UDC 681.175

J. Horský[1], J. Horská[2]

[1] *Czech calibration society*
[2] *Czech metrology institute*

CALIBRATION AND MEASUREMENT CAPABILITIES

This paper described some problems and questions for CMC tables for electrical quantity.

Keywords: *Calibration and Measurement Capability (CMC), uncertainty.*

Performance of the problem

Calibration and Measurement Capability (CMC) is used mainly to inform customers about quantities, ranges and achievable uncertainty of the measurement laboratory. They must be understandable also for customers without dedicated metrological educations and they must be accurate and clear.

Foreword

The capabilities provided by accredited calibration laboratories are described by the Calibration and Measurement Capability (CMC), which expresses the lowest uncertainty of measurement that can be achieved during a calibration.

Definition of CMC

The Definition of CMC was prepared by a paper by the joint BIPM/ILAC working group. "In the context of the CIPM MRA and ILAC Arrangement, and in relation to the CIPM-ILAC Common Statement, the following shared definition is agreed upon a CMC is a calibration and measurement capability available to customers under normal conditions:

(a) as published in the BIPM key comparison database (KCDB) of the CIPM MRA; **or**

***(b) as described in the laboratory's scope of accreditation granted by a signatory to the ILAC Arrangement.*"**

The meanings of the terms Calibration and Measurement Capability, CMC, (as used in the CIPM MRA), and Best Measurement Capability, BMC, (as used historically in connection with the uncertainties stated in the scope of an accredited laboratory) are identical.

The terms BMC and CMC should be interpreted similarly and consistently in the current areas of application.

Under a CMC, the measurement or calibration should be:

- ***performed according to a documented procedure and have an established uncertainty budget under the management system of the NMI or the accredited laboratory;***
- ***performed on a regular basis (including on demand or scheduled for convenience at specific times in the year);***
- ***available to all clients***.

Computation of CMC

Calibration laboratories accredited by the accreditation bodies shall estimate uncertainties of measurement in compliance with the "Guide to the Expression of Uncertainty in Measurement" (GUM), including its supplement documents and/or ISO Guide 35, EA-4/02 M: 2013, Evaluation of the Uncertainty of Measurement In Calibration or UKAS M3003, edition 2: January 2007.

Contributions to the uncertainty stated on the calibration certificate include the measured performance of the device under test during its calibration at the NMI or accredited laboratory. CMC uncertainty statements anticipate this situation by incorporating agreed-upon values for the 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.

Random contributions that cannot be known by the laboratory, such as transport uncertainties, should normally be excluded in the uncertainty statement. If, however, a laboratory anticipates that such contributions will have significant impact on the uncertainties attributed by the laboratory, the customer should be notified according to the general clauses regarding tenders and reviews of contracts in ISO/IEC 17025.

Traceability

The NMI CMCs which are published in the KCDB provide peer-reviewed traceability route to the SI or, where this is not possible, to agreed - upon stated references or appropriate higher order standards. Assessors of accredited laboratories are encouraged always to consult the KCDB (http://kcdb.bipm.org) when reviewing the uncertainty statement and budget of a laboratory in order to ensure that the claimed uncertainties are consistent with those of the NMI through which the laboratory claims traceability.

Description of CMC in scope of accreditation

The scope of accreditation of an accredited calibration laboratory shall include the calibration and measurement capability (CMC) expressed in terms of:

a) measurand or reference material;

b) calibration/measurement method/procedure and/or type of instrument/material to be calibrated/measured;

c) measurement range and additional parameters where applicable, e.g., frequency of applied voltage;

d) uncertainty of measurement.

Open intervals (e.g. ">*x*") are not permitted in the expression of CMCs

The number of figures in a CMC declaration should always reflect practical measurement capability. Using less than two significant figures can, however, introduce unacceptably large rounding errors. The CMC should therefore be stated to two significant figures, using the normal rules of rounding, unless there are valid technical reasons for doing otherwise.

CMC are described in table form.

Table example 1 − United Kingdom

Measured Quantity Instrument or Gauge	**Range**	**Calibration and Measurement Capability (CMC) ***	**Remarks**

* Expressed as an Expanded Uncertainty ($k = 2$)

Table example 2 − Czech republic

Measured Quantity Instrument and Range	**Frequency**	**Calibration and Measurement Capability (CMC)***	**Remarks**

* Expressed as an Expanded Uncertainty ($k = 2$)

In the column remarks is written in Czech and Slovak type of calibration procedure, too.

The uncertainty covered by the CMC shall be expressed as the expanded uncertainty having a specific coverage probability of approximately 95 % range of values.

