Consultative Committee for Length – CCL
WORKING GROUP ON MRA - WG-MRA
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Guidance Document GD-5
Version 3

Guide to formatting CMC entries ('DimVIM Guide') and to their inter-RMO review

Document history

draft1	This document was prepared for the WG-MRA meeting Oct 2014.
V1	First issue after comments from EP and Ala, issued August 2015.
V2	Comments from MM, RT, hint of coming flexible scopes and approved by WG-MRA 2015.
V3	Updated to reflect launch of the KCDB 2.0 web platform and addition of flexible scopes.

1 Rationale

This is a CCL/WG-MRA Guidance Document on Calibration and Measurement Capabilities (CMCs) in the field of length (and angle) metrology. The guidance has two aspects:

- supplementary (CCL-specific) formatting guidance (in addition to that provided by the JCRB) to be used when preparing CMCs for entry into Appendix C of the Key Comparison Database;
- guidance on the reviewing of CMCs.

This document replaces previous documents CCL/WGDM/00-51c, CCL/WGDM/00-52, CCL/WGDM/00-53c, and JCRL-02b, and should be read in association with the current CMC classification list ('DimVIM') (http://www.bipm.org/en/committees/cc/ccl/dimvim.html).

The CCL sub working group on CMCs (sWG-CMC) has, as its first item in the Terms of Reference:

> *to establish and maintain lists of service categories (DimVIM) and, where necessary, rules for the preparation of CMC entries (DimVIM Guide);*

Both the DimVIM and the four documents referenced above were prepared in former times by the Working Group on Dimensional Metrology. Whilst the DimVIM has been maintained and brought within the control of the sWG-CMC, the DimVIM Guide has been missing. Additionally, requests for clarification on the reviewing of CMCs indicate that this current document, which is a combination of the abrogated DImVIM guides and the JCRL document 'JCRL rules for reviewing Length CMCs', is needed and should be maintained by sWG-CMC. Furthermore, in 2015 the WG-MRA recommended and CCL approved, the extension of CMCs to include so-called 'flexible scope' entries, starting with generic 1-D length CMCs. In 2019 the WG-MRA approved the first 'flexible scope' CMC category "Standards of 1D point-to-point dimensions", and specific guidance for this CMC can be found in CCL-GD-06.

2 Background

During the early years of the CIPM MRA, the CCL's Working Group on Dimensional Metrology (WGDM) produced extensive guidance on how to prepare and format CMCs for the inter-RMO review process and eventual publication in the KCDB. This included two documents on formatting CMCs and an example document for use as a template for CMC preparation.

In 2010 the WGDM ceased to exist and sWG-CMC took over responsibility for CMC matters within the CCL. Furthermore, the formatting guidance available from JCRB was extended and the existing CMC files from the NMIs were available for direct download from the JCRB website (via a password protected area, accessible to RMO TC chairpersons). Therefore the previous guidance from WGDM was edited and reduced to the minimal supplementary guidance to be used in conjunction with that given in the JCRB document [CIPM MRA-D-04] and instead of using the WGDM template CMC file, the guidance from JCRB and KCDB office was to edit downloaded copies of existing NMI CMC tables.

In December 2019 the BIPM launched the KCDB 2.0 web portal. The tasks of applying for CMCs and reviewing CMCs is now handled by the website, and the use of CMC template files is no longer encouraged but is still supported. With this in mind, the following section contains the currently applicable guidance on formatting issues specific to CCL, for the submission of CMCs.

3 Supplementary CMC formatting instructions

During the early years of the CIPM MRA, the CCL's Working Group on Dimensional Metrology (WGDM) produced extensive guidance on how to prepare and format CMCs for the inter-RMO review process and eventual publication in the KCDB. This included two documents on formatting CMCs and an example document for use as a template for CMC preparation. With the transition to KCDB 2.0 CMCs are no longer submitted via an Excel file and are instead directly entered into the KCDB website. Detailed instructions on using the KCDB website have been developed by the BIPM and links to these documents can be found in section 5.1.

