CCEM Guidelines for Planning, Organizing, Conducting and Reporting Key, Supplementary and Pilot Comparisons

Version 2.1 (June 2017)

1. Introduction

The technical basis of the CIPM MRA is the set of results obtained in the course of time through Key Comparisons (KCs) carried out by the Consultative Committees of the CIPM, the BIPM and the Regional Metrology Organizations (RMOs), and Supplementary Comparisons (SCs) carried out by the RMOs. Results are published by the BIPM and reported in the BIPM key comparison database (KCDB). In addition, Pilot Comparisons (PCs) may be organized. These are meant to be a preparatory exercise to gain experience with new subject fields or measurands, to check the travelling behaviour of transfer standards or to test the feasibility of a key or supplementary comparison. They will not be recorded in the KCDB.

This document lays down guidelines to be followed by the CCEM and the Technical Committees for Electricity and Magnetism of the RMOs (RMO TCEMs) in planning, organising, conducting and reporting CCEM and RMO key, supplementary and pilot comparisons. It is supplemented by a chart for organizing a comparison (Annex 1), protocols (Annex 2), reports (Annex 3) and the presentation of results in the BIPM key comparison database (Annex 4) as well as guidance for the statistical treatment of data (Annex 5). A list of documents dealing with these issues is given in Annex 6.

The CCEM Working Groups on Low Frequency and Radio Frequency Quantities (WGLF and GT-RF) consider these guidelines a strong recommendation which should be followed unless compelling reasons are against it. The only exception is the approval process for new comparisons and comparison reports which is bindingly prescribed by the regulations of the CIPM MRA and the CCEM.

2. Initiating a comparison

Proposals for new comparisons are normally made by member institutes of the CCEM or of an RMO. For CCEM comparisons, these proposals are discussed in the relevant Working Groups of the CCEM – the Working Group on Low Frequency Quantities (WGLF) and the Working Group on Radio-frequency Quantities (GT-RF). Accepted proposals are then forwarded to the CCEM for final approval. Proposals for RMO comparisons are discussed and agreed upon in the relevant RMO TCEMs. RMO key comparisons cannot be carried out until a CCEM KC having the same scope has been completed. RMO KCs must be approved by the WGLF or the GT-RF and then agreed with the CCEM.

For each comparison, a pilot laboratory is appointed. It assumes the main responsibility for running the comparison and producing the Draft A and Draft B versions of the report. A support group, normally consisting of the pilot laboratory itself and three experts from participating institutes, is formed to help the pilot laboratory to draw up the technical protocol and timetable for the comparison. This group also helps with the preparation of the Draft A and B reports, especially in the statistical treatment of the data and by checking the calculations. A support group is not required for bilateral comparisons.

Participation in CCEM KCs or PCs is open to laboratories having the highest technical competence and experience, normally the member laboratories of the CCEM. A participating laboratory that is not a member of the CCEM must be a signatory of the CIPM MRA or a designated institute, listed in Appendix A of the MRA. Any of the members of an RMO can take part in an RMO KC, SC or PC, provided the technical competence of the institute is appropriate to the particular comparison. With the consent of all participating RMO members, corresponding organizations and also laboratories from outside the RMO may take part in RMO comparisons. Only the results from institutes listed in Appendix A of the MRA will be reported in the KCDB.

2.1 Key Comparisons

The CCEM is responsible for choosing CCEM KCs. In drawing up the list of participants and an approximate timetable, the CCEM ensures that enough participants from each RMO take part so that corresponding regional KCs are properly linked to the CCEM KC. In case the number of participants from a single RMO is considered to be too great, which might lead to undue delays in the comparison, the RMO will be asked to decide which institutes are to be admitted to participate in the CCEM comparison. This decision should be based on the degree of independence in realizing the quantity to be measured and the willingness to participate in subsequent RMO comparisons. KCs are carried out only for quantities identified by the CCEM as key quantities. For each key quantity the CCEM allows only one KC at a time. The list of key quantities currently adopted by the CCEM is given in the CCEM Strategic Plan (see Annex 6).