This is generally achieved through employing one or more of the following methods for expression of the uncertainty.

a) A single value, which is valid throughout the measurement range.

Measured Quantity Instrument and Range	Frequency	Calibration and Measurement Capability (CMC)*	Remarks
DC V			
400V to 1000V		0,001%	

b) A range. In this case a calibration laboratory should have proper assumption for the interpolation to find the uncertainty at intermediate values.

Measured Quantity Instrument and Range	Frequency	Calibration and Measurement Capability (CMC)*	Remarks
Hf atten. A			
A=(0 to 65) dB	10 MHz to 18 GHz	(0,02+0,006A)dB	

c) An explicit function of the measurand or a parameter.

d) A matrix where the values of the uncertainty depend on the values of the measurand and additional parameters.

Measured Quantity Instrument and Range	**Frequency**	**Calibration and Measurement Capability (CMC)***	**Remarks**
AC I			

	10 Hz	20 Hz / 30 Hz	40 Hz / 55 Hz / 300 Hz / 1 kHz	5 kHz	10 kHz
100 μA	100	90	70	70	80
1 mA	100	90	70	70	80
10 mA	90	75	65	70	70
100 mA	80	65	65	70	80
1 A	120	100	90	100	120
10 A	180	160	110	140	160

Uncertainty is in mV/V

e) A graphical form, providing there is sufficient resolution on each axis to obtain at least two significant figures for the uncertainty.

It should be particularly noted that relative expressions, such as percentages or parts per million, are not admissible when the range of the quantity values include, or is close to, zero. Under such conditions, an absolute term must also be present; either on its own or in conjunction with the relative term.

Measured Quantity Instrument and Range	**Frequency**	**Calibration and Measurement Capability (CMC)***	**Remarks**
DC V			
0 V to 1 V		25 ppm	***noncorrect***
0 V to 1 V		25 ppm + 5,0 µV	correct

Symbols and units

It is recommended that only units of the SI and those units recognized for use with the SI should be used to express the values of quantities and of the associated CMCs. Nevertheless, other commonly used units may be used in some countries, where considered necessary for the intended audience. For example, the term "ppm" (part per million) is frequently used by manufacturers of test and measurement equipment to specify the performance of their products. Terms like this may be used in Schedules of Accreditation where they are in common use and understood by the users of such equipment, providing their use does not introduce any ambiguity in the capability that is being described. In most countries is ppm prohibited, because is not recommended and in and Based on the technical standard ISO 80000-1, paragraph 6.5.5 is used concrete formulation in the power of ten and IEC advised already in 1978 not to use ppm. Also it is not allowed to use ppm in the database KCDB BIPM.

Description of units

µV/V	KCDB database BIPM, USA, many others outside Europe
Exponential 10^{-3} or 10^{-6}	Germany and many European countries
ppm	UKAS, Singapore
%	China, USA, Many Asians, Great Britain-UKAS

There are also units that are not part of the SI system but the use of which may be necessary for historical purposes or for calibration of instruments that are scaled in such units. One specific unit that is not mentioned in the SI system is that of relative humidity. It is recommended that the expression "%rh" be for this quantity. Other commonly encountered units that are not defined in the SI system relate to units of time, in particular days, hours and minutes. The following are recommended for use in Schedules of Accreditation.

Particular care should be taken when the unit itself is normally expressed in percentage terms; examples are relative humidity (% rh) and amplitude modulation (% AM). For example 50 % rh ± 10 % rh means the boundaries are 40 % rh and 60 % rh, whereas 50 % rh ± 10 % means the boundaries are 45 %rh and 55 % rh.

In Ancient Rome, long before the existence of the decimal system, computations were often made in fractions which were multiples of 1/100 and till now, % is very popular.

Ranges

Particular care should be taken when the measurand covers a range of values.

It is frequently the case that a measurement capability is broken down into ranges corresponding to those available on the measuring instrument upon which the capability is based. Under such circumstances, the ranges described in the Schedule of Accreditation should correspond to the nominal range change points. It is frequently the case that a measurement capability is broken down into ranges corresponding to those available on the measuring instrument upon which the capability is based. Under such circumstances, the ranges described in the Schedule of Accreditation should correspond to the nominal range change points, as in the example below.

The rationale behind this reasoning is as follows.

The intermediate ranges contain values that are repeated in the previous and subsequent ranges. So the question arises: "What is the CMC at these repeated points?"

