt{3}$	0,057 7 %	1	0,057 7 %
δ_{eccent}	Eccentricity of axes	X_{eccent}	B	0,1 %	Rectangular	$\sqrt{3}$	0,057 7 %	1	0,057 7 %
δ_{repeat}	Repeatability of measurement	X_{repeat}	B	0,5 %	Rectangular	$\sqrt{3}$	0,289 %	1	0,289 %
					Relative combined standard uncertainty, u_c				0,030 7 %
					Relative coverage factor k_p = 2; confidence level: 95 %				–
					Relative expanded uncertainty, $U = u_c \times k_p$				0,61 %

Reported result – The measured torque is m_x (1 ± 0,006 1) N·m, k = 2, 95 % confidence interval.

$\delta_{friction}$ loss because of mechanical friction (clamping unit). Because of practical experience, this error is estimated as +0,1 % of the final result. Estimation: average 0,05 % ± 0,05 %.

Distribution is rectangular, $k = \sqrt{3}$, u_1 = 0,05 %/ $\sqrt{3}$ = 0,028 9 %.

δ_{MPE} standard measuring amplifier; MPE = 0,1 % (accuracy class I).

Distribution is rectangular, $k = \sqrt{3}$, u_2 = 0,1 %/ $\sqrt{3}$ = 0,057 7 %.

$\delta_{plotter}$ normally signals from torque sensors are sampled electronically to be evaluated statistically by plotting unit (e.g. computers and specific measuring boards). Because of practical experience, the error is assumed as ±0,1 % of the final value.

Distribution is rectangular, $k = \sqrt{3}$, u_3 = 0,1 %/ $\sqrt{3}$ = 0,057 7 %.

~~δ_{excent}~~ δ_{eccent} because of misalignment of axes (eccentricity) there are superposed torques (dynamic and static rates of torque) which lead to additional losses. Because of practical experience, the error is assumed as ±0,1 % of the final value.

Distribution is rectangular, $k = \sqrt{3}$, u_4 = 0,1 %/ $\sqrt{3}$ = 0,057 7 %.

δ_{repeat} because of non-identical settings of the measuring device and clamping situation (often because of high/lower experienced staff), there are repeatability errors. Because of practical experience, the error is assumed as ±0,5 % of the final value.

Distribution is rectangular, $k = \sqrt{3}$, u_5 = 0,5 %/ $\sqrt{3}$ = 0,289 %.

Example 6: Pre-conditioning for ball pressure test

Result variable: uncertainty of temperature of test sample.

Description: influence by possible factors: set point of the heater, reading accuracy, spatial temperature gradient based on the thermal isolation of the heater, influence of the two-stage heater control, thermal/temporal inertia of the system, surface/volume ratio of the test specimen (the smaller the ratio, the greater the thermal inertia), uncertainty of thermocouple.

See Table A.6.

Table A.6 – Pre-conditioning for ball pressure test

Quantity X_i	Source of uncertainty	X_i	Type	Error quantity, $S_p(X_i)$	Probability shape	Distribution division factor, k	Standard uncertainty, $u(X_i)$	Sensitivity coefficient, C_i	Uncertainty contribution, $u_i(y)$
δT_R	Spatial temperature gradient and fluctuation	XT_R	B	0,1 °C	Rectangular	$\sqrt{3}$	0,057 7 °C	1	0,057 7 °C
δ_{Indic}	Rough scale for temperature set	X_{Indic}	B	0,5 °C	Rectangular	$\sqrt{3}$	0,289 °C	1	0,289 °C
δT_{contr}	Function of heating control	XT_{contr}	B	1 °C	Rectangular	$\sqrt{3}$	0,577 °C	1	0,577 °C
δ_{Rec}	Influence of recorder	X_{Rec}	B	1,5 °C	Rectangular	$\sqrt{3}$	0,866 °C	1	0,866 °C
δTr_{res}	Transition of resistance	XTr_{res}	B	0,25 °C	Rectangular	$\sqrt{3}$	0,144 °C	1	0,144 °C
δ_{ref}	Calibration of reference thermocouple	X_{ref}	B	0,1 °C	Rectangular	$\sqrt{3}$	0,057 7 °C	1	0,057 7 °C
					Combined standard uncertainty, u_c				1,093 °C
					Coverage factor k_p = 2; confidence level: 95 %				–
					Expanded uncertainty, $U = u_c \times k_p$				2,2 °C

Reported result – The measured temperature is 70,6 °C ± 2,2 °C, k = 2, 95 % confidence interval.

T_{INVP} constant value: 75 °C; temperature set with control dial.

T_R constant value: 4,4 °C; according to the manufacturer's specification, the spatial temperature gradient is ±2 % of maximum temperature (220 °C). Practical experience shows that this value can be divided into one systematic and one random failure. Extreme estimate for systematic fluctuation: due to thermal loss, there is a spatial temperature difference of −4,4 °C.

δ_R extreme estimate for random fluctuation: the mean values fluctuate at intervals (0,08; −0,03). An approximate spatial temperature fluctuation of ±0,1 °C can be specified.

Distribution is rectangular, $k = \sqrt{3}$, u_1 = 0,1 °C/ $\sqrt{3}$ = 0,057 7 °C.

δ_{Indic} due to the rough scale, the temperature of the warming cabinet can only be set with a tolerance of ±0,5 °C (estimated value).

Distribution is rectangular, $k = \sqrt{3}$, u_2 = 0,5 °C/ $\sqrt{3}$ = 0,289 °C.

δ_{contr} distribution is rectangular, $k = \sqrt{3}$, u_3 = 1,0 °C/ $\sqrt{3}$ = 0,577 °C.

~~δ_{secr}~~ δ_{Rec} summarized all impacts on uncertainty of the recorder.

Distribution is rectangular, $k = \sqrt{3}$, u_4 = 1,5 °C/ $\sqrt{3}$ = 0,866 °C.

δTr_{res} estimated impact of transition of resistance based on practical experience.

Distribution is rectangular, $k = \sqrt{3}$, u_5 = 0,25 °C/ $\sqrt{3}$ = 0,144 °C.

δ_{ref} estimated impact of reference element (PT100 based on practical experience).

Distribution is rectangular, $k = \sqrt{3}$, u_6 = 0,1 °C/ $\sqrt{3}$ = 0,057 7 °C.

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Application of uncertainty of measurement to conformity assessment activities in the electrotechnical sector

Application de l'incertitude de mesure aux activités d'évaluation de la conformité dans le secteur électrotechnique

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

APPLICATION OF UNCERTAINTY OF MEASUREMENT TO CONFORMITY ASSESSMENT ACTIVITIES IN THE ELECTROTECHNICAL SECTOR

FOREWORD

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This second edition of IEC Guide 115 has been prepared, in accordance with ISO/IEC Directives, Part 1, Annex A, by IECEE/CTL. This is a non-mandatory guide in accordance with SMB Decision 136/8.

This second edition cancels and replaces the first edition published in 2007.

The main changes with respect to the previous edition are as follows:

a) editorial alignment to ISO/IEC 17025:2017 without adapting the technical content;
b) references to ISO/IEC 17025:2005 and ISO/IEC 17025:2017 in order to help for the transition to the new edition of ISO/IEC 17025.

The text of this IEC Guide is based on the following documents:

Four months' vote	Report on voting
SMBNC/8/DV	SMBNC/14/RV

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 Guide is English.

This publication has been drafted in accordance with the 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/standardsdev/publications.

INTRODUCTION

This document has been prepared by the IECEE Committee of Testing Laboratories (CTL) to provide guidance on the practical application of the measurement uncertainty requirements of ISO/IEC 17025 to the electrical safety testing conducted within the IECEE CB Scheme.

The IECEE CB Scheme is a multilateral, international agreement, among over 40 countries and some 60 national certification bodies, for the acceptance of test reports on electrical products tested to IEC standards.

The aim of the CTL is, among other tasks, to define a common understanding of the test methodology with regard to the IEC standards as well as to ensure and continually improve the repeatability and reproducibility of test results among the member laboratories.

The practical approach to measurement uncertainty outlined in this document has been adopted for use in the IECEE Schemes, and is also extensively used around the world by testing laboratories engaged in testing electrical products to national safety standards.

This document is of particular interest to the following IEC technical committees, which can decide to make use of it if necessary:

TECHNICAL COMMITTEE 13:	ELECTRICAL ENERGY MEASUREMENT AND CONTROL
TECHNICAL COMMITTEE 17:	HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR
TECHNICAL COMMITTEE 18:	ELECTRICAL INSTALLATIONS OF SHIPS AND OF MOBILE AND FIXED OFFSHORE UNITS
TECHNICAL COMMITTEE 20:	ELECTRIC CABLES
TECHNICAL COMMITTEE 21:	SECONDARY CELLS AND BATTERIES
TECHNICAL COMMITTEE 22:	POWER ELECTRONIC SYSTEMS AND EQUIPMENT
TECHNICAL COMMITTEE 23:	ELECTRICAL ACCESSORIES
TECHNICAL COMMITTEE 32:	FUSES
TECHNICAL COMMITTEE 33:	POWER CAPACITORS AND THEIR APPLICATIONS
TECHNICAL COMMITTEE 34:	LIGHTING
TECHNICAL COMMITTEE 35:	PRIMARY CELLS AND BATTERIES
TECHNICAL COMMITTEE 38:	INSTRUMENT TRANSFORMERS
TECHNICAL COMMITTEE 40:	CAPACITORS AND RESISTORS FOR ELECTRONIC EQUIPMENT
TECHNICAL COMMITTEE 47:	SEMICONDUCTOR DEVICES
TECHNICAL COMMITTEE 59:	PERFORMANCE OF HOUSEHOLD AND SIMILAR ELECTRICAL APPLIANCES
TECHNICAL COMMITTEE 61:	SAFETY OF HOUSEHOLD AND SIMILAR ELECTRICAL APPLIANCES
TECHNICAL COMMITTEE 62:	ELECTRICAL EQUIPMENT IN MEDICAL PRACTICE
TECHNICAL COMMITTEE 64:	ELECTRICAL INSTALLATIONS AND PROTECTION AGAINST ELECTRIC SHOCK
TECHNICAL COMMITTEE 65:	INDUSTRIAL-PROCESS MEASUREMENT, CONTROL AND AUTOMATION
TECHNICAL COMMITTEE 66:	SAFETY OF MEASURING, CONTROL AND LABORATORY EQUIPMENT
TECHNICAL COMMITTEE 76:	OPTICAL RADIATION SAFETY AND LASER EQUIPMENT
TECHNICAL COMMITTEE 77:	ELECTROMAGNETIC COMPATIBILITY

TECHNICAL COMMITTEE 78:	LIVE WORKING
TECHNICAL COMMITTEE 80:	MARITIME NAVIGATION AND RADIOCOMMUNICATION EQUIPMENT AND SYSTEMS
TECHNICAL COMMITTEE 82:	SOLAR PHOTOVOLTAIC ENERGY SYSTEMS
TECHNICAL COMMITTEE 110:	ELECTRONIC DISPLAYS

APPLICATION OF UNCERTAINTY OF MEASUREMENT TO CONFORMITY ASSESSMENT ACTIVITIES IN THE ELECTROTECHNICAL SECTOR

1 Scope

This Guide presents a practical approach to the application of uncertainty of measurement to conformity assessment activities in the electrotechnical sector. It is specifically conceived for use in IECEE Schemes as well as by testing laboratories engaged in testing electrical products to national safety standards. It describes the application of uncertainty of measurement principles and provides guidance on making uncertainty of measurement calculations. It also gives some examples relating to uncertainty of measurement calculations for product conformity assessment testing.

