

GUIDELINES FOR DETERMINATION OF UNCERTAINTY OF MEASUREMENT IN CALIBRATION

1. Introduction:

ISO/IEC 17025 requires calibration laboratories to apply and harmonize procedures for determination of calibration and measurement capability (CMC) values and report the uncertainty of measurement and/or a statement of compliance with an identified metrological specification or clauses thereof. In order to prevent laboratories interpreting the terms of uncertainty of measurement and CMC incorrectly and giving wrong impression to customers, it would be necessary to guide them in the proper direction.

2. Scope:

This guideline provides general principles required to estimate and calculate uncertainty of measurement and calibration and measurement capability of calibrations in different fields.

3. Responsibility:

Technical staff of SLAB
Technical Assessors

4. Reference:

ISO/ IEC 17025: General Requirements for the Competence of Testing and Calibration Laboratories
ILAC – P14: ILAC Policy for Uncertainty in Calibration
EA 4/02: Expression of the Uncertainty of Measurement in Calibration

5. Definitions:

- 5.1 Calibration and measurement capability:** the smallest uncertainty of measurement that can be expected to be achieved by a laboratory during a calibration or a measurement.
- 5.2 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.
- 5.3 Standard uncertainty:** Uncertainty of the result of a measurement expressed as a standard deviation.
- 5.4 Combined standard uncertainty:** Standard uncertainty of the results of a measurement when the result is obtained from the values of a number of other quantities equal to the positive square root of a sum of terms, the terms being the variances of these other quantities weighted according to how the measurement result varies with these quantities.
- 5.5 Expanded uncertainty:** Quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand.
- 5.6 Validation:** confirmation by examination and the provision of objective evidence that the particular requirements for a specific intended use are fulfilled.

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6. Procedure:

6.1 Each calibration laboratory shall estimate uncertainty of measurement for all calibrations and measurements covered by the scope of accreditation in compliance with the “Guide to the Expression of Uncertainty in Measurement, (GUM) including its supplement documents and/or ISO Guide 35. The scope of accreditation shall include the CMC expressed in terms of measurand or reference material, calibration or measurement method and/or type of instrument/material to be calibrated/measured, measurement range and additional parameters, if applicable and uncertainty of measurement.

6.2 In calibration, one measurand or output quantity may depend upon a number of input quantities. The output quantity can be in most cases an analytical expression or group of such expressions which include corrections or correction factors.

The input quantities which are determined for measurement of uncertainty may be grouped into two categories;

- a) quantities whose estimate and associated uncertainty are directly determined in the current measurement, eg. single observations, repeated observations, or judgement based on experience
- b) quantities whose estimate and associated uncertainty are brought into the measurement from external sources, eg. quantities associated with calibrated measurement standards, certified reference materials or reference data.

6.3 The uncertainty of measurement associated with input estimates is evaluated according to either ‘Type A’ or ‘Type B’.

Type A - method of evaluating the uncertainty by the statistical analysis of a series of observations, eg. experimental standard deviation. This evaluation can be applied when several independent observations have been made for one of the input quantities under the same conditions of measurement.

Type B - method of evaluating the uncertainty by means of other than the statistical analysis of a series of observations, eg. based on scientific knowledge. This is the evaluation of the uncertainty associated with an estimate of an input quantity by means other than the statistical analysis of a series of observations. The standard uncertainty is evaluated by scientific judgement based on all available information on the possible variability of values which may be derived from the following sources.

- previous measurement data
- experience with or general knowledge of the behavior and properties of relevant materials and instruments
- manufacturer’s specifications
- data provided in calibration and other certificates
- uncertainties assigned to reference data taken from handbooks.

