Electricity and Magnetism Supplementary Guide to the JCRB Instructions for Appendix C of MRA

Version 4.4 (May 2011)

0. Scope

This Supplementary Guide reports information on how to draw Calibration and Measurement Capability (CMC) Excel files in the field of Electricity and Magnetism (EM). The Guide is intended to be used worldwide, but makes provision for specific requirements of each Regional Metrology Organisation (RMO), particularly concerning the way the information supporting CMCs is gathered and the detailed CMC intra-regional review process.

For general information related to the CMC review process, acceptance criteria, support by key and supplementary comparisons etc. the reader is addressed to a set of JCRB documents, downloadable from the web at: http://www.bipm.org/en/committees/jc/jcrb/documents.html.

This Guide is addressed to both the NMIs that have not yet submitted their capabilities and the NMIs that would like to add CMCs to their set or modify CMCs already published.

Suggestions about presentation of specific quantities in CMC entries are given in Appendix 1.

A list of questions and answers and of pending problems is given in Appendix 2.

0.1 Closely related documents

The following documents are cited in this Supplementary Guide and must be used with it.

	File Name or Document Name	*Comment*
1	*RMO_Country_EM_date*	CMC Excel template, available from the Technical Committee (TC) chairperson and from the JCRB documents web site, see link above
2	*EM Classification for CMCs, (with column A definitions)*	Classification of the EM calibration and measurement services, with standard definitions of the measurand, available from TC chairperson.
3	*BIPM Instructions for Drawing up CMC Excel Files* (in short *BIPM Instructions*)	Rules of writing approved at the 6th JCRB meeting in March 2001, downloadable from the JCRB open access documents web page [1].
4	*Additional Instructions for CMC files in EM*	Rules to report uncertainty in matrices and to tag closely related CMCs, downloadable from the JCRB open access documents web page [1].
5	*Instructions for uncertainty matrices in CMC files*	Excel file with example on how to prepare an uncertainty matrix, downloadable from the JCRB open access documents web page [1].
6	*Instructions for closely related CMCs*	Excel file with example on how to tag closely related CMCs, to have them close-by in the database, downloadable from the JCRB open access documents web page [1].

[1] http://www.bipm.org/en/committees/jc/jcrb/cmc_excel_files.html

7	*Procedure for modifying CMCs already in Appendix C*	JCRB criteria about modification of CMCs already published in the database, Doc. JCRB 8/10, downloadable from the JCRB open access documents web page [2].
8	*CIPM MRA-D-04*	Calibration and Measurement Capabilities in the context of the CIPM MRA

0.2 Quality System requirement

Since the transition period of the Mutual Recognition Arrangement (MRA) has ended on 31 December 2004, the CMCs submitted must now be covered by a Quality System (QS) reviewed and approved by the RMO.

0.3 Modification of CMCs already in Appendix C

Following the JCRB document "*Procedure for modifying CMCs already in Appendix C*", modified CMCs fall into three categories:

a) CMCs corrected for material or editorial errors or for improving the explanatory text; these CMCs do not require a new review;

b) CMCs modified to increase the uncertainty or to reduce the scope; also these CMCs do not require a new review, but if the change is due to the results of a comparison the other RMOs are to be notified;

c) CMCs modified to change the method of measurement or to reduce the uncertainty or to increase the scope; these CMCs require a new review.

For CMCs of categories a) and b), modifications must be made on the Excel files corresponding to the published CMCs. Download these files from the restricted access JCRB CMC site (ask your TC chairperson for user name and password). After downloading the file of your Country, modify its name as follows:

RMO_Country_EM_date_mod_ab

where *RMO* is the acronym of the regional metrology organisation, *Country* is the ISO two-letter abbreviation for the Country[3], and *date* is the date of submission in the form yymmdd. *EM* stays for Electricity and Magnetism and *mod_ab* is to show the type of file. No other documentation is due to support the proposed changes, unless requested by the TC chairperson.

Modified CMCs of category c) will be reported together with and will follow the same rules as new CMCs (see after).

The following colour codes, suggested by the BIPM, will be used in all cases, a), b) and c), to highlight the changes in a CMC entry:

1) any modification of an existing entry will be written **in bold red character;**
2) in case of cancellation of words in a cell do **not use the strike-through character formatting** but change to **bold red** the remaining cell content;
3) in the rare case that the whole cell content is deleted, highlight the now empty cell by a light pink background;

[2] http://www.bipm.org/en/committees/jc/jcrb/documents.html
[3] http://www.iso.org/iso/en/prods-services/iso3166ma/02iso-3166-code-lists/list-en1.html

4) withdrawn CMCs will be highlighted by a light pink background extending over **Columns A to P** and the words "to be deleted from the KCDB" placed in the yellow Comment Column (**Column T**).

The NMI internal service identification of the modified CMCs (**Column Q**) will not be changed. Internal service identifications of withdrawn CMCs will not be used for new CMCs. After downloading the file of your Country take care to convert into black, or to delete, all previous colour coded entries, as applicable.

0.4 Submission of new CMCs or of modified CMCs requiring new review.

New CMCs and modified CMCs under category c) above will be reported in the same CMC Excel file, whose filename will be coded as explained in the following §1. In this file the modified CMCs will be recognised for the use of the colour codes suggested by the BIPM, as explained in the previous paragraph. Care should be taken that new CMCs do not have the same NMI internal identification (**column Q**) of CMCs already published in the Appendix C.

