Reducing the CIPM MRA Workload: Case Study for the Contact Thermometry and Hygrometry fields

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Abstract. The workload to publish and maintain Calibration and Measurement Capabilities (CMCs) in the framework of the CIPM MRA has increased over the years for all parties involved in the process. Prompted by the directors of the national metrology institutes, the Consultative Committees of the International Committee for Weights and Measures (CIPM) are investigating new approaches that could allow a reduction of invested work. This paper presents a possible approach applied as an example to the contact thermometry and hygrometry fields of the Consultative Committee for Thermometry.

1. Introduction

In 1999 the International Committee of Weights and Measures (CIPM) implemented the Mutual Recognition Arrangement (CIPM MRA) [1]. This arrangement has been signed by 98 state economies and 4 international organizations (IAEA (Vienna), JRC (Geel), WMO (Geneva) and ESA (Paris)).

The CIPM MRA provides the society with a secure technical foundation for wider agreements related to international trade, commerce and regulatory affairs. The objectives of the MRA are 1) to establish the degree of equivalence between national measurement standards maintained by the national metrology institutes (NMIs)¹ and 2) to establish a mutual recognition of calibration and measurement certificates issued by the NMIs.

The technical basis of this arrangement is the set of results obtained in the course of time through comparisons, carried out under the auspices of the Consultative Committees (CCs) of the CIPM and the Regional Metrology Organizations (RMOs) and published by the BIPM in the Appendix B of the BIPM Key Comparison Database (KCDB) [2]. Today the KCDB contains data on almost 1500 comparisons.

The outcome of the CIPM MRA, based on the results of the above-mentioned comparisons and on the operation of an appropriate peer-reviewed quality management system, are the Calibration and Measurement Capabilities (CMCs) of the NMIs. Approved CMCs are publicly available in the BIPM KCDB Appendix C [3], today containing almost 25000 CMC entries.

While the CIPM MRA allows reduced expenses in commerce and regulatory affairs, it represents a significant commitment in terms of time, staff and resources from the NMIs, for example:

- The NMI submitting a CMC must take part in a comparison
- The comparison protocol and report are reviewed by experts in the field and may require several iterations before approval
- The NMI drafts its CMC and submits it to its RMO
- The CMC is reviewed by the RMO experts and this may require several iterations before approval
- When required, the CMC is reviewed also by the other RMOs (Inter-RMO review) and this may also require several iterations before approval
- The comparison is published in the BIPM database.

¹ In the following by the wording National Metrology Institutes (NMIs) we also refer to Designated Institutes.
Many signatories continuously expand the number of declared capabilities, continuously increasing the demand on resources from the NMIs, because the NMIs not only generate data but also provide expertise in preparing the comparison technical protocols, in reviewing the comparison technical reports and in reviewing the claimed CMCs.

Moreover, as staff changes and new techniques appear, the validity of a comparison is limited in time and its ability to underpin CMC expires.

The increased demand of resources and the time required for bringing comparisons to conclusion (see Table 1) is a concern for the NMIs. NMI directors met at the BIPM in October 2014 where they confirmed their support to the CIPM MRA but requested a revision of its implementation. As a result, the CIPM created a working group that issued a number of recommendations to reduce the required workload and notably invited the CCs to act in the same direction.

| KC       | Measurements | Year of publication of report |
|----------|--------------|-------------------------------|
| CCT-K1   | 1997 to 2001 | 2006                          |
| CCT-K2   | 1997 to 2001 | 2001                          |
| CCT-K3   | 1997 to 2001 | 2003                          |
| CCT-K4   | 1998 to 2000 | 2002                          |
| CCT-K7   | 2002 to 2004 | 2006                          |

The Consultative Committee for Thermometry (CCT) already applies a so-called risk-based review of CMCs, based on a set of review protocols [4]. CCT review protocols are pragmatic technical guidelines designed to let the CMC review process proceed according to a set of objective numerical criteria and specified technical evidence. One important concept introduced by the CCT Review Protocols is that the level of scrutiny increases as uncertainty values decrease. A preliminary three-tier screening process identifies the level of review required for the CMC acceptance (Tier 1: no RMO-level detailed review required, Tier 2: RMO-level detailed review required and Tier 3: CCT WG-CMC-level detailed review required). Such an approach already reduces the review workload.

In this paper an approach is described that, while preserving the scientific objectiveness of the process, could substantially reduce the workload further. It is based on taking a broader view of the impact of the comparisons. As an example, this approach is applied to the Contact Thermometry and Hygrometry fields of the CCT, but it can be applied to other CCT sub-fields such as Radiation Thermometry and Thermo-Physical Quantities and possibly to other CC fields.

2. Contact Thermometry Field

It is useful to refer to the CCT approved document “Classification of Services in Thermometry” [5]. When a CMC is submitted, it must be classified under one of the service categories listed in [5]. Currently, for the primary services (all services starting with number 1), the CCT requires a successful participation in the corresponding KC. For the secondary services (all services starting with number 2), there is currently no uniform approach among the different RMOs to get CMCs agreed, with APMP tending to require a comparison also for secondary services (Supplementary Comparisons, SCs).