1 Scope

The purpose of this section of the document is to provide detailed guidance that is in addition to both the JCRB instructions for completing submissions for the CIPM MRA Appendix C (herein referred to as AppC) listings of NMI services and the KCDB 2.0 documents listed in section 5.1. The harmonization of the naming of services is enforced by the KCDB website via support for the "DimVIM". The "DimVIM" is a classification document that provides the approved terminology and is available in several languages from the CCL open access website (http://www.bipm.org/en/committees/cc/ccl/dimvim.html). The latest English version of the DimVIM is available from the Appendix C area of the KCDB.

2 Access to the KCDB website

Details on getting a user account for submitting and reviewing CMCs can be found in Section 4 of the "Getting started on the KCDB web platform" document [KCDB GettingStarted].

3 Creating a new CMC

The following instructions follow the layout of the KCDB CMC submission form and are separated into six areas: Classification of service, Measurand, Parameters, Expanded uncertainty, and References. Only fields that require additional explanation are discussed.

Note the following general rules:

3.1 Language is English only. The DimVIM has been translated into other languages by expert volunteers from the CCL to guide others.

A common confusion is that the SI unit of length is "metre", and a measuring device is a "meter", so a *micrometer* is tool that may measure to a *micrometre* (µm) resolution.

3.2 Decimal point: use period (.), not comma (,). [95.37 okay, not 95,37]

4 Classification of service

The Dim VIM is a classification scheme that provides NMIs with a uniform terminology in creating their AppC listings. It helps regional and CCL working groups to identify similar services, and to determine where key and supplementary comparisons are needed to support mutual recognition. The terminology is organized under six major headings, each with one or more groups (Classes) of instrument/artifact types and their measurands. For example:

2 Linear Dimensions ← Main Heading

2.3 Line Standards	← Class	
2.3.1 precision line scale	← artifact	(3-digit number is "CCL Service Category" code)

The DimVIM lists most instruments/artifacts and measurands offered as a Length calibration service by NMIs participating in the CIPM MRA. Terms in the DimVIM have been chosen by experts from the CCL, and most NMIs will be able to express their AppC services using the current choices.

Locate the appropriate instrument/artifact and measurand in the DimVIM; note the CCL Service Category code and also the Class name for that item (such as 2.3.1 for precision line scale, with Class name Line Standards). If you cannot locate an appropriate entry within the DimVIM then you will not be able to proceed with the entry of the CMC. Contact your regional Length chairman, who will in turn contact the sWG-MRA, to initiate the process to add a new entry to the DimVIM.

The KCDB enforces use of the CCL Service Category code via the following required fields in the CMC application form:

4.1 **Service** corresponds to the main heading, i.e. left most numeral, of the CCL Service Category code.

4.2 **Sub-service** corresponds to the class associated with the chosen main heading, i.e. middle numeral of the CCL Service Category code.

4.3 **Individual service** corresponds to the artifact associated with a class, i.e. right most numeral of the CCL Service Category code.

5 Measurand

5.1 **Quantity** Measurand chosen from one of the options specified by the DimVIM for the specified service code.

5.2 **Instrument or artifact** chosen from one of the options specified by the DimVIM for the specified service code.

5.3 **Instrument Type or method** used to make the measurement. The phrase should suggest (to an expert) the main scale, how the gauging features are probed, and any differential scale. These factors, combined with the identification of the reference standards used, tell an expert much about your procedure.

Examples:

Artifact	**Quantity**	**Instrument Type or Method**	**Reference Used**
gauge blocks	central length	interferometry, exact fractions	stabilized lasers
Stage micrometer	line spacing	video microscope & 1-D comparator	length interferometer
Index table	angle	index table & one autocollimator	index table, autocollimator

5.4 **Lower limit**, and **Upper limit** define the range of the measurand using the units chosen in **Unit**. The limits are not to be confused with measurement conditions that define a size limitation independent of the measurand. Note that the lower limit will often not be zero and zero should not be used if such a measurand cannot be physically realized.