Each CMC Excel file with new CMCs, or modified CMCs requiring new review, will be accompanied by all information needed to substantiate claims and methods. The way this information is organised is decided by the region. For example it can be reported in a standard questionnaire approved by the region.

0.5 Intra-RMO review process

Even if the review process can be different in the details from region to region, it will always follow the following main steps:

- each NMI sends its CMC file together with related supporting information to the TC chairperson;
- the TC chairperson sends all the files to the technical group of his region in charge of the analysis of the CMCs, which will carry out the review following the JCRB criteria, as instructed from the TC chairperson (intra-regional review); to help the chairperson to supervise the review work, it is suggested that agreed changes are coded in colour by the reviewer, to be clearly visible: for example modifications or additions, with respect to the version submitted, will be **written in bold blue**, and deleted CMCs will be highlighted with light blue background and corresponding comment "to be deleted" in **Column T;**
- at the end of the review, the TC chairperson receives the files with approved CMCs from the reviewers and prepares them for the inter-RMO review, taking care that only the correct BIPM colour codes (see § 0.3) are maintained;
- the TC chairperson posts the CMC files, together with a report, on the JCRB web page for the inter-regional review of CMCs, which will automatically start the inter-RMO review process.

0.6 Inter-RMO review process

- Document CIPM MRA-D-04 states in section 8 that

CC-WG on CMCs may establish their own rules and timelines for coordinating the interregional review of CMCs. Therefore, posting, distribution and submission of comments on CMC submissions may be done without the use of the JCRB website and without following the deadlines specified for this purpose.

The CCEM WGRMO has decided in its 2011 meeting on the following deadlines to accelerate the inter-RMO review process:

● The announcement of the review of the submitted CMCs by another RMO shall be made not later than four weeks after posting the CMC set on the JCRB web site.

● The review report shall be sent not more than four months after the announcement of the review.

● If a reviewer cannot accept the submitted entry on the basis of the information available, he/she should contact the submitting NMI within three weeks after the start of the review. A maximum of three weeks is allowed for the first reaction of the submitting NMI to requests of the reviewer. Once the contact is established and the first positions are given, further iterations of the process should take less time (typically less than two weeks per iteration). In any case, the time allocated to the whole review process should not be exceeded.

● The enforcement of these shorter deadlines needs to be made by the chair of WGRMO, because the JCRB website sends reminders after the - longer - deadlines specified in the document CIPM MRA-D-04.

In addition, the following recommendations are made:

● The review should be restricted to new and improved services, with either reduced uncertainty or wider scope.

● RMOs are encouraged to cooperate in reviewing submitted CMCs. It is not necessary that all RMOs review the same CMC set. RMOs (through the TC-chairs) may communicate with one another to divide responsibility or to decide who will participate. However, it is important to be careful that the process works in a way that ensures that all CMCs are reviewed with the same rigor and are subjected to equal treatment.

● Technical peer review reports should be included in the CMC submission, when available, and the information be used by the reviewers.

1 Structure of the CMC table

The Excel template for the compilation of a CMC table is given in the Excel file named:

RMO_Country_EM_date

This template is only to be used if an NMI declares CMCs for the first time. In all other cases, the Excel table of already existing CMCs shall be used instead of the template, see the end of this section. Only one file per Country must be submitted. The submitting NMI will change the name of the file by introducing the acronym of the regional metrology organisation for *RMO* and the ISO two-letter abbreviation for *Country*. For *date* the form yymmdd will be used.

Header and footer are provided in the Excel template to help to identify the table when printed. In the header the acronyms of the NMI and of the Country must be introduced. In case of more than one NMI per Country, all the NMI acronyms will be reported in the header.

In the table, at the right side of the white columns, there are three blue, six yellow (divided by a white column for *Comments to be published via the database*) and three green columns. The blue columns are for supporting the CMC traceability. The yellow columns are for the administration of the table and for the names of the uncertainty matrices and of the tags for closely related CMCs. The green columns are to be used during the review processes. The white columns and the blue and yellow columns, not the green ones, are to be filled in by the submitting NMI.

Only the white columns, and the yellow columns "NMI Service Identifier", "NMI", and "Uncertainty Matrix" will be reported, with attached uncertainty matrices, into the Appendix C. Of course also the columns "Service category" and "Tag for closely related CMCs" are essential for a correct transfer of the table into the Key Comparison Database.

If the NMI has already CMCs in the KCDB, all changes (additions, modifications, deletions) shall be made in the Excel table of the existing CMCs. This file can be downloaded from the JCRB CMC website using the "get published CMCs" link. All changes shall be made on this file, using the color codes described in section 0.3. Before submission, all CMCs which are unchanged shall be hidden by using the Excel "hide" function, so that only the changes are visible to the reviewers.

2 General Criteria of compilation

2.1 The MRA Appendix C submission is an Excel spreadsheet where separate NMI services are listed in rows, and columns are used to organise the attributes of the services.

2.2 The CMCs will be reported in a single spreadsheet, following strictly the order of the EM *Classification* of services. A disordered list would give unnecessary, additional work to the TC chairperson.

2.3 Make a separate CMC entry in case of a distinct measurand or a distinct calibration procedure or a distinct uncertainty declaration. If the uncertainty depends on two variables (like the range of the measurand and the range of a parameter) use can be made of an uncertainty matrix to reduce the number of entries (see §§ 8.3 and 11.6).