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/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

3 Terms and definitions

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

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
coverage factor
number that, when multiplied by the combined standard uncertainty, produces an interval (the expanded uncertainty) about the measurement result that can be expected to encompass a large, specified fraction (e.g. 95 %) of the distribution of values that could be reasonably attributed to the measurand

3.2
combined standard uncertainty
result of the combination of standard uncertainty components

3.3
error of measurement
result of a measurement minus a true value of the measurand

Note 1 to entry: The error of measurement is not precisely quantifiable because the true value lies somewhere unknown within the range of measurement uncertainty.

3.4
expanded uncertainty
value obtained by multiplying the combined standard uncertainty by a coverage factor

3.5
level of confidence
probability that the value of the measurand lies within the quoted range of uncertainty

3.6
measurand
quantity subjected to measurement, evaluated in the state assumed by the measured system during the measurement itself

[SOURCE: IEC 60359:2001, 3.1.1, modified – The NOTES have been deleted.]

3.7
quantity X_i
source of uncertainty

3.8
standard deviation
positive square root of the variance

3.9
standard uncertainty
estimated standard deviation

3.10
uncertainty of measurement
parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

[SOURCE: IEC 60359:2001, 3.1.4, modified – The NOTES have been deleted.]

3.11
Type A evaluation method
method of evaluation of uncertainty of measurement by the statistical analysis of a series of observations

3.12
Type B evaluation method
method of evaluation of uncertainty of measurement by means other than the statistical analysis of a series of observations

4 Application of uncertainty of measurement principles

4.1 General

4.1.1 Qualification and acceptance of Certification Body Testing Laboratories (CBTLs), e.g. in the IECEE, are performed according to ISO/IEC 17025.

ISO/IEC 17025:2005, 5.4.6.2

"Testing laboratories shall have and apply procedures for estimating uncertainty of measurement. In certain cases, the nature of the test method may preclude rigourous, metrologically and statistically valid, calculation of uncertainty of measurement. In these cases the laboratory shall at least attempt to identify all the components of uncertainty and make a reasonable estimation, and shall ensure that the form of reporting of the result does not give a wrong impression of the uncertainty. Reasonable estimation shall be based on knowledge of the performance of the method and on the measurement scope and shall make use of, for example, previous experience and validation data.

NOTE 1 The degree of rigour needed in an estimation of uncertainty of measurement depends on factors such as:

– the requirements of the test method;
– the requirements of the client;
– the existence of narrow limits on which decisions on conformance to a specification are based.

NOTE 2 In those cases where a well-recognized test method specifies limits to the values of the major sources of uncertainty of measurement and specifies the form of presentation of calculated results, the laboratory is considered to have satisfied this clause by following the test method and reporting instructions (see 5.10)."

ISO/IEC 17025:2017, 7.6

"7.6 Evaluation of measurement uncertainty

7.6.1 Laboratories shall identify the contributions to measurement uncertainty. When evaluating measurement uncertainty, all contributions that are of significance, including those arising from sampling, shall be taken into account using appropriate methods of analysis.

7.6.2 A laboratory performing calibrations, including of its own equipment, shall evaluate the measurement uncertainty for all calibrations.

7.6.3 A laboratory performing testing shall evaluate measurement uncertainty. Where the test method precludes rigorous evaluation of measurement uncertainty, an estimation shall be made based on an understanding of the theoretical principles or practical experience of the performance of the method.

NOTE 1 In those cases where a well-recognized test method specifies limits to the values of the major sources of measurement uncertainty and specifies the form of presentation of the calculated results, the laboratory is considered to have satisfied 7.6.3 by following the test method and reporting instructions.

NOTE 2 For a particular method where the measurement uncertainty of the results has been established and verified, there is no need to evaluate measurement uncertainty for each result if the laboratory can demonstrate that the identified critical influencing factors are under control."

4.1.2 ISO/IEC 17025:2005, 5.10.3.1 c) states:

"c) where applicable, a statement on the estimated uncertainty of measurement; information on uncertainty is needed in test reports, when it is relevant to the validity or application of the test results, when a customer's instruction so requires, or when the uncertainty affects compliance to a specification limit;".

ISO/IEC17025:2017, 7.8.3.1 c) states:

"c) where applicable, the measurement uncertainty presented in the same unit as that of the measurand or in a term relative to the measurand (e.g. percent) when:

– it is relevant to the validity or application of the test results;
– a customer's instruction so requires, or

– the measurement uncertainty affects conformity to a specification limit;".

4.1.3 ISO/IEC 17025 was written as a general use document, for all industries. Uncertainty of measurement principles are applied to laboratory testing and presentation of test results to provide a degree of assurance that decisions made about conformance of the products tested according to the relevant requirements are valid. Procedures and techniques for uncertainty of measurement calculations are well established. This document is written to provide more specific guidance on the application of uncertainty of measurement principles to reporting of testing results under the CB Scheme.

4.1.4 Clause 4 of this document focuses on the application of uncertainty of measurement principles under the CB Scheme, while Clause 5 provides guidance on making uncertainty of measurement calculations and includes examples.

4.2 Uncertainty of measurement principles

A challenge to applying uncertainty of measurement principles to conformity assessment activities is managing the cost, time and practical aspects of determining the relationships between various sources of uncertainty. Some relationships are either unknown or would take considerable effort, time and cost to establish. There are a number of proven techniques available to address this challenge. These techniques include eliminating from consideration those sources of variability which have little influence on the outcome and minimizing significant sources of variability by controlling them.

4.3 Background

4.3.1 Test methods used under the IECEE CB Scheme are in essence consensus standards. Criteria used to determine conformance with requirements are most often based on a consensus of judgment of what the limits of the test result should be. Exceeding the limit by a small amount does not result in an imminent hazard. Test methods used can have a precision statement expressing the maximum permissible uncertainty expected to be achieved when the method is used. Historically, test laboratories have used state-of-the-art equipment and not considered uncertainty of measurement when comparing results to limits. Safety standards have been developed in this environment and the limits in the standards reflect this practice.

4.3.2 Test parameters that influence the results of tests can be numerous. Nominal variations in some test parameters have little effect on the uncertainty of the measurement result. Variations in other parameters can have an effect. However, the degree of influence can be minimized by limiting the variability of the parameter when performing the test.

4.3.3 A frequent way of accounting for the effects of test parameters on test results is to define the acceptable limits of variability of test parameters. When this is done, any variability in measurement results obtained due to changes in the controlled parameters is not considered significant if the parameters are controlled within the limits. Examples of the application of this technique require:

a) input power source to be maintained: voltage ±2 %, frequency ±0,5 %, total harmonic distortion maximum 3 %;
b) ambient temperature: 23 °C ± 2 °C;
c) relative humidity: 93 % ± 2 % (RH);
d) personnel: documented technical competency requirements for the test;
e) procedures: documented laboratory procedures;
f) equipment accuracy: instrumentation with accuracy according to CTL OD-5014.

NOTE The acceptable limits in items a) through c) are given as examples and do not necessarily represent actual limits established.

4.3.4 The end result of controlling sources of variability within prescribed limits is that the measurement result can be used as the best estimate of the measurand. In effect, the uncertainty of measurement about the measured result is negligible with regard to the final pass/fail decision.

4.4 Uncertainty of measurement principles – Application of procedures

4.4.1 When a test results in measurement of a variable, there is uncertainty associated with the test result obtained.

4.4.2 Procedure 1, see Figure 1, is used when calculation of uncertainty of measurement is required by ISO/IEC 17025:2017, 7.6.3 and 7.8.3.1 c). Calculate the uncertainty for measurement (see Clause 5) and compare the measured result with the uncertainty band to a defined acceptable limit. The measurement complies with the requirement if the probability of its being within the limit is at least 50 %.

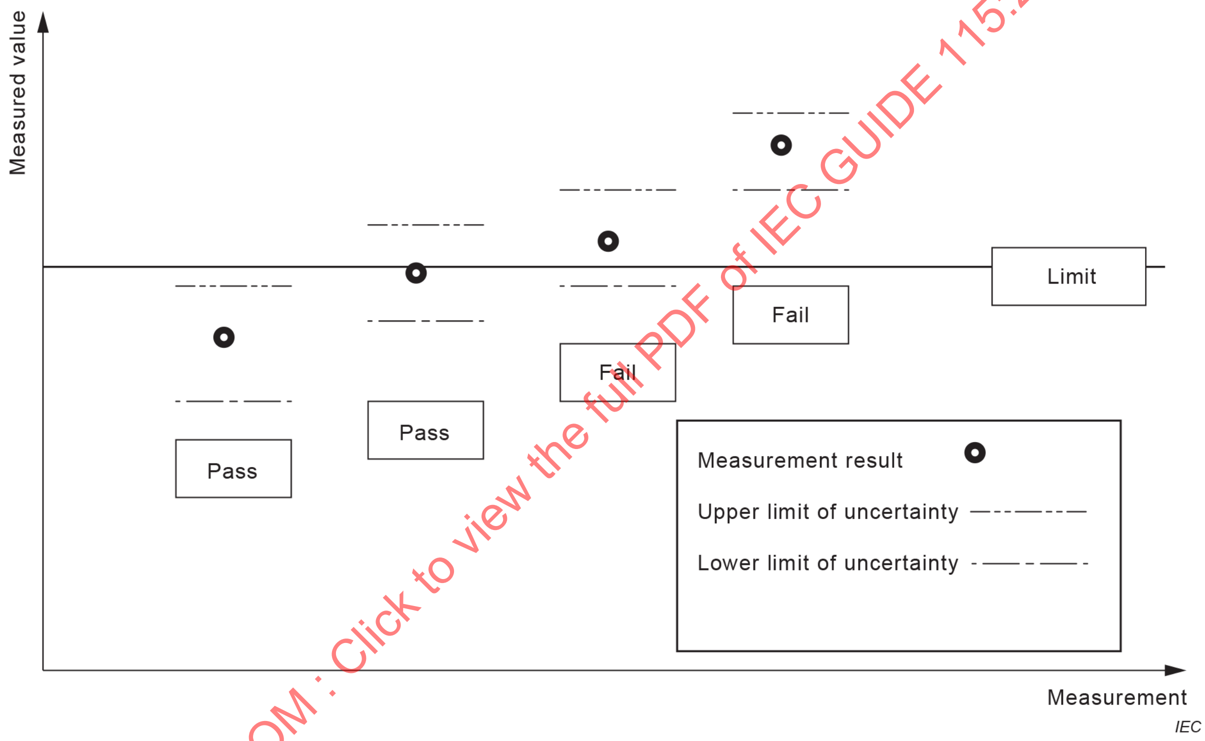

Figure 1 – Procedure 1: uncertainty of measurement calculated

4.4.3 Procedure 2, see Figure 2, is used when ISO/IEC 17025:2017, 7.6.3, Note 2, applies. Procedure 2 is the traditional method used under the CB Scheme and has been referred to as the "accuracy method". The test performed is routine. Sources of uncertainty are minimized so that the uncertainty of the measurement need not be calculated to determine conformance with the limit. Variability in test parameters is within acceptable limits. Test parameters such as power source voltage, ambient temperature and ambient humidity are maintained within the defined acceptable limits for the test. Personnel training and laboratory procedures minimize uncertainty of measurement due to human factors. Instrumentation used has an uncertainty within prescribed limits.

NOTE The name, accuracy method, comes from the concept of limiting uncertainty due to instrumentation by using instruments within prescribed accuracy limits. For this purpose, the accuracy specification for an instrument is considered the maximum uncertainty of measurement attributable to the instrument.

