Critical analysis of Calibration and Measurement Capabilities (CMC) presented in accreditation scopes

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Abstract. Calibrations must be performed properly. Thus, the calibration results can be compared to the respective maximum permissible errors established for measuring instruments. This requires that laboratories establish the Measurement and Calibration Capacity (CMC) consistently and referenced in valid and updated normative documents, when available. This paper provides a critical review on CMC made available by accredited laboratories and makes considerations for appropriate selection of the calibration service provider.

1. Introduction
The calibration activities are part of the routine of industrial organizations, being a prerequisite to evaluate the adequacy to the equipment’s use in the measurement tasks. Calibration is defined as the operation that, under specified conditions, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties [1]. The International Metrology Vocabulary - IMV itself [1] notifies that calibration should not be confused with adjustment or verification. This note comes because of several organizations considering that calibration means leaving the instrument with no errors or deviations less than the maximum permissible errors (MPE) set out in normative documents, manufacturer's manuals or even by the organization itself. Also, ISO 9001 [2], either in previous editions or in the 2015 version, describes that measuring equipment must be checked or calibrated, or both, leading to the understanding that there is a choice between calibration and verification, when they are different activities. This interpretation would be a great mistake, making instruments that returned from the calibration being directly released to the productive sector, without making any analysis of the calibration results contained in the certificate issued.

It is important to be clear that a calibrated instrument is not necessarily suitable for use, but it is a device whose biases were determined. A sequential activity would then be the verification, defined as the provision of objective evidence that a given item fulfils specified requirements [1]. ISO 14978: 2006 [3], document that deals with general concepts and requirements for Geometrical Product Specifications (GPS) measuring equipment, establishes that the MPEs can be defined by the manufacturers in their data sheets, but they can also be established by the users, according to the internal applications of the organization. In this sense, the ISO standards for GPS measuring equipment no longer present the MPE. They limit themselves in establishing which characteristics are to be assessed, and how the data sheet should be drawn up. Examples are the standards of callipers, micrometers and dial gauges. Not agreeing with this guideline, some countries have chosen to adjust...
or maintain their national standard, establishing the maximum permissible errors for the equipment, according to the metrological characteristics related to ISO standards. Table 1 lists national standards in addition to ISO standards.

### Table 1: ISO Standards and National Standards edited with maximum permissible errors

| Measuring equipment | International Standard | German Standard | British Standard | Japanese Standard |
|---------------------|------------------------|-----------------|-----------------|------------------|
| Calliper            | ISO 13385-1:2011       | DIN 862:2015    | BS 887:2008     | JIS B 7507:2016  |
| Micrometer          | ISO 3611:2010          | DIN 863-1:2017  | BS 870:2008     | JIS B 7502:2016  |
| Dial gauge          | ISO 463:2006           | DIN 878:2018    | BS 907:2008     | JIS B 7503:2017  |

Of course, for internal applications, organizations make some changes to the equipment's permissible errors, which should be in a technical and appropriate way, considering the constructive characteristics of the equipment. It is a practice that, for equipment in use, no more than two times what has been established for new equipment is allowed. This is sometimes necessary due to use, environmental conditions and due to uncertainty of measurement which is sometimes not considered in the manufacturers’ specification.

Metrological confirmation is a set of operations required that the measuring equipment conforms to the requirements for its intend use. Metrological confirmation generally includes calibration, verification, any necessary adjustment or repair, and subsequent recalibration, comparison with the metrological requirements for the intended use of the equipment, as well as any required sealing and labeling. [4].

When the calibration is performed by a laboratory external to the company, it is the responsibility of the metrological function to select an appropriate service provider. In addition to cost and time, a key factor is the assessment as to the competence of the laboratory to carry out the calibration within suitable uncertainties. At this point, the critical analysis of Calibration and Measurement Capabilities (CMC) presented in the scopes of the accredited services should play a decisive role.

This article discusses the importance of a coherent presentation of the CMC in the scopes of accredited services to assist the end user in a correct selection of the accredited laboratory. The article is structured to make some considerations about the CMC and, based on some accreditation scopes presented by different countries, to do a critical analysis of the presentation.

2. Calibration and Measurement Capability (CMC)

According to ILAC-P14 [5], in the context of service scopes of the laboratory accredited by a signatory to the ILAC Mutual Recognition Agreement, CMC is the measurement and calibration capability available to customers under normal conditions, ie, should be performed according to a documented procedure and have an established uncertainty budget under the management system of the accredited laboratory, performed on a regular basis and available to all customers.

What is observed in the scopes issued by the accreditation bodies is a subtle treatment in the definition of what are normal conditions of calibration. For IAJapan is the smallest uncertainty of measurement when performing routine calibrations [6]. A2LA (USA) considers the smallest uncertainty of measurement when performing more or less routine calibrations of nearly ideal measurement standards or nearly ideal measuring equipment [7]. DAkkS (Germany), UKAS (United Kingdom) e CGCRE (Brazil) define CMC as lowest uncertainty of measurement that can be achieved during a calibration [8][9][10]. But all these accrediting agencies express CMC as an expanded uncertainty having a level of confidence of approximately 95%, having as a reference for calculation the Guide to the expression of Measurement Uncertainty - GUM [11].

Despite the recommendation to consider the best existing device in the CMC assessment, there are cases in which a laboratory only intends to calibrate devices that do not represent the state of the art, or best existing devices. In such cases, for the purpose of CMC evaluation, UKAS [12] establishes that
the type of device they intend to calibrate may be considered to be the “best existing device” for that laboratory and the characteristics of that device should be incorporated into the CMC.