2.4 Each entry must correspond to only one classification category and to only one measurand: for example electrical power and energies, even if in the same classification category, are different measurands and should be reported in different CMC entries.

2.5 Each CMC entry should be self consistent, without reference to other entries, because each CMC will be usually displayed alone by the database.

2.6 For each CMC, multiple entries in the two columns on Measurement Conditions (i.e. when CMC has more than one parameter) must be separated vertically into separate cells.

2.7 Do not insert headings nor blank rows in the table. Do not merge any cells vertically and do not use symbols of repetition (“), to show that the information is the same as in the previous CMC, but repeat the information.

2.8 Do not use the Excel facility to append comments to the cells, but use the *Comments* columns on the right side of the table (see §§ 10.2 and 10.3).

NOTE 1. For some quantities (power and energy, AC-DC transfer, voltage and current ratios, RF calibration factor, RF reflection coefficient and RF scattering parameters) recommendations for a uniform presentation are reported in Appendix 1.

3 Language and Symbols

3.1 Detailed writing rules for preparing the CMC files are given in the *BIPM Instructions.* **These Instructions must be carefully read and the rules carefully applied.** If too many violations are found, the CMC file will be sent back to the submitting NMI for correction. Compliance with the writing rules will greatly help the BIPM in the importation of the Excel files into the database.

3.2 The following rules complement the *BIPM Instructions*:

- as units for angle use the symbols °,'," or rad; do not use: deg, min, sec, nor degree, minute, second, nor arc-second;
- use SI accepted prefixes for decimal multiples and sub-multiples; they must be written close to the symbol of the unit of measurement, in the appropriate columns, and not close to the numerical values;
- when reporting a list of items in the same cell use the comma (,) as the separation character [e.g.: DC voltmeter, multimeter, multifunction transfer standard];
- use a colon (:) to introduce a specification of a previous text-item of information [e.g.: reflection coefficient on coaxial: phase]

4 Electricity and Magnetism Classification scheme

4.1 The *Classification of Electricity and Magnetism CMCs*, approved by the CCEM, provides the NMIs with uniform and world-wide agreed terminology for the classification of their services. These are divided in major headings, sub-headings and categories. For each category, characterised by a 3-number classification, a list of instruments/artefacts is given.

4.2 Usually it should be possible to find classified denominations for the quantity of interest and the instrument/artefact, to be reported in **columns A** and **B**. In case applicable terms can not be found in the classification (new quantity or instrument/artefact) follow § 5.1.

4.3 At the time of writing this Guide, the more recent, approved, classification version is 7.3.

5 Calibration or Measurement Service (col. A, B. C)

5.1 The Quantity and the Instrument/Artefact names will usually be found in the *Classification.* If this is the case, use the given terms as explained in § 5.2 and § 5.3, then take note of the corresponding 3-number classification for introduction in **column R** (§ 11.3). If this is not the case, discuss with the TC chairperson about entering your own English term for Quantity or Instrument/Artefact or both and about assigning to your service a provisional three-number classification (in the form: *heading.sub-heading.x*) in **column R.** This case should be an absolute exception, given the extensive revision that has led to the present version of the classification.

5.2 **In column A**, insert the appropriate description of the Quantity. This is usually given in the *Classification* by the names of the heading, sub-heading and category. If needed for better understanding, a specification character (:) and/or separation characters (,) can be used [e.g.: capacitance: dissipation factor]. Because combining heading, sub-heading and category could lead to a cumbersome and unnecessarily long definition of the Quantity, you are very much encouraged to use one of the standardised wordings reported in the classification file *with column A definitions*, provided with this Guide.

5.3 **In column B**, insert the appropriate name for the Instrument/Artefact. If more than one instrument applies, report a list using the separation character (,). If the measurand is not clearly identified by the Instrument/Artefact name, introduce a further specification using the specification character (:). If a symbol referring to the measurand is used in one of the subsequent columns, introduce this symbol, *in Italics*, in **column B** as the last piece of information, separated from the previous item(s) by a specification or separation character, whatever is more convenient [e.g.: multifunction calibrator: *V*] [e.g.: fixed capacitor: dissipation factor, *d*]. Do not use the symbol *k*, as this symbol is reserved for the uncertainty coverage factor.

5.4 **In column C**, a synthetic but clear definition of the method of measurement must be reported. This information, combined with that in **column N** about the standard(s) used as the reference(s), is of fundamental importance to allow an expert to identify the measurement technique.

Examples 1:

A	B	C	R
DC resistance standards and sources: intermediate values	Fixed resistor: *R*	Comparison by means of current comparator bridge	2.1.2
AC high voltage: ratio error	Voltage transformer bridge	Generation of known reference error	8.3.4

6 Measurand Level or Range (col. D, E, F)

6.1 **In column D**, insert the minimum value of the range of the measurand as a single numerical value. If you introduce zero for this number, check that the expression for the uncertainty, reported in **column I**, is still meaningful.

6.2 **In column E**, insert the maximum value of the range of the measurand as a single numerical value. If your measurement refers to a single value of the measurand, **column D** and **E** will report the same number.

6.3 **In column F**, report the unit of measurement that applies to the minimum and maximum values in the two previous columns. Use accepted SI prefixes if needed. If a unit like dB needs a reference value, include this value in **column B** (see last line of Examples 2, below). In case of quantities without dimension leave **column F** blank. In case of quantities that can be better given in relative terms it is also possible to express the unit as a ratio of different multiples of the same pertinent unit or to use the symbol %.