The RMO TCEMs are responsible for initiating RMO KCs. In drawing up the list of participants for an RMO KC, the TCEM ensures that at least two of the participants have taken part in the preceding CCEM KC so that the RMO comparison is properly linked to the CCEM comparison. All RMO KCs must be declared in advance. The RMO TCEM chairperson does so by completing the *Key and supplementary comparison registration and progress form* (see Annex 6) and submitting it to the WGLF or GT-RF chairperson and the Executive Secretary of the CCEM. When approved, the RMO TCEM chairperson notifies the KCDB Coordinator who enters the comparison into the database (for details, see Annex 1).

When carrying out a CCEM key comparison it is sometimes possible to use the same travelling standard to measure such a great number of parameters that the detailed calculation, checking and presentation of the degrees of equivalence becomes unwieldy. In such cases, it may be desirable to specify in the protocol a subset of quantities considered as the objects of the key comparison and to specify that the other quantities make up the Additional Measurements (AM). AM's must be attached to the parent KC. For convenience, the results of the AM's may be included in the final report of the KC but these results will not be tabulated and plotted in Appendix B of the MRA. Note, however, that they can be used as evidence to support CMC statements.

2.2 Supplementary Comparisons and Pilot Comparisons

To meet specific needs not covered by KCs such as, the inclusion of a quantity not covered by the set of key quantities or the extension of the range of parameters over which a quantity is compared, supplementary comparisons (SCs) are carried out by the RMOs. Pilot comparisons (PCs) are carried out to validate new devices and/or new measurement techniques. In some cases, they can be carried out by the CCEM. They will not be recorded in the KCDB and are normally not considered sufficient support for calibration and measurement capabilities (CMCs).

For RMO SCs the RMO TCEM chairperson should use the form in Annex 6 to notify the WGLF or GT-RF chairperson and the Executive Secretary of the CCEM of the activity. The Executive Secretary will inform the KCDB Coordinator. At the end of a SC the final report is approved by the RMO. The RMO TCEM chair forwards it to the CCEM Executive Secretary and the chair of WGLF or GT-RF to allow for a six-week period of comment and editorial control. If at the end of the period, no objections have been raised within the working group, the final report, accompanied by a statement that the control and comment procedure has been completed, will be sent by the RMO TCEM chair to the KCDB Office for publication in the KCDB.

2.3 Bilateral Comparisons

A bilateral CCEM or RMO KC is typically performed as a follow-up to a previous KC. Bilateral CCEM KCs may be carried out by two institutes, provided that one of them has already participated in a relevant CCEM KC. For reasons of easy access to the travelling standards, this often is the KC pilot laboratory. The technical protocol must be similar to that of the KC. The comparison identifier must be chosen to show the close links to the main comparison, e.g., CCEM-K8 and CCEM-K8.1. The other participant must meet the requirements for participation in a KC. The participants must file the form in Annex 6 to notify the WGLF or GT-RF chairperson and the CCEM Executive Secretary of the bilateral comparison before it takes place (for details, see Annex 1).

Similarly, bilateral RMO comparisons may be carried out by two institutes. For a KC, one

of the participants must have participated in the relevant CCEM KC or RMO KC; this institute normally acts as pilot for the bilateral comparison. The technical protocol must be similar to that of the KC. The other participant must meet the requirements for participation in a KC. The bilateral comparison needs to be approved by the RMO TCEM and the TCEM chair shall use the form in Annex 6 to notify the WGLF or GT-RF chairperson and the CCEM Executive Secretary of the bilateral comparison before it takes place.

If the pilot laboratory of a bilateral comparison is not the institute which participated in the corresponding CCEM or RMO comparison, each participant sends his results to a third party, either the chairperson of the appropriate CCEM working group or the RMO TCEM chairperson, who will then forward the results to the pilot laboratory for the preparation of draft A. Any modification of the results (values and uncertainties) would have to be accepted by the participants and the chairperson.

In a similar way, this procedure is also applicable to SCs and PCs. The institutes must inform the RMO TCEM chairperson before the comparison starts.