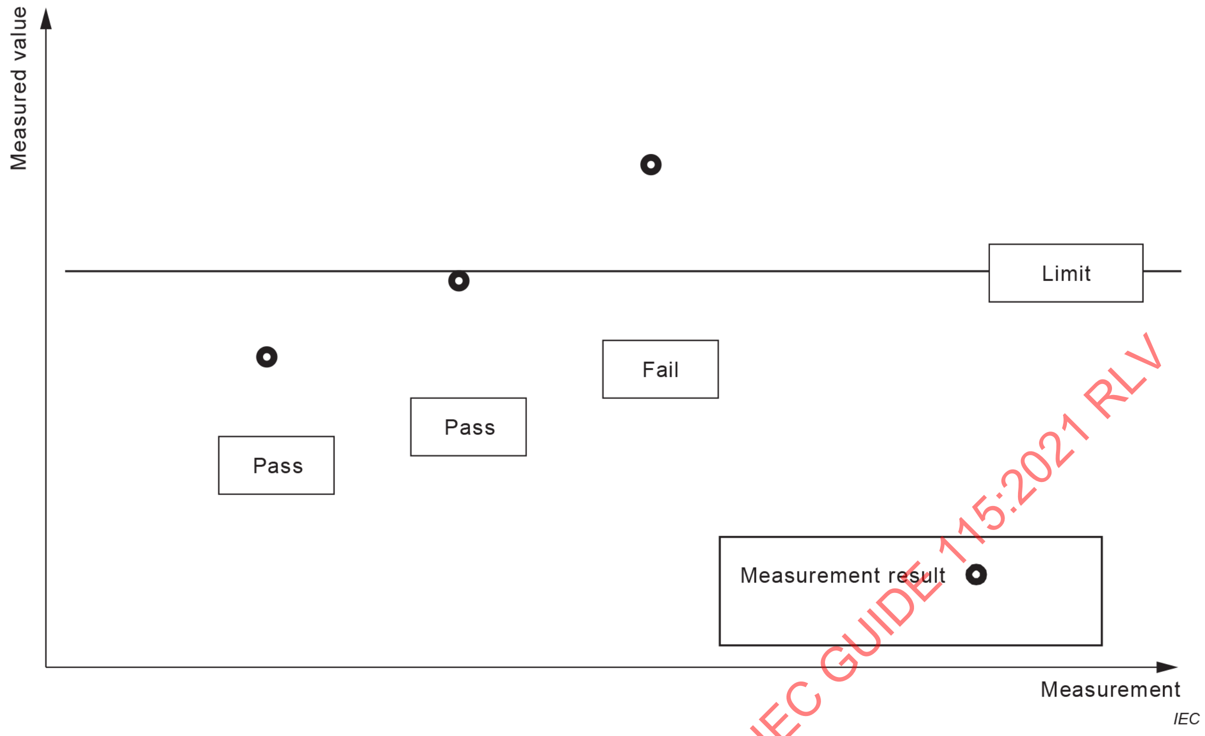

Figure 2 – Procedure 2: accuracy method

4.4.4 The measurement result is considered in conformance with the requirement if it is within the prescribed limit. It is not necessary to calculate the uncertainty associated with the measurement result.

4.4.5 Example – Procedure 2

- Power supply output voltage measurement test
  a) Method

  Connect the power supply to a mains source of rated voltage, ±2 %, and rated frequency. Measure output voltage from power supply while loaded to rated current, ±2 %, with a non-inductive resistive load. The test is to be performed in an ambient temperature of 23 °C ± 2 °C.

  Use meters having an accuracy conforming to CTL OD-5014.

  The power supply conforms to the requirements if the output voltage is ±5 % of rated value.

  b) Results

  Power supply rating: 240 V, 50 Hz input; 5 V d.c., 2 A output. See Table 1.

Table 1

Input		Output	
U V	**Frequency** Hz	*I* A	*U* V
242	50	2,01	5,1

Test ambient temperature: 24 °C.

The accuracy of the instruments used is shown in Table 2.

Table 2

Meter	Calibrated accuracy for scale used for measurement	CTL decision 251A, max.
Thermometer	±1,0 °C	±2,0 °C
Voltmeter	±0,5 %	±1,5 %
Frequency meter	±0,2 %	±0,2 %
Current meter	±0,5 %	±1,5 %

The conclusion of the test is that the power supply conforms to the requirement.

4.5 Conclusion

4.5.1 The traditional approach to addressing uncertainty of measurement for conformity assessment activities under the CB Scheme has been the application of the accuracy method. This method minimizes sources of uncertainty associated with the performance of routine tests so that the measurement result can be directly compared with the test limit to determine conformance with the requirement. This method conforms to the requirements in ISO/IEC 17025. The accuracy method takes less time and costs less to implement than detailed uncertainty of measurement calculations and the conclusions reached are valid with regard to the final pass/fail decision.

4.5.2 In situations where the traditional, accuracy method does not apply, uncertainty of measurement values are calculated and reported along with the variables results obtained during testing.

5 Guidance on making uncertainty of measurement calculations including examples of how to perform the calculations

5.1 General principles

5.1.1 Clause 5 is meant to be a short and simplified summary of the steps to be taken by a CBTL when the need to estimate uncertainties arises. It also includes examples of how to perform the calculations.

5.1.2 It is by no means a comprehensive paper about measurement uncertainty (MU), its sources and estimation in general, but is supposed to offer a practical approach for most applicable circumstances within a CBTL in the IECEE CB Scheme.

5.1.3 No measurement is perfect and the imperfections give rise to error of measurement in the result. Consequently, the result of a measurement is only an approximation to the measured value (measurand) and is only complete when accompanied by a statement of the uncertainty of that approximation. Indeed, because of measurement uncertainty, a true value can never be known.

5.1.4 The total uncertainty of a measurement is a combination of a number of component uncertainties. Even a single instrument reading may be influenced by several factors. Careful consideration of each measurement involved in the test is required to identify and list all the factors that contribute to the overall uncertainty. This is a very important step and requires a good understanding of the measuring equipment, the principles and practice of the test and the influence of environment.

5.1.5 ISO/IEC GUIDE 98-3:2008 has adopted the approach of grouping uncertainty components into two categories based on their method of evaluation: Type A and Type B. This categorization of the methods of evaluation, rather than of the components themselves, avoids certain ambiguities.

5.1.6 Type A evaluation is carried out by calculation from a series of repeated observations, using statistical methods.

5.1.7 Type B evaluation is carried out by means other than that used for Type A. For example, by judgment based on Table 3.

Table 3

Data in calibration certificates	This enables corrections to be made and Type B uncertainties to be assigned
Previous measurement data	For example, history graphs can be constructed and yield useful information about changes with time
Experience or general knowledge	Behaviour and properties of similar materials and equipment
Accepted values of constants	Associated with materials and quantities
Manufacturers' specifications	
All other relevant information	

5.1.8 Individual uncertainties are evaluated by the appropriate method and each is expressed as a standard deviation and is referred to as a standard uncertainty.

5.2 Summary of steps when estimating uncertainty

5.2.1 Identify the factors that can significantly influence the measured values and review their applicability. There are many possible sources in practice, mainly including the following.

a) Contribution from calibration of the measuring instruments, including contribution from reference or working standards.

b) Temperature error at the beginning and end of a test (e.g. winding resistance method).

c) Uncertainty related to the loading applied and the measurement of it.

d) Velocity of air flow over the test sample and uncertainty in measuring it.

e) For digital instruments, there are the number of displayed digits and the stability of the display at the time the reading is taken. In addition, the reported uncertainty of an instrument does not necessarily include the display.

f) Instrument resolution, limits in graduation of a scale.

g) Approximations and assumptions incorporated in the measurement method.

h) Uncertainty due to the procedures used to prepare the sample for test and actually testing it.

i) If a computer is used to acquire the readings from the instrument, there is uncertainty associated with the processing of the data due to calculations or other manipulations within the computer such as analogue-to-digital conversions, and conversions between floating point and integer numbers.

j) Rounded values of constants and other parameters used for calculations.

k) Effects of environmental conditions (e.g. variation in ambient temperature) or measurement of these on the measurement.

NOTE 1 Negligible in case environmental conditions are stable (which is assumed and expected from a CBTL).

l) Variability of the power supply source (voltage, current, frequency) the sample is connected to and the uncertainty in measuring it.

NOTE 2 Negligible in case stabilized supply sources are used (which is assumed and expected from a CBTL).

m) Personal bias in reading analogue instruments (e.g. parallax error or the number of significant figures that can be interpolated).

NOTE 3 Negligible in case of digital displays or in case of appropriate training (which is assumed and expected from a CBTL).

n) Variation between test samples and in case the samples are not fully representative.

Unless the IEC standard specifies tests on multiple samples, only one sample is tested.

NOTE 4 The variation between test samples is assumed to be negligible by CBTLs.

NOTE 5 This list does not state all of the items that can contribute to MU. It is possible that other factors will need to be identified and considered by each individual laboratory.

5.2.2 Transform influencing factors x_i to the unit of the measured value (quantify), for which you are going to estimate the uncertainty, if not already given in that unit (e.g. if the unit of the measured value is the volt (V) and a resistor's tolerance in ohms (Ω) is one of the influencing factors, transform the change of resistance to the resulting contribution in volts).

Once the uncertainty contributions associated with a measurement process have been identified and quantified, a combination of them in some manner provides a single value of uncertainty that can be associated with the measurement result.

5.2.3 Determine the probability distribution

The probability distribution of the measured quantity describes the variation in probability of the true value lying at any particular difference from the measured or assigned result. The form of the probability distribution will often not be known, and an assumption shall be made, based on prior knowledge or theory, that it approximates to one of the common forms. It is then possible to calculate the standard uncertainty, $U(x_i)$, for the assigned form from simple expressions. The four main distributions of interest are

– normal,
– rectangular,
– triangular, and
– U-shaped.

5.2.4 Normal distribution is assigned when the uncertainty is taken from, for example, a calibration certificate/report where the coverage factor, k, is stated. The standard uncertainty is found by dividing the stated uncertainty from the calibration certificate by its coverage factor k, which is $k = 2$ for a level of confidence of approximately 95 % (recommended for CBTLs in the IECEE CB Scheme). It is possible that k will need to be confirmed with the calibration laboratory in case it is not stated on the certificate.

Normal: $u(x_i) = \dfrac{U}{k}$

where U is the expanded uncertainty stated on the certificate.

5.2.5 Rectangular distribution means that the probability density is constant within the prescribed limits. A rectangular distribution should be assigned where a manufacturer's specification limits are used as the uncertainty, unless there is a statement of confidence associated with the specification, in which case a normal distribution can be assumed.

Rectangular: $u(x_i) = \dfrac{a_i}{\sqrt{3}}$

where a_i is the half width of the rectangular distribution.

5.2.6 U-shaped distribution is applicable to mismatch uncertainty. The value of the limit for the mismatch uncertainty, *M*, associated with the power transfer at a junction is obtained from

$$100\,((1 \pm |\Gamma_G||\Gamma_L|)^2 - 1)\,\% \text{ or } 20\log_{10}(1 \pm |\Gamma_G||\Gamma_L|)\text{ dB (logarithmic units)}$$

where Γ_G and Γ_L are the reflection coefficients for the source and load.

The mismatch uncertainty is asymmetric about the measured result; however, the difference this makes to the total uncertainty is often insignificant, and it is acceptable to use the larger of the two limits.

U-shaped distribution is used for electromagnetic compatibility purposes but also for climatic control of temperature and humidity.