3. Analysis of scopes of accreditation
In the case of calibration laboratories, the details of the accreditation scope are divided by service groups, relating: instrument, measuring range and CMC.

For analysis of the accreditation scopes, geometric control measurement instruments were selected, specifically: calliper, micrometer and dial gauge. These devices were chosen for the case study, because they have an international standardization.

Table 2 shows the minimum and maximum CMC values observed in different accreditation bodies, when more than 50% of the accreditation scopes were consulted. The table is subdivided by instrument type and measuring range.

| Accreditation body | Measuring equipment: Calliper | Measuring range: 150 mm | Minimum CMC (µm) | Maximum CMC (µm) | Measuring range: 600 mm | Minimum CMC (µm) | Maximum CMC (µm) |
|--------------------|-------------------------------|-------------------------|------------------|------------------|-------------------------|------------------|------------------|
| A2LA               |                               | 3                       | 30               | 3                | 40                      | 3                | 40               |
| CGCRE              |                               | 7                       | 30               | 7                | 40                      | 7                | 40               |
| DAKKS              |                               | 30                      | 30               | 50               | 70                      | 70               | 70               |
| JCSS               |                               | 20                      | 80               | 20               | 80                      | 80               | 80               |
| UKAS               |                               | 15                      | 15               | 30               | 30                      | 30               | 30               |

| Accreditation body | Measuring equipment: Micrometer | Measuring range: 25 mm | Minimum CMC (µm) | Maximum CMC (µm) | Measuring range: 300 mm | Minimum CMC (µm) | Maximum CMC (µm) |
|--------------------|---------------------------------|------------------------|------------------|------------------|-------------------------|------------------|------------------|
| A2LA               |                                 | 0,3                    | 4,0              | 0,3              | 15,0                    | 15,0             | 15,0             |
| CGCRE              |                                 | 0,4                    | 3,0              | 0,5              | 10,0                    | 10,0             | 10,0             |
| DAKKS              |                                 | 1,4                    | 3,8              | 6,0              | 12,0                    | 12,0             | 12,0             |
| JCSS               |                                 | 2,0                    | 6,0              | 3,0              | 6,0                     | 6,0              | 6,0              |
| UKAS               |                                 | 2,0                    | 2,0              | 2,0              | 2,0                     | 2,0              | 2,0              |

| Accreditation body | Measuring equipment: Dial gauge | Measuring range: 1mm | Minimum CMC (µm) | Maximum CMC (µm) | Measuring range: 10mm | Minimum CMC (µm) | Maximum CMC (µm) |
|--------------------|---------------------------------|----------------------|------------------|------------------|-----------------------|------------------|------------------|
| A2LA               |                                 | 0,5                  | 12,5             | 0,5              | 12,5                  | 12,5             | 12,5             |
| CGCRE              |                                 | 0,3                  | 6,0              | 0,4              | 8,0                   | 8,0              | 8,0              |
| DAKKS              |                                 | 0,5                  | 5,0              | 0,7              | 4,0                   | 4,0              | 4,0              |
| JCSS               |                                 | 0,5                  | 4,0              | 1,1              | 4,0                   | 4,0              | 4,0              |
| UKAS               |                                 | 1,0                  | 1,0              | 1,0              | 3,0                   | 3,0              | 3,0              |

According to ILAC-P14 [5], when contributions to the uncertainty attributed to the device significantly affect the uncertainty, these contributions may be excluded from the CMC statement. For such case, however, the scope of accreditation shall clearly identify that the contributions to the uncertainty from the device are not included. However, for the above survey, only accreditation scopes that considered the influences of the “best existing device” in the CMC evaluation were considered.

Table 2 shows that there is a large variation between the CMCs declared for the same item. Further standardization takes place between UKAS laboratories, followed by DAkkS.
ISO/IEC 17025: 2017 [13] requires that the laboratory shall use appropriate procedure for calibration and for evaluation of measurement uncertainty. Methods published either in international, national or regional standards, or by reputable technical organization, or in relevant scientific texts or journals, or as specified by the manufacturer of the equipment, are recommended. Laboratory-developed or modified methods may also be used but need to be validated. It further specifies that the laboratory shall ensure that it uses the latest valid version of a method unless it is appropriate or possible to do so. To achieve greater uniformity in the presentation of CMCs, the requirement of ISO 17025 regarding the use of reference documents should be observed. And CMCs should be compatible with the specifications of the maximum permissible errors defined in standards or by recognized manufacturers. Since there are standards specifying normal calibration conditions, these should be followed. Thus, CMCs should be evaluated under these conditions, taking into account the “best existing device” for that condition.

On the other hand, it is important that the user of the calibration services has clarity of the meaning of the CMC and how the influences of the instrument were treated. In this sense, the resolution and repeatability of the measuring instrument has a direct impact. To avoid selecting a service provider with discrepancy in the presentation of the CMC, it is recommended that the most common CMC values submitted by accredited laboratories be selected.

An estimate of the measurement uncertainty can be made by combining the CMC with the device resolution. This uncertainty must be less than the maximum errors allowed for the equipment. If this value is higher or already consumes more than 50% of MPE, there may be a risk of improper rejection when calibrating measuring instruments.

4. Conclusions
The effect of precision on calibration results should be as small as possible. The sources of uncertainty arising from the standards used, environment, method, repeatability and the instrument subject to calibration must be minimized and in accordance with the guidelines given in valid and updated normative documents, assuring to the user that the adopted calibration method is compliant and which will allow the calibration result to be compared with the maximum permissible error of the measuring instrument. In this sense, greater convergence is expected in the CMCs made available by accredited laboratories. And it is up to the user to demand better calibration conditions, so that the accredited laboratories seek compliance with the best calibration practices.

5. References
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