2.4 Comparison Identifier

It is recommended to adopt the present CCEM key comparison identifier scheme for all types of comparisons, i.e., CCEM and BIPM KCs and RMO KCs and SCs. Using this scheme will minimise possible confusion, in particular for the customers of the KCDB. An RMO comparison cannot just be a KC on its own – it must be linked to a CCEM or BIPM KC. It is therefore recommended that RMOs make early contact with the KCDB Coordinator when developing key comparisons to check whether or not a link to a CCEM or BIPM KC can be made. Otherwise, a comparison should be organised as an RMO SC. It does not need a KC to justify CMCs. The comparison identifier must be fixed before the comparison declaration form and protocol is drawn up. The KCDB office can provide help in defining the identifier.

The principle structure of a comparison identifier must be as follows:

Institution[1)].Subject-field[2)].Subfield[3)]-Type[4)].Consecutive Number[5)]. Subordinate Number[6)].RF Identifier[7)] .Year[8)]

1. As institution choose **“CCEM”**, **“BIPM”** or an RMO (**“APMP”**,**”** **COOMET”**, **“EURAMET”**, “**GULFMET**”, **“AFRIMETS”**, **“SIM”**).
2. As only electricity and magnetism is dealt with, the subject-field is **“EM”**. For a CCEM comparison, the subject-field **“EM”** is omitted.
3. The subfield is omitted for ordinary DC and low frequency comparisons. For comparisons in the high-frequency field use **“RF”** as subfield, and **“M”** for magnetic quantities.
4. The type of a comparison is a key **“K”** or a supplementary **“S”** comparison. Note

that supplementary comparisons are normally organised by the RMOs.

5. The consecutive number will be given by the KCDB Coordinator. For key comparisons, one attempts to use the same number for a whole family of key comparisons whose results are linked. For supplementary comparisons, numbers are simply incremented by 1 at each new comparison inside a given RMO.
6. The subordinate number is only necessary for subsequent key comparisons (generally bilateral key comparisons) to already existing key comparisons. It may also sometimes be a letter for a sub-comparison (same measurand with a different nominal value).
7. The RF identifier describes the medium of propagation of the electromagnetic wave. **"CL"** stands for coaxial line, **"F"** for field and **"W"** for waveguide.
8. Repetitions of a key comparison shall use the same consecutive number as the original comparison. In addition the year of start of the measurements shall be added.

Examples

- "CCEM-K8": CCEM key comparison K8;
- "CCEM-K8.1": bilateral key comparison subsequent to CCEM-K8;
- "EUROMET.EM-K8": EUROMET key comparison linked to CCEM-K8;
- "EUROMET.EM-K8.1": bilateral key comparison subsequent to EUROMET.EM- K8
- "BIPM.EM-K11.a": BIPM key comparison K11.a (Zener, 1.018 V; K11.b corresponds to Zener, 10 V);
- "APMP.EM-S7": APMP supplementary comparison S7
- "CCEM.RF-K10.CL": CCEM key comparison in RF (power on coaxial lines)
- "CCEM-K4.2017": repetition of the CCEM-K4 comparison in 2017

Note: In the case where an RMO key comparison is to be linked to a BIPM key comparison rather than to a CCEM key comparison, **"BIPM"** is introduced in the identifier between the sub-field and the hyphen; for example: "COOMET.EM.BIPM-K11.a", COOMET key comparison linked to "BIPM.EM-K11.a", but "COOMET.EM-K4" to be linked to "CCEM-K4".

3. Organization of a comparison

Once the proposal for a new comparison has been approved (see section 2), the pilot laboratory, with help from the support group, is responsible for the organization of the comparison. The first task is to draw up a detailed technical protocol, including a tentative circulation schedule, considering feedback from prospective participants. For a CCEM KC having additional measurements, the protocol and the declaration form must clearly identify which quantities make up the KC and which quantities form the AM's.