U-shaped: $u(x_i) = \frac{M}{\sqrt{2}}$

5.2.7 Triangular distribution means that the probability of the true value lying at a point between two prescribed limits increases uniformly from zero at the extremities to the maximum at the centre. A triangular distribution should be assigned where the contribution has a distribution with defined limits and where the majority of the values between the limits lie around the central point.

Triangular: $u(x_i) = \frac{a_i}{\sqrt{6}}$

5.2.8 A detailed approach to the determination of probability distribution can be found in ISO/IEC GUIDE 98-3:2008.

5.2.9 Correlation: For the statistical approach to the combination of individual uncertainty contributions to be valid, it is assumed that there are no common factors associated with these contributions.

5.2.10 The effect of correlated input quantities can be to increase or decrease the combined standard uncertainty. For example, if the area of a rectangle is determined by measurement of its width and height using the same measuring implement the correlation will increase the uncertainty. On the other hand, if a gauge block were to be measured by comparison with another of identical material, the effect of uncertainty due to temperature will depend on the difference in temperature between the two blocks and will therefore tend to cancel.

5.2.11 If the correlation is such that the combined standard uncertainty is increased, the most straightforward approach is to add the standard uncertainties for these quantities before combining the result statistically with other contributions.

5.2.12 If, however, the correlation is such that the combined standard uncertainty will be decreased, as in the gauge-block comparison above, the difference in standard uncertainty would be used as the input quantity.

5.2.13 A detailed approach to the treatment of correlated input quantities can be found in ISO/IEC GUIDE 98-3:2008.

5.2.14 Establish the uncertainty budget m_x, containing the standard uncertainties of each influencing factor (quantity) $u(x_i)$. Usually $u(x_i)$ will already represent the uncertainty contribution $u_i(y)$ of each factor. A convenient way to do that is to write the identified and potential contributing factors and their estimates into a table (see examples). The uncertainty contribution $u(m_x)$ is calculated by the formula:

$$u(m_x) = \sqrt{\left(u_1(y)^2 + u_2(y)^2 + \ldots + u_i(y)^2\right)}$$

5.2.15 Calculate the expanded uncertainty *U*, considering your level of confidence. The expanded uncertainty is calculated by multiplying the standard uncertainty with the coverage factor *k*, which is $k = 2$ for a level of confidence of approximately 95 % (recommended for CBTLs in the IECEE CB Scheme), or $k = 3$ for approximately 99,7 % level of confidence.

$$u = k \times u(m_x)$$

5.2.16 Report the result of the measurement comprising the measured value, the associated expanded uncertainty *U* and the coverage factor *k*.

EXAMPLE 10,5 V ± 0,4 V (coverage factor $k = 2$, for a level of confidence of approximately 95 %).

5.3 Simple example – Estimation of measurement uncertainty for a temperature-rise test with thermocouples

The following example has been chosen to demonstrate the basic method of evaluating the uncertainty of measurement. It has been simplified in order to provide transparency for the reader and intended to be general guidance on how to proceed. The contributions and values are not intended to imply mandatory or preferred requirements. The input quantities are regarded as being not correlated.

a) Identification of significant influencing factors

See Table 4.

Table 4

Quantity X_i	Source of uncertainty	Source of error quantity $s_p(x_i)$
δ_{TC}	Uncertainty of thermocouple	For example, from specifications
δ_{HR}	Uncertainty of hybrid recorder	For example, from the calibration certificate of a calibration laboratory, including their inherited uncertainty and the listed coverage factor of $k = 3$
δ_{Fixing}	Influence of fixing method of thermocouples	For example, from the laboratory's own investigation campaign
$\delta_{ambient}$	Uncertainty of ambient temperature measurement	For example, measured by a separate instrument, data taken from the manufacturer's specifications

b) Relating influencing factors to the measured value

The relationship between the influencing factor and the measured value evaluated at the point of measurement is known as the sensitivity coefficient. In this simple example, there is a 1-to-1 relationship between the influencing factors and the measured value. Therefore, the sensitivity coefficient is 1. For more complex relationships, the sensitivity coefficient can take on other values. See Table 5.

Table 5

Quantity X_i	Estimate x_i	Sensitivity coefficient	Error quantity s_p (x_i)
δ_{TC}	−40 °C to +350 °C	1	0,5 °C
δ_{HR}	Worst case of calibrated items, e.g. −25 °C to +250 °C	1	1,8 °C
δ_{Fixing}	Worst case of investigated temperatures, e.g. 25 °C, 85 °C, 150 °C	1	2,4 °C
$\delta_{ambient}$	Usually used in the vicinity of 25 °C	1	1,25 °C

c) Uncertainty budget, m_x

See Table 6.

Table 6

Quantity X_i	Estimate x_i	Error quantity s_p (x_i)	Probability distribution	Standard uncertainty $u(x_i)$	Sensitivity coefficient	Uncertainty contribution $u_i(y)$
δ_{TC}	−40 °C to +350 °C	0,5 °C	Rectangular	0,29 °C	1	0,29 °C
δ_{HR}	−25 °C to +250 °C	1,8 °C	Normal	0,6 °C	1	0,6 °C
δ_{Fixing}	25 °C, 85 °C, 150 °C	2,4 °C	Normal	2,4 °C	1	2,4 °C
$\delta_{ambient}$	–	1,25 °C	Rectangular	0,72 °C	1	0,72 °C
m_x	25 °C to 150 °C	–				$u(m_x)$ = 2,63 °C

$$u(m_x) = \sqrt{\left(u_1^2 + u_2^2 + u_3^2 + \ldots\right)}$$

$\sqrt{3}$ = 1,73, $\sqrt{6}$ = 2,45

d) Expanded uncertainty, U

$U = k \times u(m_x)$ = 2 × 2,63 °C = 5,27 °C = approximately 5,3 °C

e) Reported result

The measured temperature rise is xx,x K ± 5,3 °C

The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k = 2, which for a normal distribution corresponds to a coverage probability of approximately 95 %.

Annex A
(informative)

Uncertainty of measurement calculations for product conformity assessment testing – Examples 1 to 6

IECEE CTL WG 1 provides the following set of examples of calculations to illustrate the application of uncertainty of measurement to conformity assessment activities carried out under the IECEE CB Scheme.

Example 1 – Input test

Example 2 – Input power test

Example 3 – Leakage current measurement test

Example 4 – Distance measurement using calliper gauge

Example 5 – Torque measurement

Example 6 – Pre-conditioning for ball pressure test

These examples have been simplified to illustrate various steps of the process for performing uncertainty of measurement calculations.

Example 1: Input test

Result: uncertainty of input current expressed as a percentage of reading in amperes.

Description: Input current is measured to product connected to mains power source. Input current to product is proportional to voltage applied.

See Table A.1.

Table A.1 – Input test

Quantity X_i	Source of uncertainty	X_i	Type	Relative error quantity, $S_p(X_i)$	Probability shape	Distribution division factor, k	Relative standard uncertainty, $u(X_i)$	Sensitivity coefficient, C_i	Relative uncertainty contribution, $u_i(y)$
δ_R	Repeatability of measurement	X_R	A		Normal		0,2 %	1	0,2 %
δ_{instr}	Specification for instrument	X_{instr}	B	0,5 %	Rectangular	$\sqrt{3}$	0,3 %	1	0,3 %
$\delta_{reading}$	Reading error	$X_{reading}$	B	0,3 %	Rectangular	$\sqrt{3}$	0,17 %	1	0,17 %
δ_{power}	Specification for power mains fluctuation	X_{power}	B	0,17 %	Rectangular	$\sqrt{3}$	0,1 %	1	0,1 %
					Relative combined standard uncertainty, u_c				0,41 %
					Coverage factor k_p = 2; confidence level: 95 %				–
					Relative expanded uncertainty, $U = u_c \times k_P$				0,81 %

Reported result – The measured input current is m_x (1 ± 0,008 1) A, k = 2,95 % confidence level.

δ_R repeatability of measurement – uncertainty due to repeatedly making the same measurement – Type A with normal distribution

$$u_1 = \bar{\sigma}_{n-1} = \sqrt{\frac{\sum\left(x_i - \bar{x}\right)^2}{n(n-1)}} = 0{,}2\ \%$$

NOTE This formula is used to estimate the standard deviation of the sampling distribution of the mean (i.e. to estimate the standard error of the mean). This estimate is represented by the symbol u_1 in the equation for δ_R.

δ_{instr} specification for instrument – uncertainty due to instrument used for measurements. Determined from specifications in instrument manual (MPE). Meter is 0,5 class. Error is ±0,5 %. Rectangular distribution, $k = \sqrt{3}$.

$u_2 = 0{,}5 / \sqrt{3} = 0{,}3\ \%$

$\delta_{reading}$ reading of instrument – uncertainty due to technician reading the instrument. When testing meter is 0,5 A per graduation and 100 graduations, estimating reading error is 1/10 graduation. In the practice testing, reading value is 34,8 line. Rectangular distribution, $k = \sqrt{3}$.

$u_3 = [(0{,}1)(0{,}5)]/[(34{,}5)(0{,}5)\ \sqrt{3}\,] \times 100 = 0{,}17\ \%$

δ_{power} power mains fluctuation – uncertainty due to fluctuations in power mains voltage. Uncertainty of the regulator is 0,2%. Rectangular distribution, $k = \sqrt{3}$. Sensitivity coefficient = 1.

$u_4 = 0{,}2 / \sqrt{3} = 0{,}1$ %

Example 2: Input power test

Result: uncertainties expressed as a percentage of input power in watts.

Description: input power is measured to product operating in stable condition while connected to regulated mains power source. Input power is measured by analogue or digital power meter.

See Table A.2.

Table A.2 – Input power test

Quantity X_i	Source of uncertainty	X_i	Type	Relative error quantity, $S_p(X_i)$	Probability shape	Distribution division factor, k	Relative standard uncertainty, $u(X_i)$	Sensitivity coefficient, c_i	Relative uncertainty contribution, $u_i(y)$
δ_R	Repeatability of measurement	X_R	A		Normal		0,2 %	1	0,2 %
δ_{instr}	Specification for instrument	X_{instr}	A	0,2 %	Normal	2	0,1 %	1	0,1 %
$\delta_{reading}$	Reading error	$X_{reading}$	B	0,45 %	Rectangular	$\sqrt{3}$	0,26 %	1	0,26 %
δ_{power}	Specification for power mains fluctuation	X_{power}	B	0,35 %	Rectangular	$\sqrt{3}$	0,2 %	1	0,20 %
					Relative combined standard uncertainty, u_c				0,40 %
					Coverage factor k_p = 2; confidence level: 95 %				–
					Relative expanded uncertainty, $U = u_c \times k_p$				0,80 %

Reported result – The measured input power is m_x (1 ± 0,008) W, k = 2, 95 % confidence level.

δ_R repeating error repeatability of measurement – uncertainty due to repeatedly making the same measurement – Type A with normal distribution

$$u_1 = \sigma_{n-1} = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n(n-1)}} = 0{,}2\ \%$$

δ_{instr} specification for instrument – uncertainty due to instrument used for measurements. Determined from calibration laboratory report. Expanded uncertainty reported is ±0,2. Distribution is normal, k = 2.

u_2 = 0,2/2 = 0,1 %

$\delta_{reading}$ reading of instrument – uncertainty due to technician reading instrument – estimated.

δ_{power} specification of power mains fluctuation – uncertainty due to fluctuations in power mains voltage.

Example 3: Leakage current measurement test

Result: uncertainties of leakage current expressed in micro-amperes.