Our proposal for contact thermometry is illustrated Table 2.

In the first column the thermometry Key Comparisons (KCs) are listed. In the second column the corresponding KC temperature ranges are reported for convenience. Note that the color of these first two rows is brighter, indicating that the KCS are the primary “sources of the light”. In the third column, for each KC, the device that is calibrated in the KC is indicated along with, in parenthesis, the corresponding code according to the classification of services in thermometry [5]. In the fourth column the CMC entries that are directly tested by the corresponding KC are listed (again the code in parenthesis is the service classification according to [5]). In the last column, for each KC, the other services that a successful participant in the KC can reasonably be assumed to be capable of providing (although such services were not directly tested in the KC) are listed. Note that the brightness of the columns decreases from left to right, meaning that, the further you move away from the light source (the KC), the more the light is toned down.

An NMI, after successful participation in a KC, can obviously publish CMCs on the services directly tested by the KC (column 4), but also publish CMCs on other services that are reasonably underpinned by the KC (column 5), without needing to perform a comparison to support its claims.
This clearly alleviates the workload by relieving the NMIs that have taken part in KCs from taking part also in SCs.

An NMI that does not take part in KCs must support its secondary services through participation in comparisons, which are frequently provided on a commercial basis by the NMI/DIs that have participated in KCs.

Table 2: Contact Thermometry field: KCs (column 1), KC ranges (column 2), devices calibrated in each KC (column 3), services directly tested by each KC (column 4) and other services underpinned by each KC (column 5).

| KC          | Range                     | Devices calibrated in the KC | Calibration services tested by the KC in the range                                                                 | Other calibration services underpinned by the KC |
|-------------|---------------------------|-----------------------------|-------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|
| CCT-K1      | 235.6 K to 240.4 K        | Capsule-type SPRTs (1.3.1)   | Calibration of fixed point cells for CSPRTs (1.3.1)                                                              | Calibration of LSPRTs at fixed points (2.2.3)      |
|             |                           |                             | Calibration of complete apparatus realizing fixed points for CSPRTs (1.3.2)                                      |                                                   |
|             |                           |                             | Calibration of Rhodium-Iron resistance thermometers (2.2.3)                                                      |                                                   |
|             |                           |                             | Calibration of CSPRTs in the ITS-90 sub-ranges (2.3.1)                                                            |                                                   |
|             |                           |                             | Calibration of industrial platinum resistance thermometers (2.2.2)                                                |                                                   |
|             |                           |                             | Calibration of thermistors and other resistive thermometers (2.2.3)                                               |                                                   |
|             |                           |                             | Calibration of noble-, base- and pure-metal thermocouples (2.3.1, 2.3.2, 2.3.3)                                 |                                                   |
|             |                           |                             | Calibration of liquid-in-glass thermometers (2.4.1)                                                               |                                                   |
|             |                           |                             | Calibration of temperature sensors with display unit (2.7.1)                                                     |                                                   |
|             |                           |                             | Calibration of dry-well block calibration (2.8.4)                                                                   |                                                   |
|             |                           |                             | Calibration of fixed point cells for LSPRTs (1.3.1)                                                              |                                                   |
|             |                           |                             | Calibration of LSPRTs at fixed points (1.3.4)                                                                   |                                                   |
|             |                           |                             | Calibration of fixed point cells for LSPRTs (1.3.1)                                                              |                                                   |
|             |                           |                             | Calibration of complete apparatus realizing fixed points for LSPRTs (1.3.2)                                      |                                                   |
|             |                           |                             | Calibration of industrial platinum resistance thermometers (2.2.2)                                                |                                                   |
|             |                           |                             | Calibration of thermistors and other resistive thermometers (2.2.3)                                               |                                                   |
|             |                           |                             | Calibration of noble-, base- and pure-metal thermocouples (2.3.1, 2.3.2, 2.3.3)                                 |                                                   |
|             |                           |                             | Calibration of liquid-in-glass thermometers (2.4.1)                                                               |                                                   |
|             |                           |                             | Calibration of temperature sensors with display unit (2.7.1)                                                     |                                                   |
|             |                           |                             | Calibration of dry-well block calibration (2.8.4)                                                                   |                                                   |
|             |                           |                             | Calibration of fixed point cells for CSPRTs (1.3.1)                                                              |                                                   |
|             |                           |                             | Calibration of LSPRTs at fixed points (1.3.4)                                                                   |                                                   |
|             |                           |                             | Calibration of fixed point cells for CSPRTs (1.3.1)                                                              |                                                   |
|             |                           |                             | Calibration of complete apparatus realizing fixed points for CSPRTs (1.3.2)                                      |                                                   |
|             |                           |                             | Calibration of industrial platinum resistance thermometers (2.2.2)                                                |                                                   |
|             |                           |                             | Calibration of thermistors and other resistive thermometers (2.2.3)                                               |                                                   |
|             |                           |                             | Calibration of noble-, base- and pure-metal thermocouples (2.3.1, 2.3.2, 2.3.3)                                 |                                                   |
|             |                           |                             | Calibration of liquid-in-glass thermometers (2.4.1)                                                               |                                                   |
|             |                           |                             | Calibration of temperature sensors with display unit (2.7.1)                                                     |                                                   |
|             |                           |                             | Calibration of dry-well block calibration (2.8.4)                                                                   |                                                   |