For a CCEM key comparison, the technical protocol and the declaration form are sent to the CCEM Executive Secretary and the chairperson of the relevant working group (WGLF, GT-RF)

for review. The chairperson reviews the declaration form and organizes the review of the protocol within the working group. Following approval, the pilot laboratory sends the protocol and the declaration form to the KCDB coordinator for registration.

For an RMO key comparison, the protocol and the declaration form are submitted to the RMO TCEM chairperson who takes the necessary measures to have them approved with the RMO technical committee. The RMO TC chairperson then submits the protocol and the declaration form to the CCEM Executive Secretary and the chairperson of the relevant CCEM working group (WGLF, GT-RF). Following approval, the RMO TC chair sends the protocol and the declaration form to the KCDB coordinator for registration.

The protocol for an RMO supplementary comparison does not require approval from the CCEM working groups, since it is done under the authority of the RMO. No declaration form is needed for pilot comparisons and the protocol need not be approved or registered.

The invitation to participate is sent by the pilot laboratory directly to all members of the CCEM or RMO TCEM stating a deadline for the reply. After the answers have been received, the pilot laboratory must draw up an itinerary and inform the participants when they can expect to receive the travelling standards. The total circulation time for the standards must be fixed and should not exceed 18 months except under unusual circumstances. In addition, the pilot laboratory is responsible for organizing the circulation and transport of the travelling standards and requesting the participants to make proper arrangements for local customs clearance.

The main points decided by the pilot laboratory together with the support group are the following:

- Suitability of the travelling standards for use in the comparison (in some cases a study of the long-term stability and the transport behaviour of the standards will be necessary)
- The pattern of the full scale comparison; examples are: single loop (pilot→A→B→...→N→pilot), multiple loop (pilot→A→B→pilot→C→...→pilot) and star configuration (pilot→A→pilot→B... →pilot)
- The list of participants, technical contact persons and mailing addresses
- The starting date, detailed timetable, means of transport and itinerary
- The procedures in the case of failure of a travelling standard or an unexpected delay on the part of a participant
- The customs documents to accompany the travelling standards.

4. The technical protocol for a comparison

The technical protocol is an important part of a comparison and specifies in detail the procedure to be followed for the comparison. Among the points treated in the protocol are

the following:

- Detailed description of the travelling standard(s), their operating conditions and the quantities to be measured (optional quantities included)
- For a KC having Additional Measurements, identification of the measured quantities belonging to each comparison type
- A statement of how the KCRV will be computed or a reference to the prescription that will be used
- Advice on handling the travelling standard(s)
- Actions to be taken upon receipt of the standard(s) by a participating institute
- Any tests to be carried out before measurement
- Instructions for reporting the results
- A list of the principal components of the uncertainty budget
- The traceability to the SI of each standard participating in the comparison (if applicable)
- A timetable for the communication of the results to the pilot laboratory.

A suggested pattern for a protocol is given in Annex 2.

5. Circulation of transfer standards and customs clearance

The pilot laboratory is responsible for organizing the itinerary, dispatching the standards and requesting the participants to make proper arrangements for local customs clearance.

- If an ATA carnet is used, the pilot laboratory and the participants must be familiar with its proper use. It must be stamped by the customs authorities when leaving a country, and upon arrival in the country of destination. Note that for the European Union (EU) the ATA carnet is stamped before leaving and upon re-entering the EU. The pilot laboratory must be informed if a power of attorney (a letter from the owner of the travelling standards authorizing the participating laboratory to act on its behalf) is to accompany the carnet to simplify the customs formalities.
- The equipment must be handled with care, and in some cases it is essential that the transfer instruments be hand-carried.
- A warning note should be attached to the package indicating that it should be opened only by laboratory personnel.
- The participating institutes are responsible for the transport to the next institute according to the itinerary fixed.
- Before dispatching the package, each participant must inform the next participant and the pilot laboratory, giving transportation details.
- After arrival of the package, the participating institute shall inform the pilot laboratory and the sender of this receipt and shall check for any damage to the standards.
- If a delay occurs the pilot laboratory shall inform the participants and revise the time schedule.
- A participant who is unable to perform its measurements in time due to unforeseeable reasons (e.g. damaged measurement equipment) can ask the pilot laboratory to be rescheduled

at the end of the itinerary. In any case the standards should be dispatched in time to the next participant in order not to disrupt the remaining part of the itinerary.