Description: leakage current is measured with product operating under normal working conditions. Leakage current is measured directly by a leakage current meter. The measurement is carried out under the following conditions.

a) Between any pole of the power source and metal parts that can be easily touched or the metal foil on the insulating materials that can be easily touched, not exceeding 20 cm by 10 cm.
b) Between any pole of the power source and the metal parts only using basic insulation to separate live parts of one stage apparatus.
c) Before and after humidity conditioning.

Tested parts are:

– between live parts and the enclosure isolated from the live part by only basic insulation;
– between the live parts and the shell with reinforced insulation.

See Table A.3.

Table A.3 – Leakage current measurement test

Quantity X_i	Source of uncertainty	X_i	Type	Error quantity, $S_p(X_i)$ µA	Probability shape	Distribution division factor, k	Standard uncertainty, $u(X_i)$ µA	Sensitivity coefficient, C_i	Uncertainty contribution, $u_i(y)$ µA
δ_R	Repeatability of measurement	X_R	A		Normal		1	1	1
δ_{inher}	Calibration of instrument	X_{inher}	A	15 normal 18 after	Normal	3	5 normal 6 after	1	5 normal 6 after
δ_{instr}	Quantum error of instrument	X_{instr}	B	0,5	Rectangular	$\sqrt{3}$	0,3	1	0,3
δ_{range}	Range of measurement	X_{range}	B	0,0	Rectangular	$\sqrt{3}$	0,0	1	0,0
δ_{temp}	Ambient temperature fluctuation	X_{temp}	A	3,2 normal 3,7 after	Normal	3	1 normal 1,2 after	1	1 normal 1,2 after
$\delta_{humidity}$	Relative humidity	$X_{humidity}$	B	3,7	Rectangular	$\sqrt{3}$	2 after	1	2,1 after
δ_{power}	Specification of power mains fluctuation	X_{power}	B	2	Rectangular	$\sqrt{3}$	1,2	1	1
					Combined standard uncertainty, u_c				5,3 normal 6,6 after
					Coverage factor k_p = 2; confidence level: 95 %				–
					Expanded uncertainty, $U = u_c \times k_p$				11 normal 13 after

Reported result – The measured leakage current is 320 µA ± 11 µA and 370 µA ± 13 µA after humidity, k = 2,95 % confidence level.

δ_R repeating error repeatability of measurement – uncertainty due to repeatedly making the same measurement – Type A with a normal distribution:

$$u_1 = \bar{\sigma}_{n-1} = \sqrt{\frac{\sum\left(x_i - \bar{x}\right)^2}{n(n-1)}} = 1\ \mu A$$

δ_{inher} calibration of instrument – leakage current of basic insulation is 320 µA under operating condition and 370 µA under humidity conditioning. According to the certificate of calibration, the system error of the measured instrument is ±5 %, normal, k = 3.

u_2 = 0,05 × 320/3 = 5 µA normal condition

u_2 = 0,05 × 370/3 = 6 µA humidity condition

δ_{instr} quantum error of instrument – uncertainty due to instrument used for measurements (MPE). When testing, used 2 mA measuring range, resolution is 0,001 mA, quantization error of instrument is in the same probability distribution in the 0,001/2 mA range.

$$u_3 = \frac{0{,}001/2}{\sqrt{3}}\ \text{mA} = 0{,}3\ \mu A$$

NOTE MPE is the maximum permissible error given by the manufacturer.

δ_{range} range of measurement – can be ignored because of its small value.

u_4 = 0

δ_{temp} ambient temperature fluctuation – for each 10 °C in environmental temperature, the variation of the indicated value is no more than ±1,5 % when testing. For common electronic and electro-mechanical and assembled apparatus, the temperature should be kept 20 °C ± 5 °C, we can consider that limit of variation of the indicated value is ±1 %. Normal distribution: k = 3.

u_5 = (320 µA × 0,01)/3 = 1,1 µA normal

u_5 = (370 µA × 0,01)/3 = 1,2 µA after

$\delta_{humidity}$ relative humidity – when tested under normal operation , it can be ignored. During humidity testing, the relative humidity should be kept 93 % ± 2 % (RH). If it varies, each 1 % of leakage current of basic insulation changes ±1 %. Rectangular distribution: $k = \sqrt{3}$.

u_6 = 0 normal

u_6 = (370 µA × 0,01)/ $\sqrt{3}$ = 2,1 µA

δ_{power} power mains fluctuation – the u_7 reflects the influence of output power and voltage. For the electric heating apparatus and microwave oven, $\Delta P = (0{,}25\ \% \times$ measuring range + 0,25 % $\times$ reading values$) \leq 10\ \text{W}$. Leakage current variation does not go over 2 µA. Rectangular distribution: $k = \sqrt{3}$.

$$u_7 = \frac{2}{\sqrt{3}} = 1{,}2\ \mu A$$

Example 4: Distance measurement using calliper gauge

Result: budget of uncertainty of distance for a calliper gauge (analogue).

Description: distance measurement is with a calliper gauge by an expert.

See Table A.4.

Table A.4 – Distance measurement using calliper gauge

Quantity X_i	Source of uncertainty	X_i	Type	Error quantity, $S_p(X_i)$	Probability shape	Distribution division factor, k	Standard uncertainty, $u(X_i)$	Sensitivity coefficient, C_i	Uncertainty contribution, $u_i(y)$
δ_{inst}	Specification for instrument	X_{inst}	B	50 µm	Rectangular	$\sqrt{3}$	29 µm	1	29 µm
δ_{read}	Reading of instrument (e.g. because of parallax)	X_{read}	B	5 µm	Rectangular	$\sqrt{3}$	2,89 µm	1	2,89 µm
δ_{temp}	Ambient temperature fluctuation	X_{temp}	B	0,1 µm	Rectangular	$\sqrt{3}$	0,057 7 µm	1	0,057 7 µm
δ_{calibr}	Calibration of gauge	X_{calibr}	B	0,5 µm	Rectangular	$\sqrt{3}$	2,89 µm	1	1,89 µm
δ_{abbe}	Canting of position of the measuring surface	X_{abbe}	B	60 µm	Rectangular	$\sqrt{3}$	35 µm	1	35 µm
δ_{user}	Difference in contact pressure by user	X_{user}	B	100 µm	Rectangular	$\sqrt{3}$	60 µm	1	60 µm
					Combined standard uncertainty, u_c				75 µm
					Coverage factor k_p = 2; confidence level: 95 %				–
					Expanded uncertainty, $U = u_c \times k_p$				150 µm

Reported result – The measured distance is m_x µm ± 150 µm, k = 2, 95 % confidence level.

δ_{inst} MPE is the maximum permissible error given by the manufacturer. According to the technical information of the manufacturer, MPE = 0,05 mm.

Distribution is rectangular, $k = \sqrt{3}$, u_1 = 0,05 mm/ $\sqrt{3}$ = 29 µm.

δ_{read} reading error – depends on human influences and practical experience. Estimated as ±0,005 mm.

Distribution is rectangular, $k = \sqrt{3}$, u_2 = 0,005 mm/ $\sqrt{3}$ = 2,89 µm.

δ_{temp} temperature error – because of the specific range of the calliper, influence of temperature can be neglected.

Distribution is rectangular, $k = \sqrt{3}$, u_3 = 0,000 1 mm/ $\sqrt{3}$ = 0,057 7 µm.

δ_{calibr} calibration of gauge – according to calibration certificate.

Distribution is rectangular, $k = \sqrt{3}$, u_4 = 0,005 mm/ $\sqrt{3}$ = 2,89 µm.

δ_{abbe} canting – because of the position of the measuring surface.

Distribution is rectangular, $k = \sqrt{3}$, u_5 = 0,06 mm/ $\sqrt{3}$ = 35 µm.

δ_{user} contact pressure – influence of user, depends on the practical experience of the expert.

Distribution is rectangular, $k = \sqrt{3}$, u_6 = 0,1 mm/ $\sqrt{3}$ = 60 µm.

Example 5: Torque measurement

Result: uncertainty of torque measured.

Description: the complete measurement chain consists of a torque/speed sensor with uncertainty contributions due to eccentricity, internal friction (bearings), repeatability, influence of measuring amplifier and plotting unit (computer).

See Table A.5.

Table A.5 – Torque measurement

Quantity X_i	Source of uncertainty	X_i	Type	Relative error quantity, $S_p(X_i)$	Probability shape	Distribution division factor, k	Relative standard uncertainty, $u(X_i)$	Sensitivity coefficient, C_i	Relative uncertainty contribution, $u_i(y)$
$\delta_{friction}$	Internal friction	$X_{friction}$	B	0,05 %	Rectangular	$\sqrt{3}$	0,028 9 %	1	0,028 9 %
δ_{MPE}	Measurement amplifier	X_{MPE}	B	0,1 %	Rectangular	$\sqrt{3}$	0,057 7 %	1	0,057 7 %
$\delta_{plotter}$	Plotting unit	$X_{plotter}$	B	0,1 %	Rectangular	$\sqrt{3}$	0,057 7 %	1	0,057 7 %
δ_{eccent}	Eccentricity of axes	X_{eccent}	B	0,1 %	Rectangular	$\sqrt{3}$	0,057 7 %	1	0,057 7 %
δ_{repeat}	Repeatability of measurement	X_{repeat}	B	0,5 %	Rectangular	$\sqrt{3}$	0,289 %	1	0,289 %
					Relative combined standard uncertainty, u_c				0,030 7 %
					Relative coverage factor k_p = 2; confidence level: 95 %				–
					Relative expanded uncertainty, $U = u_c \times k_p$				0,61 %

Reported result – The measured torque is m_x (1 ± 0,006 1) N·m, k = 2, 95 % confidence interval.

$\delta_{friction}$ loss because of mechanical friction (clamping unit). Because of practical experience, this error is estimated as +0,1 % of the final result. Estimation: average 0,05 % ± 0,05 %.

Distribution is rectangular, $k = \sqrt{3}$, u_1 = 0,05 %/ $\sqrt{3}$ = 0,028 9 %.

δ_{MPE} standard measuring amplifier; MPE = 0,1 % (accuracy class I).

Distribution is rectangular, $k = \sqrt{3}$, u_2 = 0,1 %/ $\sqrt{3}$ = 0,057 7 %.

$\delta_{plotter}$ normally signals from torque sensors are sampled electronically to be evaluated statistically by plotting unit (e.g. computers and specific measuring boards). Because of practical experience, the error is assumed as ±0,1 % of the final value.

Distribution is rectangular, $k = \sqrt{3}$, u_3 = 0,1 %/ $\sqrt{3}$ = 0,057 7 %.

δ_{eccent} because of misalignment of axes (eccentricity) there are superposed torques (dynamic and static rates of torque) which lead to additional losses. Because of practical experience, the error is assumed as ±0,1 % of the final value.

Distribution is rectangular, $k = \sqrt{3}$, u_4 = 0,1 %/ $\sqrt{3}$ = 0,057 7 %.

δ_{repeat} because of non-identical settings of the measuring device and clamping situation (often because of high/lower experienced staff), there are repeatability errors. Because of practical experience, the error is assumed as ±0,5 % of the final value.

Distribution is rectangular, $k = \sqrt{3}$, u_5 = 0,5 %/ $\sqrt{3}$ = 0,289 %.

Example 6: Pre-conditioning for ball pressure test

Result variable: uncertainty of temperature of test sample.

Description: influence by possible factors: set point of the heater, reading accuracy, spatial temperature gradient based on the thermal isolation of the heater, influence of the two-stage heater control, thermal/temporal inertia of the system, surface/volume ratio of the test specimen (the smaller the ratio, the greater the thermal inertia), uncertainty of thermocouple.