5.5 **Parameters** This section is used to cite any limitation or option restriction (not covered by measurand range) that is peculiar to your service, compared to what is typical from other NMIs. Examples could be possible support restrictions of artifacts such as tapes (single-catenary, or on-flat), or possible illumination restrictions for line scales (reflection or transmission only), or possible orientation restrictions for device scales (horizontal/vertical axis of autocollimator only, or both). The purpose is not to further elaborate on the information in the 'Instrument Type or Method' field, but rather to alert the client to measurement conditions or limits that may be critical to their use of the artifact. For example, an NMI may only be able to calibrate a tape on-the-flat, whereas the client may need it measured in single-catenary suspension.

Do not cite laboratory ambient conditions, such as temperature & humidity if they are within normal ranges for a dimensional calibration lab. In particular, do not cite the reference temperature if it is near 20 °C, as this is the ISO Standard Reference Temperature for all dimensional measurements, and is implicit to all services unless stated otherwise. The Expanded Uncertainty for the service will include the NMI's ability to maintain temperature (and other ambient parameters) and to compensate for measured offsets.

Do cite temperature where it purposely driven away from 20 °C, such as for thermal expansivity measurements.

Express multiple conditions for a given service by adding a separate entry for each condition.

6 Expanded Uncertainty

The Document CIPM MRA-D-04, version 5, dated March 2017 states that in the context of the CIPM MRA and ILAC Arrangement and in relation to the CIPM-ILAC Common Statement the following definition for CMCs was 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.*
>
> Also, Note N1 states: *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.*

In the scope of ILAC accredited laboratories such capabilities are inserted under the heading CMC with the following indication: (*)CMC: Calibration and Measurement Capability is the smallest uncertainty of measurement the laboratory can provide to its customers, expressed as the expanded uncertainty having a coverage probability of approximately 95 %. See also Document ILAC-G18:04/2010, Guideline for the Formulation of Scopes of Accreditation for Laboratories.

According to Document CIPM MRA-D-04, Note 2, 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); and
- available to all clients.

The CMC Uncertainty is the smallest that can be realised with real, available highest-quality artifacts. It is not the fictional uncertainty that would be possible with a perfect or ideal artifact.

6.1 **Unit**, enter the units of the CMC uncertainty value. For relative uncertainties choose '(dimensionless)'.

6.2 **Lower limit** is the minimum uncertainty possible given the measurand range entered in the Measurand section. The uncertainty should be rounded down and expressed to two significant digits. If the uncertainty is the same over the entire measurement range then enter the same uncertainty in both the **Lower limit** and **Upper limit** fields.

6.3 **Upper limit** is the maximum uncertainty possible given the measurand range entered in the Measurand section. The uncertainty should be rounded up and expressed to two significant digits.

6.4 **Coverage factor,** enter the coverage factor (usually 2).

6.5 **% confidence level**, enter the Level of Confidence (usually 95 %).

6.6 **Edit Equation**: For uncertainties determined by an ISO GUM evaluation, the preferred method is to quadrature-sum the range-independent (constant, fixed, or end-effect) terms into a single end-effect) value, and do likewise with the range-dependent (proportional) terms to form a single (proportional) term $b\ L$. These two collective terms are then used to express the uncertainty as a quadrature-sum formula, so that the end-effects and proportional components are easily recognized (each has particular metrological significance for the expert). For uncertainties evaluated this way (by GUM), use the quadratic notation $U = Q[a, b\ L]$, where a is the constant term. $Q[a, b\ L]$ means the square root of the quadratic sum of the two arguments a and $b\ L$.

Where a symbol other than L for length best describes the measurand (such as R for roundness or F for flatness), these symbols must be defined in the **Equation comments** field.

Other means for evaluating the uncertainty may result in a simple linear sum of a constant (c) and proportional term ($d\,L$), resulting in $U = c + d\,L$.

