R 50-04 (Draft 1)

ESTIMATION OF THE UNCERTAINTY OF MEASUREMENT BY CALIBRATION LABORATORIES AND SPECIFICATION OF CALIBRATION AND MEASUREMENT CAPABILITY ON SCHEDULES OF ACCREDITATION

Approved By:	Chief Executive Officer: Accreditation Executive:	Ron Josias Mpho Phaloane
Revised By:	Field Manager:	Neville Tayler
Date of Approval:	Not yet approved – Draft May 2019	
Date of Implementation:		

CONTENTS:

1. Purpose and Scope

The purpose of this document is to define the specific accreditation criteria to be met by calibration laboratories in the determination of measurement uncertainty and the specification of Calibration and Measurement Capability (CMC). This document is applicable to accredited bodies in calibration as defined in the Accreditation Act, Act No. 19 of 2006 [2].

This document is not intended to be a guidance document on the estimation of measurement uncertainty, a number of which are already freely available on the internet and are listed amongst the references listed below.

~~but rather to define the policy for the estimation of uncertainty of measurement by calibration laboratories, and to define the determination and specification of the Calibration and Measurement Capability. Where appropriate additional guidance on the interpretation of certain requirements has been provided.~~

~~This Regulatory document is applicable to all accredited calibration laboratories, and testing laboratories performing their own calibration.~~

2. References

[1]	Measurement Standards Act	No. 18 of 2006: Measurement Units and Measurement Standards Act, 2006.
[2]	Accreditation Act	No. 19 of 2006: Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act, 2006
[3]	ISO/IEC 17025: 2017	General requirements for the competence of testing and calibration laboratories, 2017
[4]	ISO/IEC 17011:2017	Conformity assessment – Requirements for accreditation bodies accrediting conformity assessment bodies.
[5]	JCGM 200 : 2012	International Vocabulary of Metrology - Basic and General concepts and associated terms (VIM), 3rd Edition. (2008 Version with minor updates)
[6]	JCGM 100:2008	Guide to the Expression of Uncertainty of Measurement, first edition, 1993, corrected and reprinted 1995, International Organization for Standardization (Geneva, Switzerland). GUM 1995 with minor corrections
[7]	EA-4/02 M: 2013	Expression of the Uncertainty of Measurement in Calibration, European co-operation for Accreditation, September 2013.
[8]	Cook Book	Assessment of Uncertainties of measurement : for Calibration and testing laboratories, 2nd Ed RR Cook, 2002
[9]	ISO 3534-1:2006	Statistics - Vocabulary and symbols - Part 1: General statistical terms and terms used in probability, International Organization for Standardization.
[10]	M3003 Ed 3: 2012	The Expression of Uncertainty and Confidence in Measurement. UKAS November 2012
[11]	ILAC-14:01/2013	ILAC Policy for Uncertainty in Calibration

3. Definitions

- **Best existing device**
  The term “best existing device” is understood as a device to be calibrated that is commercially or otherwise available for customers, even if it has a special performance (stability) or has a long history of calibration. [11]

- **Calibration and Measurement Capability**
  A CMC is a calibration and measurement capability available to customers under normal conditions:

  a) as described in the laboratory’s scope of accreditation granted by a signatory to the ILAC Arrangement; or
  b) as published in the BIPM key comparison database (KCDB) of the CIPM MRA. [11]

- **Combined standard uncertainty**
  Standard uncertainty of the result of a measurement when that result is obtained from the values of a number of other quantities, equal to the positive square root of a sum of terms being the variances or co-variances of these other quantities weighted according to how the measurement result varies with changes in these quantities. [5]

- **Correlation**
  The relationship between two or several random variables within a distribution of two or more random variables. [7]

- **Coverage Factor**.
  Numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty. Note that a coverage factor, k, is typically in the range 2 to 3.

- **Experimental Standard Deviation of the Mean**
  The Experimental Standard Deviation of the Mean (ESDM) is an estimate of the standard deviation of the means from repeated sets of measurements.
  [8 Def 3.8] and [8 Appendix ii].