See Table A.6.

Table A.6 – Pre-conditioning for ball pressure test

Quantity X_i	Source of uncertainty	X_i	Type	Error quantity, $S_p(X_i)$	Probability shape	Distribution division factor, k	Standard uncertainty, $u(X_i)$	Sensitivity coefficient, C_i	Uncertainty contribution, $u_i(y)$
δT_R	Spatial temperature gradient and fluctuation	XT_R	B	0,1 °C	Rectangular	$\sqrt{3}$	0,057 7 °C	1	0,057 7 °C
δ_{Indic}	Rough scale for temperature set	X_{Indic}	B	0,5 °C	Rectangular	$\sqrt{3}$	0,289 °C	1	0,289 °C
δT_{contr}	Function of heating control	XT_{contr}	B	1 °C	Rectangular	$\sqrt{3}$	0,577 °C	1	0,577 °C
δ_{Rec}	Influence of recorder	X_{Rec}	B	1,5 °C	Rectangular	$\sqrt{3}$	0,866 °C	1	0,866 °C
δTr_{res}	Transition of resistance	XTr_{res}	B	0,25 °C	Rectangular	$\sqrt{3}$	0,144 °C	1	0,144 °C
δ_{ref}	Calibration of reference thermocouple	X_{ref}	B	0,1 °C	Rectangular	$\sqrt{3}$	0,057 7 °C	1	0,057 7 °C
					Combined standard uncertainty, u_c				1,093 °C
					Coverage factor k_p = 2; confidence level: 95 %				–
					Expanded uncertainty, $U = u_c \times k_p$				2,2 °C

Reported result – The measured temperature is 70,6 °C ± 2,2 °C, k = 2, 95 % confidence interval.

T_{INVP} constant value: 75 °C; temperature set with control dial.

T_R constant value: 4,4 °C; according to the manufacturer's specification, the spatial temperature gradient is ±2 % of maximum temperature (220 °C). Practical experience shows that this value can be divided into one systematic and one random failure. Extreme estimate for systematic fluctuation: due to thermal loss, there is a spatial temperature difference of −4,4 °C.

δ_R extreme estimate for random fluctuation: the mean values fluctuate at intervals (0,08; −0,03). An approximate spatial temperature fluctuation of ±0,1 °C can be specified.

Distribution is rectangular, $k = \sqrt{3}$, u_1 = 0,1 °C/$\sqrt{3}$ = 0,057 7 °C.

δ_{Indic} due to the rough scale, the temperature of the warming cabinet can only be set with a tolerance of ±0,5 °C (estimated value).

Distribution is rectangular, $k = \sqrt{3}$, u_2 = 0,5 °C/$\sqrt{3}$ = 0,289 °C.

δ_{contr} distribution is rectangular, $k = \sqrt{3}$, u_3 = 1,0 °C/ $\sqrt{3}$ = 0,577 °C.

δ_{Rec} summarized all impacts on uncertainty of the recorder.

Distribution is rectangular, $k = \sqrt{3}$, u_4 = 1,5 °C/ $\sqrt{3}$ = 0,866 °C.

δTr_{res} estimated impact of transition of resistance based on practical experience.

Distribution is rectangular, $k = \sqrt{3}$, u_5 = 0,25 °C/ $\sqrt{3}$ = 0,144 °C.

δ_{ref} estimated impact of reference element (PT100 based on practical experience).

Distribution is rectangular, $k = \sqrt{3}$, u_6 = 0,1 °C/ $\sqrt{3}$ = 0,057 7 °C.

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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APPLICATION DE L'INCERTITUDE DE MESURE AUX ACTIVITÉS D'ÉVALUATION DE LA CONFORMITÉ DANS LE SECTEUR ÉLECTROTECHNIQUE

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Cette deuxième édition annule et remplace la première édition publiée en 2007.

Les modifications majeures par rapport à l'édition précédente sont les suivantes:

a) alignement rédactionnel sur l'ISO/IEC 17025:2017 sans adaptation du contenu technique;
b) références à l'ISO/IEC 17025:2005 et à l'ISO/IEC 17025:2017 afin de faciliter la transition vers la nouvelle édition de l'ISO/IEC 17025.

Le texte du présent Guide IEC est issu des documents suivants:

Vote des quatre mois	Rapport de vote
SMBNC/8/DV	SMBNC/14/RV

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de ce Guide.

La langue employée pour l'élaboration de ce Guide est l'anglais.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/standardsdev/publications.

INTRODUCTION

Le présent document a été établi par le Comité des laboratoires d'essai (CTL, *Committee of Testing Laboratories*) du système IEC d'essais de conformité et de certification des équipements électriques (IECEE, *IEC System of Conformity Assessment Schemes for Electrotechnical Equipment and Components*) afin de donner des recommandations pour l'application pratique des exigences concernant l'incertitude de mesure de l'ISO/IEC 17025 aux essais de sécurité électrique réalisés dans le cadre de la méthode des organismes de certification (OC) du système IECEE.

La méthode OC du système IECEE est un accord international multilatéral conclu entre plus de 40 pays et quelque 60 organismes nationaux de certification pour l'acceptation des rapports d'essai sur les produits électriques soumis à essai selon les normes IEC.

Le but du CTL est, entre autres tâches, de définir une analyse commune de la méthodologie d'essai selon les normes IEC ainsi que d'assurer et d'améliorer de manière continue la répétabilité et la reproductibilité des résultats d'essai entre les laboratoires membres.

L'approche pratique de l'incertitude de mesure décrite dans le présent document a été adoptée pour être utilisée dans les méthodes du système IECEE et elle est également largement utilisée dans le monde par les laboratoires d'essai pour les essais des produits électriques selon les normes nationales de sécurité.

Le présent document présente un intérêt particulier pour les Comités d'études suivants de l'IEC, qui peuvent, si nécessaire, décider de l'utiliser.

COMITE D'ETUDES 13:	COMPTAGE ET PILOTAGE DE L'ÉNERGIE ÉLECTRIQUE
COMITE D'ETUDES 17:	APPAREILLAGE HAUTE TENSION
COMITE D'ETUDES 18:	INSTALLATIONS ÉLECTRIQUES DES NAVIRES ET DES UNITÉS MOBILES ET FIXES EN MER
COMITE D'ETUDES 20:	CÂBLES ÉLECTRIQUES
COMITE D'ETUDES 21:	ACCUMULATEURS
COMITE D'ETUDES 22:	SYSTÈMES ET ÉQUIPEMENTS ÉLECTRONIQUES DE PUISSANCE
COMITE D'ETUDES 23:	PETIT APPAREILLAGE
COMITE D'ETUDES 32:	COUPE-CIRCUITS À FUSIBLES
COMITE D'ETUDES 33:	CONDENSATEURS DE PUISSANCE ET LEURS APPLICATIONS
COMITE D'ETUDES 34:	ÉCLAIRAGE
COMITE D'ETUDES 35:	PILES
COMITE D'ETUDES 38:	TRANSFORMATEURS DE MESURE
COMITE D'ETUDES 40:	CONDENSATEURS ET RÉSISTANCES POUR ÉQUIPEMENTS ÉLECTRONIQUES
COMITE D'ETUDES 47:	DISPOSITIFS A SEMICONDUCTEURS
COMITE D'ETUDES 59:	APTITUDE À LA FONCTION DES APPAREILS ÉLECTRODOMESTIQUES ET ANALOGUES
COMITE D'ETUDES 61:	SÉCURITÉ DES APPAREILS ÉLECTRODOMESTIQUES ET ANALOGUES
COMITE D'ETUDES 62:	ÉQUIPEMENTS ÉLECTRIQUES DANS LA PRATIQUE MEDICALE
COMITE D'ETUDES 64:	INSTALLATIONS ÉLECTRIQUES ET PROTECTION CONTRE LES CHOCS ÉLECTRIQUES
COMITE D'ETUDES 65:	MESURE, COMMANDE ET AUTOMATION DANS LES PROCESSUS INDUSTRIELS

COMITE D’ETUDES 66:	SÉCURITÉ DES APPAREILS DE MESURE, DE COMMANDE ET DE LABORATOIRE
COMITE D’ETUDES 76:	SÉCURITÉ DES RAYONNEMENTS OPTIQUES ET MATÉRIELS LASER
COMITE D’ETUDES 77:	COMPATIBILITÉ ÉLECTROMAGNÉTIQUE
COMITE D’ETUDES 78:	TRAVAUX SOUS TENSION
COMITE D’ETUDES 80:	MATÉRIELS ET SYSTÈMES DE NAVIGATION ET DE RADIOCOMMUNICATION MARITIMES
COMITE D’ETUDES 82:	SYSTÈMES DE CONVERSION PHOTOVOLTAÏQUES DE L’ÉNERGIE SOLAIRE
COMITE D’ETUDES 110:	AFFICHAGES ÉLECTRONIQUES

APPLICATION DE L'INCERTITUDE DE MESURE AUX ACTIVITÉS D'ÉVALUATION DE LA CONFORMITÉ DANS LE SECTEUR ÉLECTROTECHNIQUE

1 Domaine d'application

Le présent Guide présente une approche pratique de l'application de l'incertitude de mesure aux activités d'évaluation de la conformité dans le secteur électrotechnique. Il est spécifiquement conçu pour être utilisé dans les méthodes du système IECEE ainsi que par les laboratoires qui réalisent les essais des produits électriques selon les normes nationales de sécurité. Il décrit l'application des principes de l'incertitude de mesure et donne des recommandations pour la réalisation des calculs de l'incertitude de mesure. Le présent Guide donne également quelques exemples de calculs de l'incertitude de mesure pour des essais d'évaluation de la conformité de certains produits.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

ISO/IEC 17025, *Exigences générales concernant la compétence des laboratoires d'étalonnages et d'essais*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

3.1
facteur d'élargissement
facteur qui, lorsqu'il est multiplié par l'incertitude-type composée, fournit un intervalle (l'incertitude élargie) autour du résultat d'un mesurage, dont on puisse s'attendre à ce qu'il comprenne une fraction spécifiée, élevée, (par exemple 95 %) de la distribution des valeurs qui pourraient être attribuées raisonnablement au mesurande

3.2
incertitude-type composée
résultat de la combinaison des composantes de l'incertitude-type

3.3
erreur de mesure
résultat d'un mesurage moins une valeur vraie du mesurande

Note 1 à l'article: L'erreur de mesure n'est pas quantifiable de manière précise car la valeur vraie se situe à un niveau inconnu dans le domaine d'incertitude de mesure.

3.4
incertitude élargie
valeur qui s'obtient par la multiplication de l'incertitude-type composée par un facteur d'élargissement

3.5
niveau de confiance
probabilité que la valeur du mesurande se trouve à l'intérieur du domaine d'incertitude indiqué

3.6
mesurande
grandeur faisant l'objet de la mesure, évaluée dans l'état où se trouve le système mesuré pendant la mesure elle-même

[SOURCE: IEC 60359:2001, 3.1.1, modifié – Les Notes ont été supprimées.]

3.7
grandeur X_i
source d'incertitude

3.8
écart-type
racine carrée positive de la variance

3.9
incertitude-type
écart-type estimé

3.10
incertitude de mesure
paramètre, associé à une mesure, qui caractérise la dispersion des valeurs qui pourraient être attribuées raisonnablement au mesurande

[SOURCE: IEC 60359:2001, 3.1.4, modifié – Dans la définition, le texte "qui peut être attribuée" a été remplacé par "qui pourraient être attribuées". Les Notes ont été supprimées.]