Example for DC Voltage

Ranges for 4,5dig DMM	correct description
0 to 199,99 mV	0 mV to 200 mV
0 to 1,9999 V	200 mV to 2 V
0 to 19,999 V	2 V to 20 V
0 to 199,99 V	20 V to 200 V
0 to 1000,0 V	200 V to 1000 V
Mostly used in USA	Other possibility
0 mV to 200 mV	0 mV to 200 mV
> 200 mV to 2 V	201 mV to 2 V
> 2 V to 20 V	2 .01V to 20 V
> 20 V to 200 V	20.1 V to 200 V
> 200 V to 1000 V	201 V to 1000 V

In the example above, the ranges designated in multiples of "2" are nominal, as the theoretical change over point is 1 least significant digit lower. For example, the 200 mV range actually has a full-scale value of 199.9999 mV. However, there is no point in stating the capability to such a degree of resolution, for the reasons stated in b) above

The exact stimulus required to switch between ranges on any instrument will depend on the particular calibration characteristics of each range of the instrument, *including uncertainty of measurement*. That stimulus can, therefore, never be truly known. Hence, there is no point in attempting to avoid the repetition; for example, by use of the ">" symbol or by leaving small gaps in the capability.

The laboratory's procedures or records should contain sufficient information to define the range that was used in a particular calibration and hence the correct uncertainty, corresponding to that range, may be reported.

Best existing device problem

Sometimes it is difficult to define the specification for the best existing calibrated device. E.g. specification of current clamps and clamp digital multimeters is for infinite, thin wire going in the middle of the current clamp. Calibration of these measurement devices is usually done by current coils connected to output of a calibrator. The current coil is impacting the calibrator output and has also impact to the connected clamp. This impact is different for clamps in the type of a current transformer, for clamps with Hall sensor and also for clamps with more accurate converters like e.g. CT type converter. Due to this there should be for one coil specified multiple CMC, depending on the principle of measured clamp. This is normally not done, because there are not available means for validation of properties of the coils depending on used type of clamps.

Criteria for acceptance of CMCs

Documented CMC calculation and results.

Documented calibration procedures ant its validation.

On-site peer-assessment reports.

Results of comparisons.

Knowledge of technical activities.

Other available knowledge and experience.

Conclusions

A Calibration and Measurement Capability is the highest level of calibration or measurement normally offered to clients. This implies that the global uncertainty associated with a CMC should consider the contribution (noise, short term instability, resolution etc., but not transport) of the instrument/artefact under calibration, usually the best available. The uncertainty is usually expressed in terms of a confidence level of 95% and given by no more than 2 significant digits.

The definitive statement of the accreditation status of a calibration laboratory is the Accreditation Certificate and the associated Schedule of Accreditation. The Schedule of Accreditation is a critical document, as it defines the measurement capabilities, ranges and boundaries of the calibration activities for which the organization holds accreditation. It is therefore important that the Schedule of Accreditation is presented in a manner that is scientifically meaningful and presents unambiguous information in a manner that will be readily understood by the target audience.

Guidance on the format, presentation and content of Schedules of Accreditation for accredited calibration laboratories is very important document. Use of this guidance will assist in the production of consistent and meaningful schedules and will minimize the risk of customers and readers being misled.

Literature list

1. CALIBRATION AND MEASUREMENT CAPABILITIES. A paper by the joint BIPM/ILAC working group. Accepted by the CIPM 2007, (Working document CIPM 2007-11).

2. ILAC-P14:01/2013, ILAC Policy for Uncertainty in Calibration.

3. EA-4/02 M: 2013, Evaluation of the Uncertainty of Measurement In Calibration and EA-4/02:1999, Expressions of the Uncertainty of Measurements in Calibration.

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

5. ISO/IEC Guide 99:2007, International vocabulary of metrology - Basic and general concepts and associated terms (VIM).

6. UKAS M3003, edition 2: January 2007, available from www.ukas.com.

Надійшла до редколегії 9.04.2014

Рецензент: д-р техн. наук, проф. І. П. Захаров, Харківський національний університет радіоелектроніки., Харків

КАЛИБРОВОЧНЫЕ И ИЗМЕРИТЕЛЬНЫЕ ВОЗМОЖНОСТИ

Ю. Хорский, Я. Хорска

Эта статья описывает некоторые проблемы и вопросы для СМС таблиц электрических величин.

***Ключевые слова**: калибровочные и измерительные возможности, неопределенность.*

КАЛІБРУВАЛЬНІ ТА ВИМІРЮВАЛЬНІ МОЖЛИВОСТІ

Ю. Хорський, Я. Хорська

Ця стаття описує деякі проблеми і питання для СМС таблиць електричних величин.

***Ключові слова:** калібрування і оцінка можливості, невизначеність.*