6.4 Usually it is possible to understand from the quantity if measurements can be performed on both positive and negative values. Only if this is not the case report explicitly negative range limits.

Examples 2:

A	B	C	D	E	F	R
DC Voltage ratios: up to 1100 V	Resistive divider	Comparison with reference divider	1.E-06	1		1.3.1
AC power and energy: single phase (f <= 400 Hz), active power	Power converter	Comparison with reference standard	0.05	30000	W	7.1.1
Scattering parameters: reflection coefficient (Sii) in coaxial line, phase	Passive device	Dual six port	-180	180	°	11.3.1
AC resistance: argument	Fixed resistor	Calculable resistor	$-\pi$	$+\pi$	rad	4.1.1
Antenna properties: antenna factor	Log antenna, reference value for unit: 1 m^{-1}	Three antenna method	-30	80	dB	11.5.1

7 Measurement Conditions / Independent Variable (col. G, H)

7.1 In **column G**, report any condition, which imposes limitation or optional restriction to the measurement, in the form of the name of the parameter that describes this condition. If several conditions apply, the names of the parameters will be entered into separate cells in the column. If a symbol referring to the value of a parameter is used in one of the subsequent columns, report this symbol, *in Italics*, after the name of the parameter, using the specification character [e.g.: frequency: *f*]. Do not use the symbol *k*, as this symbol is reserved for the uncertainty coverage factor.

7.2 In **column H**, report the range of the parameter or other pertinent information that defines the restriction. If **column G** has several parameters, report in **column H** the corresponding ranges of variation, or pertinent information, in the corresponding cells.

7.3 When indicating a range in **column H** use the notation *minimum to maximum* [e.g.: 1 MHz to 500 MHz or (1 to 500) MHz]. If only one limit needs to be specified, use the notation *up to* (for maximum) or *down to* (for minimum).

7.4 When a parameter takes discrete values, report these values separated by commas (,) [e.g.: (1, 2, 5, 10) kV].

7.5 In some cases the measurand takes only discrete values. In this case the range **columns D** and **E** report the minimum and maximum values, while the parameter **columns G** and **H** report, respectively, the symbol of the measurand (previously defined in **column B**) and the list of values. This will be the first information in the parameter list. A typical case could be the decadic values of resistance within a certain range. This condensed presentation of a group of CMCs is possible if a single uncertainty declaration (by a numerical value or an expression) is given for the group or, in case of uncertainty dependence from two variables, if an uncertainty matrix is given (see § 8.3).

7.6 Usually do not report as parameters the ambient conditions of the measurement. These are intended to be standard laboratory conditions, whose limits of variation are taken

into account in the reported uncertainty. Report the temperature, or temperature range, of the measurement or other ambient conditions only if it is relevant to the identification of the measurement service: **column U** is usually more appropriate for this type of information (see § 10.3).

Examples 3

A	D	E	F	G	H	I	J
AC power and energy: single phase (f <= 400 Hz), active power	600	600	W	Voltage	120 V	60	µW/VA
				Current	5 A		
				Power factor	1		
				Frequency	50 Hz, 60 Hz		
AC resistance: real component	0.1	1E+05	Ω	Frequency	400 Hz	10	µΩ / Ω
				Max. voltage	10 V		
				Max. current	0.5 A		

A	B	D	E	F	G	H
DC resistance standards and sources: intermediate values	Fixed resistor: *R*	0.001	10	kΩ	*R*	1 Ω, 10 Ω, 100 Ω, 1 kΩ, 10 kΩ
DC Voltage ratios: up to 1100 V	Resistive divider	1.E-06	1		Input voltage	(1 to 10) V
Scalar RF reflection coefficient: in coaxial line	Passive device	-1	1		frequency	0.1 GHz to 40 GHz

8 Expanded Uncertainty (col. I, J, K, L, M)

8.1 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.

8.2 In **column I**, the expanded uncertainty value (without ±) must be entered. This may be a fixed value, valid over the entire range of the quantity, a range of values [e.g.: (1 to 50)E-06] or a mathematical expression.

8.3 For AC quantities, and more in general when the uncertainty depends on two variables, usually the range of the quantity and the range of one parameter, it is recommended to

use the presentation of the uncertainty in a two-dimensional matrix, following the rules given in the BIPM documents 4 and 5, listed on page 1 of this Guide. This technique will reduce the number of lines in the table and will improve presentation. In this case, **column I** will report the minimum and maximum uncertainty values. It is intended that the unit of measurement of the uncertainty values in the matrix is the one given in column J.

8.4 With the exception of presentation in matrices, if a range of values is given in **column I,** the uncertainty is considered to be varying linearly within the range, in correspondence to the variation of the measurand or of a parameter from the lower to the higher limits reported in **columns D** and **E** (for the measurand) or in **column H** (for the parameter). The functional dependence, if not clear, should be specified in the same **column I** after the uncertainty expression [e.g.: (1 to 50), depending on the frequency]. If the uncertainty variation is not linear, the user must be informed by introducing a comment in **column U,** for example specifying that the given values only define the minimum and maximum uncertainties. In this case however, the range of variation should be limited, otherwise the CMC entry would become useless.