3.11
méthode d'évaluation de Type A
méthode d'évaluation de l'incertitude de mesure par l'analyse statistique d'une série d'observations

3.12
méthode d'évaluation de Type B
méthode d'évaluation de l'incertitude de mesure par des moyens autres que l'analyse statistique d'une série d'observations

4 Application des principes de l'incertitude de mesure

4.1 Généralités

4.1.1 La qualification et l'acceptation des laboratoires d'essai OC (CBTLs, *Certification Body Testing Laboratories*), par exemple dans le système IECEE, se font conformément à l'ISO/IEC 17025.

ISO/IEC 17025:2005, 5.4.6.2

"Les laboratoires d'essais doivent aussi posséder et appliquer des procédures pour estimer l'incertitude de mesure. Dans certains cas, la nature de la méthode d'essai exclut un calcul rigoureux, métrologiquement et statistiquement valide, de l'incertitude de mesure. Dans de tels cas, le laboratoire doit au moins tenter d'identifier toutes les composantes de l'incertitude et faire une estimation raisonnable, tout en assurant que la manière d'en rendre compte ne donne pas une impression erronée de l'incertitude. Une estimation raisonnable doit se baser sur une connaissance de la performance de la méthode et sur le domaine de la mesure et faire appel, par exemple, à l'expérience acquise et aux données de validation antérieures.

NOTE 1 Le degré de rigueur requis dans une estimation de l'incertitude de mesure dépend de facteurs tels que:

– les exigences de la méthode d'essai;
– les exigences du client;
– l'existence de limites étroites sur lesquelles la décision de conformité à une spécification est basée.

NOTE 2 Dans les cas où une méthode d'essai bien établie précise des limites des valeurs des principales sources d'incertitude de mesure et spécifie la forme de présentation des résultats calculés, le laboratoire est considéré comme ayant satisfait cette clause s'il suit la méthode d'essai et les instructions concernant les rapports (voir 5.10)."

ISO/IEC 17025:2017, 7.6

"7.6 Evaluation de l'incertitude de mesure

7.6.1 Le laboratoire doit identifier les contributions à l'incertitude de mesure. Lors de l'évaluation de l'incertitude de mesure, toutes les contributions importantes, y compris celles issues de l'échantillonnage, doivent être prises en compte, en utilisant des méthodes d'analyse appropriées.

7.6.2 Un laboratoire procédant à des étalonnages, y compris de ses propres équipements, doit évaluer l'incertitude de mesure de tous les étalonnages.

7.6.3 Un laboratoire procédant à des essais doit évaluer l'incertitude de mesure. Lorsque la méthode d'essai ne permet pas une évaluation rigoureuse de l'incertitude de mesure, il faut faire une estimation sur la base d'une connaissance scientifique des principes théoriques ou d'une expérience pratique de la performance de la méthode.

NOTE 1 Dans les cas où une méthode d'essai bien établie précise des limites pour les valeurs des principales sources d'incertitude de mesure et spécifie le format de présentation des résultats calculés, le laboratoire est considéré comme ayant satisfait aux exigences de 7.6.3 s'il suit la méthode d'essai et les instructions sur la façon de rendre compte des résultats.

NOTE 2 Pour une méthode donnée dont l'incertitude de mesure associée aux résultats a été établie et vérifiée, il n'est pas nécessaire d'évaluer l'incertitude de mesure pour chaque résultat, sous réserve que le laboratoire puisse démontrer que les facteurs critiques d'influence identifiés sont sous contrôle."

4.1.2 L'ISO/IEC 17025:2005, 5.10.3.1 c) stipule:

"c) s'il y a lieu, une déclaration relative à l'incertitude de mesure estimée; l'information relative à l'incertitude est nécessaire dans les rapports d'essai lorsqu'elle est importante pour la validité ou l'application des résultats d'essai, lorsque les instructions du client l'exigent ou lorsque l'incertitude affecte la conformité aux limites d'une spécification;".

L'ISO/IEC 17025:2017, 7.8.3.1 c) stipule:

"c) s'il y a lieu, l'incertitude de mesure exprimée dans la même unité que le mesurande ou dans un terme relatif au mesurande (par exemple en pourcentage), lorsque:

– elle est importante pour la validité ou l'application des résultats d'essai,

– les instructions du client l'exigent, ou
– l'incertitude de mesure affecte la conformité aux limites d'une spécification;".

4.1.3 L'ISO/IEC 17025 a été rédigée comme un document à usage général, pour toutes les industries. Les principes de l'incertitude de mesure sont appliqués aux essais des laboratoires et à la présentation des résultats d'essai pour fournir une assurance de la validité des décisions prises concernant la conformité des produits soumis à essai selon les exigences applicables. Les procédures et les techniques concernant les calculs de l'incertitude de mesure sont bien établies. Le présent document est destiné à donner des recommandations plus spécifiques concernant l'application des principes de l'incertitude de mesure à la consignation des résultats d'essai dans le cadre de la méthode OC.

4.1.4 L'Article 4 du présent document est consacré à l'application des principes de l'incertitude de mesure dans le cadre de la méthode OC, tandis que l'Article 5 donne des recommandations pour la réalisation des calculs de l'incertitude de mesure et comprend des exemples.

4.2 Principes de l'incertitude de mesure

Un des points délicats de l'application des principes de l'incertitude de mesure aux activités d'évaluation de la conformité est la gestion des aspects de coût, de temps et des aspects pratiques pour la détermination des relations entre différentes sources d'incertitude. Certaines relations sont inconnues ou exigeraient un effort considérable, du temps et un coût élevé pour être établies. Un certain nombre de techniques éprouvées sont disponibles pour traiter ce point délicat. Ces techniques prévoient de ne pas étudier les sources de variabilité qui n'ont qu'une faible influence sur le résultat et de réduire le plus possible les sources significatives de variabilité en les contrôlant.

4.3 Contexte

4.3.1 Les méthodes d'essai utilisées dans le cadre de la méthode OC du système IECEE sont par nature des normes constituant un consensus. Les critères utilisés pour déterminer la conformité aux exigences sont la plupart du temps fondés sur un consensus quant aux limites qu'il convient d'appliquer aux résultats d'essai. Le dépassement de la limite dans une faible proportion ne donne pas lieu à un danger imminent. Les méthodes d'essai utilisées peuvent inclure une indication sur la précision stipulant l'incertitude maximale admissible attendue lorsque la méthode est utilisée. Historiquement, les laboratoires d'essai utilisaient des équipements respectant les règles de l'art et ne tenaient pas compte de l'incertitude de mesure dans leurs comparaisons des résultats avec les valeurs limites. Des normes de sécurité ont été élaborées dans ce domaine et les limites données dans les normes reflètent cette pratique.

4.3.2 Les paramètres d'essai qui influencent les résultats des essais peuvent être nombreux. Des variations nominales de certains paramètres d'essai ont peu d'effet sur l'incertitude du résultat du mesurage. Les variations d'autres paramètres peuvent avoir un effet. Toutefois, le degré d'influence peut être réduit en limitant la variabilité du paramètre lors de la réalisation de l'essai.

4.3.3 Un des moyens courants de prise en compte des effets des paramètres d'essai sur les résultats d'essai consiste à définir les limites acceptables de variabilité des paramètres d'essai. Ce faisant, toute variabilité des résultats de mesurage obtenus en raison de variations des paramètres contrôlés n'est pas considérée comme significative si les paramètres sont contrôlés dans le respect des limites. Des exemples de l'application de cette technique exigent:

a) le maintien de la source d'alimentation d'entrée: tension ±2 %, fréquence ±0,5 %, distorsion harmonique totale 3 %;
b) une température ambiante de: 23 °C ± 2 °C;
c) une humidité relative de: 93 % ± 2 % (HR);
d) pour le personnel: des exigences de compétence technique documentées pour l'essai;

e) pour les procédures: des procédures de laboratoire documentées;

f) pour la précision de l'équipement: des appareils ayant une exactitude conforme au document OD-5014 du CTL.

NOTE Les limites acceptables aux points a) à c) sont données à titre d'exemples et ne représentent pas nécessairement les limites réelles établies.

4.3.4 Le résultat final du contrôle des sources de variabilité dans les limites prescrites est que le résultat du mesurage peut être utilisé comme la meilleure estimation du mesurande. En effet, l'incertitude de mesure autour du résultat mesuré est négligeable par rapport à la décision finale d'acceptation ou de refus.

4.4 Principes de l'incertitude de mesure – Application des procédures

4.4.1 Lorsqu'un essai donne lieu au mesurage d'une variable, il existe une incertitude associée au résultat d'essai obtenu.

4.4.2 La procédure 1, représentée à la Figure 1, est utilisée lorsque le calcul de l'incertitude de mesure est exigé par l'ISO/IEC 17025:2017, 7.6.3 et 7.8.3.1 c). Calculer l'incertitude de mesure (voir l'Article 5) et comparer le résultat mesuré avec la plage d'incertitude à une limite acceptable définie. La mesure est conforme à l'exigence si la probabilité pour qu'elle soit à l'intérieur des limites est d'au moins 50 %.

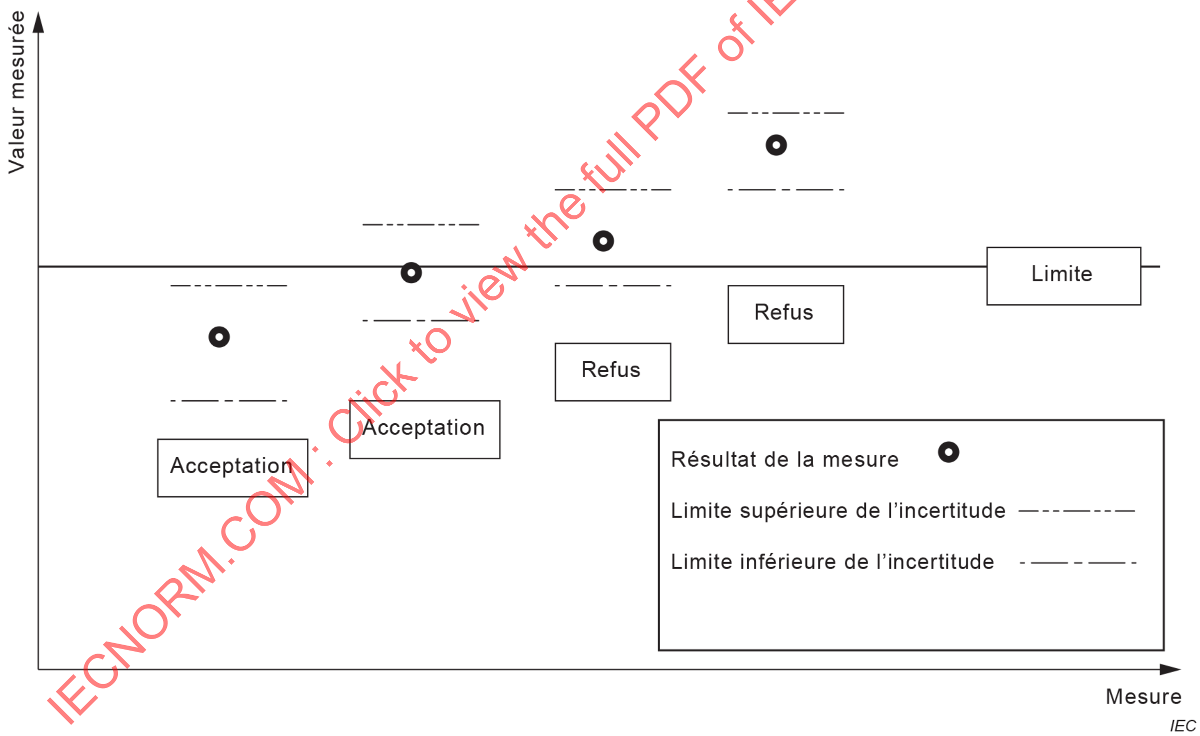

Figure 1 – Procédure 1: Incertitude de mesure calculée

4.4.3 La procédure 2, représentée à la Figure 2, est utilisée lorsque l'ISO/IEC 17025:2017, 7.6.3, Note 2, s'applique. La procédure 2 est la méthode traditionnellement utilisée dans le cadre de la méthode OC et elle est désignée sous le terme « méthode d'exactitude ». L'essai réalisé est un essai individuel de série. Les sources d'incertitude sont réduites le plus possible, de manière à ce qu'il ne soit pas nécessaire de calculer l'incertitude de mesure pour déterminer la conformité avec la limite. La variabilité des paramètres d'essai se situe dans les limites acceptables. Les paramètres d'essai comme la tension de la source d'alimentation, la température ambiante et l'humidité ambiante sont maintenus dans les limites acceptables définies pour l'essai. La formation du personnel et les procédures de laboratoire réduisent l'incertitude de mesure due aux facteurs humains. Les appareils utilisés présentent une incertitude qui se situe dans les limites prescrites.