3. Hygrometry Field

In the hygrometry field, which is less mature than the contact thermometry field, only two KCs have been performed so far (K6 and K8). Both KCs tested the same services, K6 in the low dew-point temperature range and K8 in the high dew-point temperature range. For this reason K6 and K8 are grouped together in the first column of Table 3. The devices calibrated in these comparisons were dew-point hygrometers (third column), so a K6/K8 participant directly tested its capability in calibrating dew-point hygrometers (fourth column) in the comparison itself. The K6/K8 participant calibrated the travelling standards (dewpoint hygrometers) against its primary reference hygrometry standard (dew-point generator), so it can be assumed that K6/K8 successful participants have directly demonstrated their capabilities also in calibrating dew-point generators. It is also reasonable to assume that a successful participant in K6/K8 can easily implement the calibration services listed in the fifth column (psychrometers, other hygrometers and reference gases).

The services listed in the sixth column are to be treated separately because they require traceability to non-hygrometric quantities. For example, for the calibration of relative humidity sensors, the traceability to temperature is also required. For this reason, a successful participation in K6/K8 can automatically underpin the services of the sixth column only after showing evidence of traceability to the additional quantities.

Again, an NMI, after successful participation in K6/K8, can obviously publish CMCs on the services directly tested by the KC (column 4) but also publish CMCs on other services that are reasonably underpinned by the KC (column 5), without the need of performing a comparison to support its claims. CMCs can only be published for column 6 when the additional information is forthcoming.

An NMI that does not take part in K6/K8 must support the services of column 5 and 6 with a participation in comparisons.
Table 3: Hygrometry field: KCs (column 1), KC ranges (column 2), devices calibrated in each KC (column 3), services directly tested by each KC (column 4), other services underpinned by each KC (column 5) and other services requiring traceability to other quantities (column 6).

| KC   | Range             | Device calibrated in the KC | Calibration services tested by the KC in the range | Other calibration services underpinned by the KC | Other services requiring traceability to other quantities |
|------|-------------------|-----------------------------|---------------------------------------------------|--------------------------------------------------|--------------------------------------------------------|
| K6/K8| 50 °C to 95 °C    | Dew-point hygrometer (3.1.1) | Psychrometers (3.2.1)                              | Relative humidity sensors (3.3.1) → T            | Relative humidity generators (4.2.1) → T                |
|      |                   | Dew-point generators (4.1.1) | Other hygrometers (3.4.1)                          | Flow mixing (4.3.1) → Q                         | Salt solutions (5.2.1) → T                             |
|      |                   | Reference gases (5.2.1)      |                                                   |                                                   |                                                        |

4. Discussion

We have proposed a possible approach to reduce the workload associated with the process of publishing and maintaining CMCs in the BIPM database. The intention of the authors is to stimulate discussion within and outside the CCT community on this subject.

The approach presented here could be further implemented (and the workload further reduced) in different ways:

1. By reducing the number of service categories. For example, instead of having CMCs for noble metal, base metal and pure metal thermocouples, only a single service category for thermocouples could be defined, leaving as a remark which type of thermocouples the uncertainty refers to. This will reduce the workload at a price of a moderate loss in the level of detail with which the BIPM database presents the calibration and measurement capabilities of the NMIs.

2. By assuming an even broader point of view, which includes both the CIPM MRA and the ILAC MRA. The workload is currently duplicated by the fact that the CIPM CMC review process and the ILAC CMC review process are two independently running processes. By requiring the same reviewers for both processes, the workload could be reduced by a mutual recognition of CMCs between CIPM MRA and ILAC MRA.

Currently the KCs are testing only the ITS-90 realization, however, with the redefinition of the kelvin expected in 2019, we should start reflecting on how the kelvin redefinition will affect the way KCs are performed and the way CMCs are classified: for e.g. will separate KCs need to be performed to test primary realizations? Will there need to be different CMCs for two different quantities (thermodynamic temperature, \(T\), and international temperature of 1990, \(T_{90}\))?  

References

[1] CIPM MRA, https://www.bipm.org/utils/en/pdf/CIPM-MRA-2003.pdf
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[4] G.F. Strouse, M. Ballico, J. Bokvovski, M. de Groot, H.G. Liedberg, A.I. Pokhodun, “CCT WG8 CMC Review Protocols: Development and Implementation”, Int J Thermophysics (2008) 29:1193-1203
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