8.5 Uncertainty by formula. When using a mathematical expression, defined symbols referring to the measurand or to the parameters will be entered. The units of measurement of the symbols will be specified in the same **Column I** after the expression (see examples). Do not introduce units of measurement within the expression. The unit for the resulting uncertainty is to be reported in **column J** (see § 8.11). With the exception of the proportional uncertainty (§ 8.6), for all other expressions (§§ 8.7 to 8.9) it is suggested to report the typical range that the uncertainty evaluates to [e.g.: Q[0.00002, 0.02·tanδ], values from 2E-05 to 2E-02].

8.6 Uncertainty by formula: proportional uncertainty. For range-dependent uncertainties, the form bV can be used, where V is usually the symbol of the measurand, reported in **column B**, and b is a numerical value (proportionality factor). If the lower limit of the measurand is zero, the proportional expression alone is not acceptable, an uncertainty of zero being meaningless.

8.7 Uncertainty by formula: quadratic summation. Following the ISO GUM, the composition of a constant uncertainty term (for example the limit of sensitivity) and of a range dependent (proportional) uncertainty term, is done by quadratic summation. This can be written with the expression Q[a, bV], where a is the numerical value of the constant term and bV is the proportional term (§ 8.6).

8.8 Uncertainty by formula: linear summation. In other cases the uncertainty may be given by the linear summation of a constant and a proportional term, like (d + cV).

8.9 Uncertainty by formula: 2nd degree polynomial. This type of uncertainty declaration will be used if it is of help with covering an extended range of the quantity or of the parameter by a single uncertainty declaration. Use of polynomials of degree higher than 2 or of other non elementary functions is strongly discouraged, as they are difficult to understand by the user and very often prone to errors, also due to the very limited capability of Excel in equation editing. For uncertainties depending on two variables the use of matrices (see § 8.3) should always be preferred.

8.10 When an explanation is necessary in order to allow a correct interpretation of the uncertainty expression, add a separation character (,) after the uncertainty value or expression and write the comment [e.g. for the absolute uncertainty of a voltage divider: (0.2E-06+ 0.05E-06 / U), U output voltage in V].

8.11 In **column J**, report the unit of measurement for the uncertainty. In case of relative uncertainties for quantities with dimensions, express the unit as a ratio of different multiples of the same pertinent unit. [e.g. μA/A] or, if the unit is an expression involving other units, use a negative power of 10 or use the symbol %. For quantities without dimensions, **column M** is essential for the correct interpretation of the uncertainty.

8.12 Do not use as unit of measurement the symbols ppt, ppm, ppb or similar.

8.13 In **column K**, report the coverage factor *k*.

8.14 In **column L**, report the probability corresponding to the declared uncertainty and coverage factor. A probability of 95% should in general be considered, but exceptions are allowed. The percentage sign must be reported close to the number.

8.15 In **column M** answer *Y* or *N*, thus specifying if the given uncertainty is to be interpreted as a relative or an absolute one (with respect to the measurand whose units are given in **column F**). **Column M** must always be filled in, even if the nature of the uncertainty seems to be already clear.

NOTE: do not use the symbol *k* in the mathematical expression of the uncertainty, to avoid confusion with the uncertainty coverage factor.

Examples 4:

A	B	D	E	F	I	J	K	L	M
DC resistance meters: intermediate values	Fixed resistor	0.001	10	kΩ	0.5	μΩ/Ω	2	95%	Yes
DC Voltage ratios: up to 1100 V	Resistive divider	1.E-06	1		0.3E-06		2	95%	No
Scalar RF reflection coefficient: in coaxial line	Passive device	0.01	0.2		0.005 to 0.010		2	95%	No
DC resistance standards and sources: standards for high current	DC shunt	1.E-04	100	Ω	(15 to 2)E-06		2	95%	Yes
Soft magnetic sheet and powder materials: specific apparent power	Epstein sample according to IEC 60404-2: *P*	0.1	300	VA/kg	2E-03*P*, *P* in VA/kg	VA/kg	2	95%	No
DC voltage sources: low values	DC voltage sources	1	1000	nV	Q[2, *N*], *N* is source noise in nV	nV	2	95%	No
Electric discharge: apparent charge	partial discharge calibrator: *q*	1	5000	pC	(0.2 + 0.02 *q*), values from 0.22 to 100, *q* in pC	pC	2	95%	No

A	B	D	E	F	I	J	K	L	M
Capacitance: dissipation factor for dielectric capacitors	Fixed capacitor, mica, four terminal-pair	1E-04	1E-03		4E-05 to 1E-04		2	95%	No
AC voltage ratio: real component	600-W-attenuator-boxes	60	90	dB	0.01	dB	2	95%	No

9 Reference Standard used in calibration (col. N,O)

9.1 In **column N**, the reference standard(s) used in the measurement and making the link in the traceability chain to the SI unit, must be reported. In case several references are used for a certain measurement, these must be reported in the same cell, as a list of items separated by commas.

9.2 In **column O**, identify the laboratory(ies) which is (are) the source of traceability for the calibration of the reference standard(s) in **column N**. When the reference standard is calibrated by means of an auto-calibration process, like for some ratio standards, traceability is to the laboratory performing this process. In case of more than one laboratory, the list of laboratories should correspond to the list of the standards in **column N**.