Do not linearize a GUM Uncertainty. The sWG-CMC has deemed it a poor and unacceptable practice to approximate a GUM quadrature uncertainty over a stated range of measurand by a linear sum. The coefficients of the sum no longer represent the end-effects and proportional component of the measurement process (but may be confused as such). Furthermore, for measurand ranges not starting at zero, the constant term of the sum may even be a negative value (which may be confused as a source of negative uncertainty). For these reasons, uncertainties evaluated by ISO GUM techniques must be expressed in quadrature, as per §6.7.

Some NMIs are accredited to offer a service only at discrete measurand sizes, each with a specific uncertainty. An example would be a standard set of 8 long gauge blocks – only calibrations matching the sizes in the set would be possible by mechanical comparator. For the purpose of the AppC listings, the WG-MRA requests that such a service be listed once, that the measurand range span the min/max values of the discrete sizes, that the actual sizes be listed under the Conditions (if deemed necessary to list them), and that a formula be used to convey the uncertainty over the range. (Usually, the uncertainty for each size has been calculated from an existing GUM-type formula anyway). If a separate service is available for a different range of measurands (probably with a different uncertainty), submit it as a separate entry.

Zero uncertainty is not permitted. If zero is the minimum value for range, there must always be a fixed part in the uncertainty so that the uncertainty is never zero.

7 References

7.1 **Reference standard used in calibration**, enter the directly-used reference standard(s) used to make the next link in the traceability chain to the realization of the SI unit. In any measurement process, there may be several input quantities, and each has to be traceable to its own standards. More than one reference standard can be mentioned if appropriate.

> Example: Diameter measurement, using a length-measurement machine equipped with a laser interferometer, where the zero setting is done on a reference setting ring. The two reference standards are the laser interferometer and the setting ring. (Some NMIs use a gauge block instead of a setting ring).

Where appropriate, name the standard used to make the next link in the traceability chain to:

> the realisation of a perfect form (such as a liquid surface for flatness, a master spindle for roundness, a master index table for circle division), or

to a self-calibration or error-separation techniques (such as a multi-step error separation technique for roundness, a reversal technique for straightness, or a cross-reference self- calibration technique with three independent circle divisions).

7.2 **Source of traceability** is used to indicate the official abbreviation for the institute that provides the highest link to the SI for the CMC being declared.

7.3 **Group Identifier** is used to identify linked CMC claims such as the real and imaginary components in electricity and magnetism. This feature is not currently used within the CCL and can be left blank.

7.4 **KCDB support for CMC claim**. From the drop down list choose the key comparison or supplementary comparison that supports this CMC. The comparison(s) must have directly tested this specific service (such as CCL-K3 directly supports an optical polygon service, since it required that an optical polygon be calibrated). Or the comparison must have been deemed by CCL or the region to have tested the principal techniques of this related service (such as CCL-K3 indirectly testing the principle techniques necessary for the calibration of an index table and an autocollimator.

If you are applying for a flexible CMC of category “Standards of 1D point-to-point dimensions” then refer to the CCL guidance document GD-06 [CCL-GD-06] for information on the required supporting evidence.

If you have not participated in an approved comparison for this service then the titles or references of the documents to be used to support the claim must be entered in **Other support**.

7.5 **Comments for publication**. Publicly available comments published with the CMC.

7.6 **Comments for reviewer.** Comments specifically intended for the reviewers of the CMC.

4 Rules for reviewing length CMCs

The sWG-CMC deems that the following set of rules must be applied to the review of Length CMCs in order that their claims be judged as “fully reliable”.

4.1.1 After the Provisional Period of the MRA

Now that the provisional period of the MRA has ended, the rules to be followed are simply those given in the MRA. Document CIPM MRA-D-04 contains these rules. Section 3 of that document states the necessary requirements. They are reproduced here for expediency.