- **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 with a certain level of confidence be attributed to the measurand. [6]

- **Repeatability (of results of measurements)**
  Closeness of the agreement between the results of successive measurements of the same measurand carried out under the same conditions. [5]

- **Repeatability (of a measuring instrument)**
  Ability of a measuring instrument to provide closely similar indications or repeated applications of the same measurand under the same conditions of measurement. [5]

- **Reproducibility condition of measurement**
  Condition of measurement, out of a set of conditions that includes different locations, operators, measuring systems, and replicate measurements on the same or similar objects [5]

- **Standard Uncertainty**
  Uncertainty of the result of a measurement expressed as a standard deviation. [6]

- **Type A evaluation (of uncertainty)**.
  Method of evaluation of uncertainty by the statistical analysis of series of observations. [6]

- **Type B evaluation (of uncertainty)**.
  Method of evaluation of uncertainty by means other than the statistical analysis of series of observations. [6]

- **Uncertainty of Measurement**
  Parameter, associated with the result of a measurement that characterises the dispersion of the values that could with a certain level of confidence be attributed to the measurand.
  [5 def 3.9]

4. Abbreviations

ESDM	Experimental Standard Deviation of the Mean
BIPM	International Bureau of Weights and Measures
CMC	Calibration and Measurement Capability
NMI	National Metrology Institute
RSS	Root Sum Squared
SANAS	South African National Accreditation System
UoM	Uncertainty of Measurement
UUT	Unit under Test

5. Uncertainty of Measurement

5.1 SANAS requires that all laboratories performing calibrations, including of its own equipment, shall evaluate the measurement uncertainty for all calibrations.~~calibration laboratories and testing laboratories performing their own calibrations **shall** have and apply a procedure for the estimation of the uncertainty of measurement.~~
[3 clause 7.6.2 ~~5.4.6~~]

5.2 The measurement units and measurement standards act 18 of 2006 requires that traceability for any legal purpose be traceable to one or more national standards, through an unbroken chain of comparisons stating appropriate uncertainties of measurement. [1]

5.3 Laboratories shall identify the contributions to measurement uncertainty. When evaluating measurement uncertainty, all contributions which are of significance, including those arising from sampling, shall be taken into account using appropriate methods of analysis. [3 clause 7.2.1]
~~The estimation of the uncertainty of measurement **shall** include the identification of, and analysis of all known components of importance. The degree of rigour applied to the estimation of the measurement uncertainty should be appropriate to the intended purpose of the calibration based on the customer requirements.~~
~~*[2 clause 5.4.6]*~~

5.4 In general laboratories shall use the guidelines as specified in the GUM [6] as the basis for the preparation of their procedure on the estimation of the uncertainty of measurement. These principles are expanded on in various interpretation documents such as EA-4/02 ~~EAL-R2~~ 'Expression of the Uncertainty of Measurement in Calibration' [7], Ron Cook's book 'Assessment of Uncertainties of Measurement for calibration & testing laboratories' (recommended) 2nd Ed, 2002 [8] and M3003 'The expression of Uncertainty and Confidence in Measurement' [10]. In exceptional cases other internationally recognized methodologies may be applied.

5.5 It is recommended that the data relevant to the determination of the uncertainty of measurement, including quantities, standard uncertainties, and sensitivity coefficients be available in clear, unambiguous format, such as in a spreadsheet, or tabular format.

5.6 Laboratories may elect to perform uncertainty of measurement calculations using computerised spreadsheets, in such cases the laboratory **shall** ensure that the spreadsheets are suitably documented, validated and protected against unauthorised changes.
[2 clause 7.11.2 and 7.11.3]

5.7 Certain electronic calculators used in the Statistical mode are prone to errors due to rounding; this may become evident in the calculation of standard deviation, when the calculation returns an incorrect result. Appropriate methods **shall** be applied to circumvent these calculation errors.
[10 Appendix L]

5.8 SANAS approved technical signatories **shall** be competent to evaluate and interpret the results of UoM spreadsheet calculators to confirm their correctness.

5.9 When input quantities are not independent, and are correlated, such as is the case when standard resistors are connected in series, or several Masspieces are used to produce a combined mass, then the combined uncertainty **shall** be the algebraic sum of the uncertainties **unless** the laboratory can produce evidence of the degree of correlation, the uncertainties may then be combined using the correlation coefficient.