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- 6.4 In the determination of standard uncertainty of the output estimate, an uncertainty budget of the measurement should be prepared and it should include a list of all sources of uncertainty together with the associated standard uncertainties of measurement and the methods of calculating them shall be considered. A schematic diagram of an ordered arrangement of the quantities, estimates, standard uncertainties, sensitivity coefficients and uncertainty contributions used in the uncertainty measurement of a measurement may be prepared for estimating the combined uncertainty.
- 6.5 Statistical random and systematic factors/ effects contribute to the overall uncertainty of test results. Random errors typically arise from unpredictable variations of influence quantities and such error cannot be compensated by correction but it can usually be reduced by increasing the number of observations. A systematic error which remains constant or varies in a predictable way is independent of the number of measurements and the result of measurement shall be corrected.
- 6.6 The steps which are to be performed in order to obtain an estimate of the uncertainty associated with a measurement are as follows;
- **Specification** – Clear statement of what is being measured, including the relationship between the measurand and the parameters
 - **Identification of uncertainty sources** – List possible sources of uncertainty
 - **Quantification of uncertainty components** – Estimate the size of uncertainty associated with each potential source of uncertainty identified
 - **Calculation of total uncertainty** – Combine the quantified uncertainty components expressed as standard deviations and apply the appropriate coverage factor to give an expanded combined uncertainty
- 6.7 Laboratory shall provide evidence that the measurement uncertainties derived from employing calibration or measurement method and/or type of instrument/material to be calibrated/measured equal to those covered by the CMC. In the calculation of CMC, the “best existing device” available in the laboratory for a single category of calibrations shall be considered.
- 6.8 A reasonable amount of contribution to uncertainty from repeatability shall be included and where available contributions due to reproducibility should be included in the CMC. There should be no significant contribution to the CMC attributable to physical effects that can be ascribed to imperfections of even the best existing device under calibration or measurement. If the “best existing device” does not exist, the contributions from that device shall be separated and if excluded from the CMC statement that shall be clearly identified in the scope of accreditation.
- 6.9 If a laboratory provides reference values, the uncertainty covered by CMC should generally include factors related to the measurement procedure such as typical matrix effects, interferences etc. The contributions arising from the instability or inhomogeneity of the material are not generally considered and the CMC should be based on the analysis of inherent performance of the method for typical stable and homogeneous samples.

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- 6.10** When the measurand covers a range of values, one or more of the following methods for expression of uncertainty can be employed.
- a single value which is valid throughout the measurement range
 - a range that can be interpolated to find the uncertainty at intermediate values
 - an explicit function of the measurand or a parameter
 - a matrix where the values of uncertainty depend on the values of the measurand and additional parameters
 - a graphical form providing there is sufficient resolution on each axis to obtain at least two significant figures for the uncertainty
- 6.11** In the calibration certificate, the uncertainty of measurement and/or a statement of compliance with an identified metrological specification or clauses thereof shall be reported. The uncertainty shall be expressed as the expanded uncertainty having a specific coverage probability of approximately 95%. The expanded uncertainty shall be reported to, at most, two significant figures. The final value shall be rounded off to the least significant figure in the value of the expanded uncertainty assigned to the measurement result.
- 6.12** When reporting the associated expanded uncertainty; U , the uncertainty of measurement shall be reported along with the result, i.e. $x \pm U$ (units), where x is the measured quantity value. If a tabular presentation of the measurement result is used, the relative expanded uncertainty shall be $U/|x|$. The coverage factor and the coverage probability shall be stated in the calibration certificate along with an explanatory note to imply that the reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor; k such that the coverage probability corresponds to approximately 95%.
- 6.13** When uncertainty is expressed as the combined standard uncertainty as a single standard deviation, the following form is recommended; result: X ; standard uncertainty: uncertainty value.
- 6.14** When expressing results, the unit of the uncertainty shall always be the same as that of the measurand or in a term relative to the measurand, eg. percentage.
- 6.15** Contributions to the uncertainty stated in the calibration certificate shall include relevant short-term contributions during calibrations and contributions that can be reasonably attributed to the device calibrated.
- 6.16** Numerical values of the result and its uncertainty should not be given with an excessive number of digits. Where applicable, the uncertainty shall cover the same contributions to uncertainty that were included in the evaluation of CMC uncertainty component, except that uncertainty components evaluated for the best existing device shall be replaced with those the device calibrated, giving tendency that reported uncertainties are larger than the uncertainty covered by the CMC.
- 6.17** Whether expanded uncertainty or standard uncertainty is given, it is seldom necessary to give more than two significant digits for the uncertainty. Results should be rounded off to be consistent with the uncertainty given.
- 6.18** The accredited laboratories shall not report a smaller uncertainty than the uncertainty of the CMC for which the laboratory is accredited.

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