> The JCRB requires that CMCs submitted for publication in Appendix C are accompanied by an RMO report indicating that the local Technical Committee/Working Group has approved the range and uncertainty of said CMCs and that each one of them is supported by a fully implemented Quality System reviewed and approved by the local RMO.
>
> Furthermore, the JCRB requires that the range and uncertainty of the CMCs submitted be consistent with information from some or all of the following sources:
>
> 1. Results of key and supplementary comparisons
> 2. Documented results of past CC, RMO or other comparisons (including bilateral)
> 3. Knowledge of technical activities by other NMIs, including publications
> 4. On-site peer-assessment reports
> 5. Active participation in RMO projects
> 6. Other available knowledge and experience
>
> While the results of key and supplementary comparisons are the ideal supporting evidence, all other five sources listed above may be considered to underpin CMCs not directly related to the available comparison results and those for which comparison results are not yet available.
>
> The NMIs that issue the CMCs are primarily responsible for providing, through their local TC/WGs, the information that they believe is necessary to support their claims. TC/WGs from other RMOs may request additional information, if needed.

For item 6 in the above list, *i.e.* other knowledge and experience, the sWG-CMC interprets this to include the following:

- Range and uncertainty of the CMC agree with the scope of a third party accreditation.
- CMC is closely associated (uses similar techniques/ equipment) to an accepted high level service for which there are comparison results available.
- Critical aspects of the CMC have been demonstrated in other accepted CMCs (using the ‘Technique Approach to Reviewing Services’, as outlined in the CCL Strategy document section 3.1, & figure 2).
- An uncertainty budget and calibration procedure.
- Publications acceptable to the sWG-CMC.

If you are reviewing a CMC of category “Standards of 1D point-to-point dimensions” (CCL Service Category code 2.5.1) then refer to the CCL guidance document GD-06 [CCL-GD-06] for additional

information specific to this category.

4.1.2 CMC review process

The review process for CMCs follows the guidance in CIPM MRA-D-04.

5 References to available documents

5.1 BIPM KCDB 2.0 training documents

Getting started on the KCDB web platform [KCDB GettingStarted]

https://www.bipm.org/utils/common/pdf/KCDB_2.0/Getting_started_KCDB_platform.pdf

Presentation "Create a CMC"
https://www.bipm.org/utils/common/pdf/KCDB_2.0/PPT/3-KCDB-2.0-Create-CMC.pptx

Presentation "CMC Review"
https://www.bipm.org/utils/common/pdf/KCDB_2.0/PPT/4-KCDB-2.0-CMC-review.pptx

5.2 CIPM/MRA documents

Calibration and Measurement Capabilities in the context of the CIPM MRA [CIPM MRA-D-04]
http://www.bipm.org/utils/common/CIPM_MRA/CIPM_MRA-D-04.pdf

5.3 JCRB documents

Monitoring the impact of key and supplementary comparison results on CMC claims [JCRB-11/7(a)]
http://www.bipm.org/utils/common/documents/jcrb/impact_comparisons.pdf

5.4 CCL/WGDM documents

DimVIM List of Services [DimVIM]
http://www.bipm.org/en/committees/cc/ccl/dimvim.html

CCL-WGDM Supplement to the JCRB Instructions for Appendix C [abrogated] [WGDM/00-51c] No longer available from BIPM website – contact WG chairman.

Example & Template for CMC [abrogated] [WGDM/00-52] Included in: http://www.bipm.org/wg/CCL/CCL-WG/Restricted/2001/Docs-list-for-WGDM-meeting-docs-2001.zip.doc

Guide to CCL-WGDM Supplement to the JCRB Instructions for App. C [abrogated] [WGDM/00-53c] Included in: http://www.bipm.org/wg/CCL/CCL-WG/Restricted/2001/Docs-list-for-WGDM-meeting-docs-2001.zip.doc

JCRL rules for reviewing length CMCs [JCRL-02b]
http://www.bipm.org/wg/CCL/CCL-WG/Restricted/2001/Docs-list-for-WGDM-meeting-docs-2001.zip.doc

CCL Strategy document [CCL/WGS/SD-L]
http://www.bipm.org/utils/en/pdf/CCL-strategy-document.pdf

CCL Guidance document GD-06 CMCs of category "Standards of 1D point-to-point dimensions" [CCL-GD-06]

https://www.bipm.org/utils/common/pdf/CC/CCL/CCL-GD-6.pdf