Examples 5:

A	B	N	O	S
DC Voltage sources: low values	calibrator	voltage divider, solid state voltage standard	NMI1, NMI2	NMI1

In this example, NMI1 is the submitting NMI (whose acronym is given in **column S**), which is able to perform the auto-calibration process of the voltage divider, while NMI2 is another NMI, which gives the traceability for DC voltage by calibrating a zener voltage standard of NMI1. This zener standard is the first line standard of NMI1, used for the calibration of the voltage standard reported in **column N.**

10 List of Comparisons Supporting the CMC, Internal Comments, Comments for the user (col. P, T, U)

10.1 In **column P**, enter the correct identification of one or more comparisons sufficiently related to the service being submitted, in order to demonstrate equivalence. Different types of comparisons can be considered:

- CCEM key comparisons or RMO key comparisons;
- supplementary comparisons;
- past CIPM, regional or other (e.g. pilot, BCR etc.) comparisons;
- bilateral comparisons.

In this column only comparisons for which measurements are completed and at least a draft report is available must be considered. Comparisons still running, even if close to completion, will be reported in the *Internal Comment* (yellow) **column T**.

10.2 In **column T** (yellow column) report comments related to the CMC and useful to the reviewer (this column will not be included in the Appendix C). Examples are: comparisons planned or still running, more details about traceability etc. General information supporting the CMCs (e.g. quality system, equipment, technical publications, etc.) will be reported separately, in the form established by the RMO. More detailed information will be given to the reviewer under request.

10.3 In **column U** (white column) report comments useful to the user, as this column will be included in the Appendix C. Examples are: specific limitations to the CMC, details about the conditions of measurement, options etc.

Example 6.

A	B	N	O	P	T	U
DC voltage meters: intermediate values	Multimeter	Voltage divider, solid state voltage standard	NMI1, NMI2	EUROMET.EM-K8, BIPM.EM-K11.b		
AC power and energy: single phase (f <= 400 Hz), active power	Power meter	Automated calibration system	NMI		EUROMET.EM-K5, report in progress, Draft A	Minimum value of uncertainty with power factor equal to 1
AC voltage: AC-DC transfer difference at medium voltages	Multifunctio n transfer standard	AC-DC transfer standard	NMI	CCEM-K6.a		
DC resistance standards and sources: intermediate values	Fixed resistor	Fixed reference resistor	BIPM	PRAQ III B 5 - 97- 030 (CEN)	Report available	
DC resistance standards and sources: high values	Three terminal resistor	Three terminal standard resistor	NMI1	NMI1-NMI2 intercomparison at 100 MΩ	Information on results in CPEM'98 Digest, page …	
DC resistance standards and sources: intermediate values	Fixed resistor	Fixed resistor	NMI	CCEM-K1		Measuremen ts only at 23 °C in oil or air bath
DC Voltage meters: very low value	DC voltmeter	Josephson voltage standard	NMI	BIPM.EM-K1b		

In the second example, in **column U**, the attention of the user is drawn to the fact that the range of the uncertainty (not shown) is not linearly related to the range of the measurand, as it should usually be.

In the second example reference to comparison is in **column T,** and not in **column P** because, at the time of submitting the given CMC, the results of that comparison were not yet available.

11 Euromet Electricity Services Administration (col. Q, R, S, T), Comments for the user (col. U), Matrices and Tags (col. V and W) and intra/inter RMO review (col. X, Y, Z)

11.1 **Columns Q, R, S** are of particular importance for the management of the CMC table: they allow the experts to easily refer to a certain CMC, which facilitates, for example, e-mail discussions. Also, it is possible to merge rows from tables of different laboratories, for example for comparison purposes, without loosing knowledge of the service identification and originating NMI.

11.2 **Column Q** is provided for numerical identification of each service of an NMI.

If an entry is a modified CMC, aimed at substituting a CMC already published in the database, the published service identification number will not be changed.

If an entry is new, it will have a new identification number, which, in case the submitting NMI has already EM CMCs published in the database, should not be equal to numbers already used in the published set. If an NMI is submitting its CMC set for the first time, progressive numbering starting from 1 will preferably be attributed to the CMCs. If an Excel formula is used to generate these progressive numbers, the Excel command "Copy+Paste-special|Values" must be used at the end to leave only numbers in **column Q**. In case a CMC extends over more than one line, only the first line will be numbered.

11.3 In **column R** report the service category, which can be found in the *Classification* and depends on the Quantity and the Instrument/Artefact reported in **columns A and B** (see § 4). In case of lack of applicable terms see § 5.1. If more than one classification applies, one CMC entry for each classification must be provided, in order to have only one category per entry. In a few cases, different quantities have the same classification, like power and energy: in such cases different CMCs must be provided for the different quantities.

11.4 In **column S**, report the acronym of the submitting NMI. In case of more than one NMI per Country, the acronym pertinent to each CMC will be reported. It is not possible to have in the same Country two or more NMIs submitting the same CMC.

11.5 **Columns T and U** were covered in §§ 10.3 and 10.4.

11.6 In **column V** report the name of the matrix, included in the Excel file, where the uncertainties corresponding to the CMC are reported. If the uncertainty declaration has not used a matrix presentation, this column will be left blank (see documents 4 and 5 listed on page 1 of this Guide for details).

11.7 In **column W** report the tag chosen to identify the CMC as closely related to the previous or the following one having the same tag (usually for real and imaginary parts of the same quantity). This tag will alert the BIPM that these closely related CMCs must be presented close-by in the database (see documents 4 and 6 listed on page 1 of this Guide for details).