NOTE Le terme "méthode d'exactitude" vient du concept de limitation de l'incertitude due aux appareils en utilisant des appareils qui se situent dans les limites d'exactitude prescrites. A cet effet, la spécification d'exactitude d'un appareil est considérée comme l'incertitude maximale de mesure pouvant être attribuée à l'appareil.

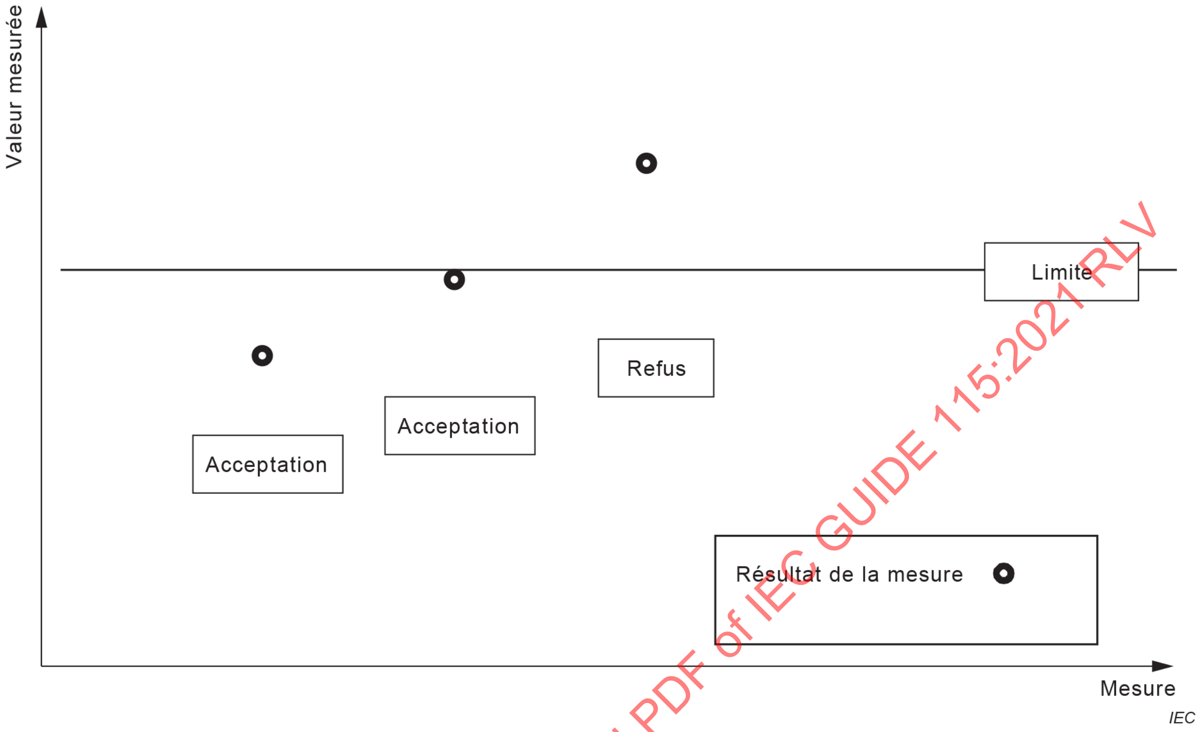

Figure 2 – Procédure 2: Méthode d'exactitude

4.4.4 Le résultat du mesurage est considéré conforme à l'exigence s'il respecte la limite prescrite. Il n'est pas nécessaire de calculer l'incertitude associée au résultat du mesurage.

4.4.5 Exemple – Procédure 2

- Essai de mesure de la tension de sortie de l'alimentation
  a) Méthode

  Connecter l'alimentation à une source réseau de tension assignée, ±2 % et de fréquence assignée. Mesurer la tension de sortie de l'alimentation lorsqu'elle subit le courant assigné, ±2 %, avec une charge résistive non inductive. L'essai est réalisé à une température ambiante de 23 °C ± 2 °C.

  Utiliser des appareils dont l'exactitude est conforme au document OD-5014 du CTL.

  L'alimentation est conforme aux exigences si la tension de sortie se situe à ±5 % de la valeur assignée.

  b) Résultats

  Caractéristiques assignées de l'alimentation électrique: 240 V, 50 Hz en entrée; 5 V en courant continu, 2 A en sortie. Voir Tableau 1.

Tableau 1

Entrée		**Sortie**	
U V	**Fréquence** Hz	I A	U V
242	50	2,01	5,1

Température ambiante d'essai: 24 °C.

L'exactitude des appareils utilisés est montrée dans le Tableau 2.

Tableau 2

Appareil de mesure	Exactitude étalonnée pour l'échelle utilisée pour la mesure	Décision CTL 251A, max.
Thermomètre	±1,0 °C	±2,0 °C
Voltmètre	±0,5 %	±1,5 %
Fréquencemètre	±0,2 %	±0,2 %
Ampèremètre	±0,5 %	±1,5 %

La conclusion de l'essai est que l'alimentation est conforme à l'exigence.

4.5 Conclusion

4.5.1 L'approche traditionnelle de l'incertitude de mesure pour les activités d'évaluation de la conformité dans le cadre de la méthode OC est l'application de la méthode d'exactitude. Cette méthode permet de réduire les sources d'incertitude associées aux performances des essais individuels de série de manière à ce que le résultat de mesure puisse être directement comparé à la limite d'essai pour déterminer la conformité à l'exigence. Cette méthode est conforme aux exigences de l'ISO/IEC 17025. La méthode d'exactitude prend moins de temps et présente un coût inférieur à celle des calculs détaillés de l'incertitude de mesure et les conclusions obtenues sont valables pour la décision finale d'acceptation ou de refus.

4.5.2 Dans les situations où la méthode traditionnelle d'exactitude ne s'applique pas, les valeurs de l'incertitude de mesure sont calculées et consignées avec les résultats des variables obtenus au cours des essais.

5 Recommandations pour la réalisation des calculs de l'incertitude de mesure avec des exemples de calculs

5.1 Principes généraux

5.1.1 L'Article 5 est destiné à constituer un bref résumé simplifié des étapes à suivre par un laboratoire CBTL lorsqu'il a besoin d'estimer des incertitudes. Il donne également des exemples sur la manière d'effectuer les calculs.

5.1.2 Il ne s'agit en aucune mesure d'un document complet sur l'incertitude de mesure (MU, *Measurement Uncertainty*), ses sources et son estimation en général, mais il est présumé offrir une approche pratique dans la plupart des circonstances applicables dans un laboratoire CBTL dans le cadre de la méthode OC du système IECEE.

5.1.3 Aucun mesurage n'est parfait et les imperfections donnent lieu à des erreurs de mesure dans le résultat. Par conséquent, le résultat d'un mesurage est uniquement une approximation de la valeur mesurée (mesurande) et il est complet uniquement lorsqu'il est accompagné de l'indication de l'incertitude de cette approximation. En fait, compte tenu de l'incertitude de mesure, une valeur vraie reste toujours inconnue.

5.1.4 L'incertitude totale d'un mesurage est une combinaison d'un certain nombre de composantes d'incertitude. Même la lecture d'un seul appareil de mesure peut être influencée par plusieurs facteurs. Un examen attentif de chaque mesurage réalisé au cours d'un essai est nécessaire pour identifier et énumérer tous les facteurs qui contribuent à l'incertitude globale. Il s'agit d'une étape très importante et elle exige une bonne compréhension de l'équipement de mesure, des principes et de la pratique de l'essai et de l'influence de l'environnement.

5.1.5 L'ISO/IEC GUIDE 98-3:2008 a adopté une approche qui regroupe les composantes de l'incertitude en deux catégories fondées sur leur méthode d'évaluation, le Type A et le Type B. Ce classement en catégories des méthodes d'évaluation, plutôt que le classement des composantes elles-mêmes évite certaines ambiguïtés.

5.1.6 L'évaluation de Type A est effectuée par un calcul à partir d'une série d'observations répétées, en utilisant des méthodes statistiques.

5.1.7 L'évaluation de Type B est effectuée par des moyens différents de ceux utilisés pour le Type A. Par exemple, par un jugement à partir du Tableau 3.

Tableau 3

Données des certificats d'étalonnage	Cela permet d'apporter des corrections et d'assigner des incertitudes de Type B
Données de mesurage antérieures	Par exemple, il est possible de construire des historigrammes et d'en déduire des informations utiles sur les variations dans le temps
Expérience ou connaissances générales	Comportement et propriétés de matériaux et équipements similaires
Valeurs acceptées des constantes	Associées aux matériaux et aux grandeurs
Spécifications du fabricant	
Toute autre information utile	

5.1.8 Les incertitudes individuelles sont évaluées par la méthode appropriée et chacune est exprimée comme un écart-type et il y est fait référence comme à une incertitude-type.

5.2 Résumé des étapes pour l'estimation d'une incertitude

5.2.1 Identifier les facteurs qui peuvent influencer de manière significative les valeurs mesurées et examiner leur applicabilité. Il existe de nombreuses sources possibles en pratique, les principales étant les suivantes.

a) La part due à l'étalonnage des appareils de mesure, y compris la part apportée par les normes de référence ou les normes de travail.
b) L'erreur de température au début et à la fin de l'essai (par exemple méthode de la résistance de bobinage).
c) L'incertitude liée aux charges appliquées et au mesurage qui en est fait.
d) La vitesse du flux d'air sur l'échantillon d'essai et l'incertitude de son mesurage.
e) Pour les appareils de mesure numériques, il y a le nombre de chiffres affichés et la stabilité de l'affichage au moment de la lecture. En outre, l'incertitude consignée d'un appareil de mesure n'inclut pas nécessairement l'affichage.
f) La résolution de l'appareil de mesure, les limites de graduation d'une échelle.
g) Les approximations et les hypothèses intégrées à la méthode de mesurage.
h) L'incertitude due aux procédures utilisées pour préparer l'échantillon pour l'essai et l'essai réel.
i) Si un ordinateur est utilisé pour l'acquisition des valeurs lues provenant de l'appareil de mesure, il existe une incertitude associée au traitement des données due aux calculs ou aux autres manipulations qui sont réalisés dans l'ordinateur comme les conversions d'analogique en numérique et les conversions entre nombres à virgule flottante et nombres entiers.
j) Les valeurs arrondies des constantes et les autres paramètres utilisés pour les calculs.