5.10 ~~If an uncertainty assessment involves a single Type A evaluation and the number of readings, ***n***, is greater than 2 ***(n ≥ 3)*** *and* the combined standard uncertainty is more than twice ***(x2)*** the type A uncertainty, ***or*** the number of readings, ***n***, is greater than 4 **(n ≥ 5)** *and* the combined standard uncertainty is greater than 1,5 times ***(x1,5)*** the Type A uncertainty, then ***k = 2*** will provide a coverage probability of *approximately 95%* and thus there is no need to apply the Welch-Satterthwaite equation to determine the effective degrees of freedom v_{eff} , and the coverage factor ***k***.~~
~~*[8 Section 7.3] and [4 Annex G]*~~

5.10 When conditions are not repeatable, the inappropriate use of ESDM as a measure of the Type A uncertainty may result in an underestimation of measurement uncertainty, and should therefore be used after due consideration. For example, when a torque wrench is used in practice, the device is not used repeatedly to torque the same bolt, and the torque applied to a bolt is the result of a single measurement, and not the mean of a set of measurements. The same principle is applicable to other types of measurement tools used in industry.

In addition, in instances where the number of repeated measurements is small, the reliability of a Type A evaluation has to be considered, and the option of using other means of evaluating the standard uncertainty should be considered.
[7 Section 3.2]

5.11 The uncertainty of measurement shall not be reported to more than 2 significant digits. When calculating the CMC the uncertainty of measurement shall always be rounded up, unless the rounding reduces the uncertainty by less than 5%.
[11 Section 6.3] and [10 Section 8]

6. Calibration and Measurement Capability

6.1 The Calibration and Measurement Capability (CMC) is represented on the schedule of accreditation issued by SANAS. The CMC is expressed in terms of:

a) measurand or reference material;
b) calibration or measurement or ~~method/~~procedure, and ~~or~~ type of instrument or material to be calibrated or measured;
c) measurement range and additional parameters where applicable, e.g. frequency of applied voltage; ~~and~~
d) measurement uncertainty ~~of measurement~~; [4]

6.2 The uncertainty of Measurement represented as part of the CMC represents the smallest uncertainty of measurement that a laboratory can claim for any measurement or calibration performed and reported in a certificate which makes reference to accreditation and/or includes the accreditation symbol.

6.3 The CMC uncertainty is stated as an expanded uncertainty with a coverage probability of approximately 95%.

6.4 When the uncertainty of measurement is dependent upon an additional parameter, e.g. frequency, the additional parameter **shall** be stated together with the physical quantity in question and the specified CMC shall take cognisance of this additional parameter, this may be accomplished by specifying the CMC as a function of these parameters.
[7 Appendix A]

6.5 All components contributing significantly to the uncertainty of measurement *including the drift between subsequent calibrations of the measurement standard* **shall** be taken into account when evaluating the measurement capability.

6.6 The determination of the uncertainty of measurement, for the purposes of the establishment of the CMC uncertainty **shall** include at least the uncertainty contribution from a "best existing device" to be calibrated. [11]

6.7 When the accreditation schedule includes a range of measurement for a specified parameter, the laboratory **shall** be capable of achieving the CMC uncertainty throughout the specified range. In instances where this is not possible sub-ranges, single values, or a matrix shall be introduced with separate CMC's specified for the individual sub-ranges, or single values or matrix entries.

6.8 Applicant laboratories, and laboratories wishing to have changes made to their laboratories CMC's shall submit an Uncertainty of Measurement calculation in support of the requested CMC.

6.9 Laboratories who fail to demonstrate the ability to produce acceptable measurement results as evidenced through proficiency testing ~~and the National audit program~~ may at the discretion of SANAS have their measurement capability increased to a level, which would result in an En value of less than 0,9 (absolute).

ADDENDUM 1: Amendment Record

Proposed By:	Section	Change
CEO	Page 1	Changed to new logo & Front page
Rev 03		
FM	Title Page	Minor change to the Title
FM	Page 2	Updated references, included ILAC 14, included Act 18
FM	Page 3	Added definitions for best existing device & CMC, delete definition for Measurement capability, added definition for reproducibility
FM	Page 6	5.1.2 amended to bring in line with ILAC P14 requirement
FM	Page 6	6.1 amended to be in line with ILAC P14
FM	Page 6	References to MC changed to CMC
AM	Purpose & Scope	Updated purpose and scope and included reference to the Accreditation Act, Act 19 of 2006.
AM	References	• Updated references to include the latest versions of documents; • Included a reference to the accreditation act, Act 19 of 2006; • Included a reference to ISO/IEC 17011:2017.
AM	§ 5.1	Aligned text with ISO/IEC 17025:2017
AM	§ 5.3	Aligned text with ISO/IEC 17025:2017
AM	§ 5.10	Deleted requirement
AM	§ 6.1	Text amended to align with ISO/IEC 17025:2017, previous text aligned with ILAC P14
AM	§ 6.9	Deleted reference to National Measurement Audit