11.8 **Columns X, Y, Z** are reserved for the review processes and should not be used during the preparation of the CMC tables.

Example 7

(examples for uncertainties presented in a matrix and for tagged CMCs are given in documents 5 and 6 listed on page 1 of this Guide)

A	B	Q	R	S	T	U
AC voltage up to 1000 V: sources	Multifunction calibrator	86a	5.2.1	METAS	EUROMET 464, participation planned	
AC voltage up to 1000 V: meters	Multimeter; multifunction transfer standard	86b	5.2.2	METAS	EUROMET 464, participation planned	
DC voltage ratio: up to 1100 V	DC voltage divider	9	1.3.1	NMi-VSL		
AC voltage ratio: imaginary component	One-decade inductive voltage divider with 11, 10 or 8 taps	315	5.3.1	PTB		Minimum step depends on the type of divider

Appendix 1

Presentation of some CMCs in Electricity and Magnetism

In the following some suggestions are given in order to harmonise the presentation of CMCs concerning particular quantities.

a) DC and AC Divider Ratios. Divider ratios will be presented as output/input, so that ratio values will usually be lower than 1.

b) LF Electrical Power and Energy. The following points should be considered:

- the unit of measurement must be in agreement with the type of power (W for active, var for reactive, VA for apparent), which suggests to have one separate entry for each type;
- the relative uncertainty is usually referred to the apparent power so that units like mW/VA (for active power) should be used;
- in the parameter column, the ranges for voltage, current, active or reactive power factor (with indication if inductive or capacitive) and frequency must be reported;
- for energy, the minimum and maximum measuring times must be reported;
- for three-phase power, it is usual to report the range values per phase: for clarity the information that the given range is "per phase" is to be specified in the user comment column.

c) AC-DC (voltage or current) transfer difference. In the range columns, voltage or current values must be reported and not values for the transfer difference. This approach is suggested also for HF AC-DC transfer difference. The uncertainty is generally given as relative to the voltage or current values.

d) AC-DC voltage transfer category boundaries

It is suggested to use 0.5 V and 5 V as the boundaries for the low, medium and higher voltage categories.

e) AC high voltage and current transformers

For these CMCs it is proposed to always report the ratio error for the real part (or modulus) of the ratio and the phase displacement (in rad or better in mrad) for the argument. The primary and the secondary voltage or current should be reported as parameters. This format is in accordance with the corresponding IEC standards for instrument transformers.

f) RF calibration factor

NMIs should report in the column *measurand level and range* the maximum and minimum power levels.

g) RF categories 11.2 (reflection coefficient and attenuation) and 11.3 (scattering parameters)

The first distinction between categories 11.2 and 11.3 is the type of measuring equipment used. If it only measures the magnitude of the quantity involved (and does not give any phase information) then the CMC line belongs under category 11.2, otherwise under 11.3.
For category 11.3.1 and 11.3.2, reflection coefficient is usually reported in linear terms. For categories 11.3.3 and 11.3.4, transmission/attenuation, values are often reported in dB, which is familiar to the customer. But from a physical point of view, a presentation as a complex value in linear terms should be preferred. The Euromet HF experts have agreed to use the latter format: the exact format is not yet fixed. In case of a linear presentation, information about the dB-range concerned may be given in column U (comments for the user).

h) Presentation of related quantities (complex quantities).

Real and imaginary parts of complex quantities belong to the same classification category. Such closely related CMCs will be tagged in order to alert the BIPM that they must be presented close-by in the database (see § 11.7).

Appendix 2

Answers to questions and problems

1)
Problem. If an NMI can offer the calibration of certain instruments and standards at two different levels of uncertainty, for example using a more refined (but time consuming) and a more straightforward method, can both services be submitted as two different CMCs?
Comment. In principle a CMC should correspond to the best capability of the NMI, but some CMC users, for example the secondary laboratories, would like to have all the NMI services they use listed in the database. Then the answer could be: propose as CMCs also lower level services if they employ different methods of measurement and are used to transfer traceability to secondary laboratories.

2)
Problem. Are there cases when the range columns of a CMC can be left blank?
Answer. Even if quite rare, it can happen. For example it has happened for category 11.9.1, for a CMC on the measurement of the geometrical dimensions of different types of HF waveguides. If columns D and E are left blank, the parameter columns should report sufficient information to identify the CMC.

3)
Problem. What is the meaning of "Source of traceability" (column O)?
Comment. In general it is the laboratory performing the first step of the traceability chain that ends at the corresponding standard reported in column N. But for complex traceability chains it is often the laboratory performing the last part of the chain. An example is the case of resistance scaling, where laboratories that obtain traceability from the BIPM in the range 1 Ω to 10 kΩ, report traceability to themselves for higher resistance ranges, where they use their own measurement procedures to extend the traceability given by the BIPM.

4)
Problem. Is it possible for the same standard in column N to report, as sources of traceability in column O, two different NMIs?
Comment. The only case when this can be accepted is when a CMC covers a wide range of values and traceability is different in different parts of this range. Otherwise traceability must be to only one laboratory. Of course, if this is metrologically correct, it does not take into account that, for example, commercial reasons could lead to change the NMI providing traceability. On the other side it is believed that the choice of an NMI as traceability provider is a medium or long term decision: for example, within EUROMET it is usual to register traceability agreements as EUROMET projects.

5)
Problem. It may happen that an NMI asks to reduce its uncertainty during the review process.
Answer. This situation does not give any problem, if the reviewer has enough supporting evidence for the new uncertainty. When the review process is finished, the CMC uncertainties should not be reduced any more, if not as a consequence of a new review (see the JCRB document on how to modify existing CMCs).

6)
Problem. Is it possible to present an uncertainty dependent only on one variable (e.g. the range of the quantity) with a matrix?
Answer. Yes, this is possible and can be used when it is difficult to express the dependence of the uncertainty on the variable by an equation.

7)
Problem. Is it possible to use an uncertainty matrix when one of the two variables on which the uncertainty depends is not a physical quantity but, for example, the type of connector, as in some HF measurements?
Answer. Yes. This has indeed been done by an NMI for RF-DC transfer difference.

8)
Problem. Is it possible to use a range declaration for the uncertainty in a cell of an uncertainty matrix?
Answer. No! The cells of an uncertainty matrix should contain only numbers. If mathematical expressions are used in the matrix to obtain the uncertainty values, after calculation these expression must be substituted by numbers having the right number of significant digits.

9)
Problem. When the uncertainty (column I) is given as a range (u_1 to u_2) sometimes it is not clear if it varies linearly with the range of the quantity or with the range of a parameter, or if the variation is not linear at all and the limits are just the extreme values of the uncertainty.
Answer. The general rule says that in case of a range declaration the uncertainty should vary linearly from the lowest to the highest value of the independent variable. Of course this is not relevant if the uncertainty declaration is supported by an uncertainty matrix, where the functional dependence is clearly visible. If there is no matrix, it is suggested to follow § 8.4: the dependence on the quantity or on a parameter or on both can be specified with a short text in the same column I; the non linear variation can be explained in column U, comment for the user. But if the dependence is not linear, as there is no way to evaluate the uncertainty in the middle of the range, the total variation of the uncertainty must be limited, or the CMC will become useless.

10)
Problem. For AC-DC transfer measurements, where the quantity is reported as a voltage or as a current (as agreed among the AC-DC experts), the uncertainty given as μV/V or as μA/A is relative or absolute?
Answer. It is relative, because it must be applied to the reported quantity, voltage or current.

11)
Problem. There has been the proposal to report asymmetric limits for the uncertainty in certain cases. Examples are quantities that have physical limits (like a reflection or transmission coefficient, which is always limited between 0 and 1) or quantities given in non linear units.
Answer. Reporting asymmetric uncertainties is quite difficult and not easy to understand on the part of the user. If the approximation introduced by a symmetric declaration is considered not good enough, the range in the CMC line could be adequately reduced and the CMC line split.

12)
Problem. For complex quantities, the form of presentation varies widely. For example, for AC voltage ratio, we have at least three different presentations for the imaginary component: same unit as the real component, as an angle in radian, or as an angle in degrees. For HF transmission and reflections coefficients, in some cases two lines are presented, one for real and one for imaginary, in other cases only one line for both is given. In the last case the two range-columns usually report only one value each (e.g.: -1; 1) but in other cases two values are reported in each column, with vector notation (e.g.: [-1,-1]; [1,1]).
Comment. This matter should be discussed by the LF and HF experts. When an agreement is reached, the solution suggested could be reported in Appendix 1. As it is obviously not possible to describe complex quantities in the different measurement fields in a unique way, the minimum which we should try to reach is to have only one description for one field. To give an example: for AC voltage ratios we should only use either the same description as it is used for the real component or an angle in rad or an angle in degrees. This would be much easier to understand for our customers.

13)
Problem. Different forms of presentation are still given for AC power measurements. For example the range of the power factor is given as: "1 to 0 i/c", "0 ind./cap. to 1", "0 leading to 0 lagging", "0 to 1 inductive or capacitive".
Comment. This matter should be discussed by the LF experts. When an agreement is reached, the solution suggested could be reported in Appendix 1. We should try to agree on one format. This would be much easier to understand for our customers.

14)
Problem. At present there are different ways to report the unit of measurement of the uncertainty in case of quantities without dimension or for relative uncertainty of quantities with dimension.
Comment. A way to unify this could be the following:
Absolute uncertainty for quantities without dimensions: no unit in column J (there should be no unit also in column F).
Relative uncertainty for quantities without dimension: negative power of 10 or % in column J.
Absolute uncertainty for quantities with dimensions: appropriate unit in column J (same unit as in col. F or a sub-multiple of it).
Relative uncertainty for quantities with dimension: report the pertinent ratio of submultiples of the considered unit (for example μV/V) in column J; but if the unit is a combination of other units , it is better to use a negative power of 10 or % in col. J.

History of changes

Version number	Changes
4.2 (4 May 2009)	Note (f) on page 15: For the quantity rf calibration factor, the minimum and maximum power levels shall be stated in the column *measurand level and range* (instead of the calibration factor).
4.3 (6 August 2009)	Clarification in section 1 that changes of CMCs (additions, deletions, modifications) must be made in the Excel file of already existing CMCs.
4.4 (April 2011)	Insertion of chapter 0.6 on the inter-RMO review process, with deadlines and recommendations on how to accelerate the CMC review process. Modification of the answer to question 6 on page 17. It is now allowed to express the dependence of the uncertainty on one single variable by a 1 x n matrix.