6. Reporting the results of a comparison

The participating institutes must report the results of a comparison to the pilot laboratory as soon as possible and in every case not later than six weeks after the measurements are completed. If a report is delayed for more than three months, the pilot laboratory acting through the chairperson of the WGLF/GT-RF or the RMO TCEM, may inform the director of the participating institute. In the worst case, the participating institute can be excluded from the comparison. This will be mentioned in the comparison report.

The measurement results together with the uncertainties supported by a complete detailed uncertainty budget and any additional information required should be reported in a format given in the instructions as part of the protocol (see Annex 2), usually by completing the standard forms annexed to the instructions. Any additional significant detail should also be reported to the pilot laboratory.

7. Preparation of the report of a comparison

The pilot laboratory is responsible for the preparation of the comparison report. Before publication, the report passes through the draft A and draft B stage. The first version, draft A, is prepared as soon as all results have been received from the participants. It includes the results transmitted by the participants, identified by name, and a first calculation of the key comparison reference value, and the unilateral degrees of equivalence. It is confidential to the participants. Until all the participants have agreed on the report, it should be considered to be in Draft A stage. Once the final version of Draft A is approved by the participants, the report is considered as Draft B. The Draft B report is subsequently submitted to WGLF/GT-RF or the RMO TCEM. The report of an RMO KC must include a proposal for linking the results with those of the corresponding CCEM KC.

Once the Draft B report is available, the pilot laboratory shall ask all participants to submit a declaration that they have checked their results against their CMC claims and a statement whether or not these claims are supported by their results. The pilot shall collect these statements in the *Executive Report* and send it to the CCEM Executive Secretary, who will transmit it to the members of WGRMO.

In more detail the procedure is as follows:

- During the comparison the results received by the pilot laboratory are kept confidential

until all participants have completed their measurements.

- A result from a participant is not considered complete and is not included in the draft A report without an associated uncertainty supported by a complete detailed uncertainty budget drawn up according to the instructions given in the technical protocol.
- If, on examination of the complete set of results, the pilot laboratory finds that the results of some participants appear to be anomalous, these participants are invited to check their results for numerical errors. No information can be given as to the magnitude or sign of the apparent anomaly. If no numerical error is found, the result stands.
- The pilot laboratory prepares the Draft A report, which includes the results of all participants, the calculation of the key comparison reference value and the degrees of equivalence with respect to the KCRV. The first version of the Draft A report shall be reviewed by the support group.
- Draft A of the report is sent as soon as possible to all the participants for comment, with a reasonable deadline for replies. Draft A is considered confidential to the participants; copies are not given to non-participants.
- Note that once all participants have been informed of the results, individual values and uncertainties may be changed or removed, or the complete comparison abandoned, only with the agreement of all participants and on the basis of a clear failure of the travelling standard or some other phenomenon that renders the comparison or part of it invalid..
- An institute that considers its result non-representative of its standards may request a separate subsequent bilateral comparison with the pilot laboratory or one of the participants. It has to follow the same rules as the KC and the results will be entered into the KCDB as a bilateral comparison.
- If any controversial or contradictory comments are received by the pilot laboratory, they are circulated to all participants and the support group, and the discussion continues until a consensus is reached.
- On receipt of final comments from the participants, draft B is prepared according to Annex 3. Draft B, which supersedes draft A, is not considered to be confidential and becomes the final report after approval by the CCEM (for a CCEM or RMO KC), the WGLF or GT-RF (for Additional Measurements) or the RMO TCEM (for an RMO supplementary comparison).

8. Getting approval of the report of a comparison

The support group helps the pilot laboratory to prepare the Draft A report, and especially in the statistical treatment of the data, and checks the conformity of the report with the requirements of the MRA or the RMOs. The CCEM at its 22nd meeting in 2000 approved document CCEM/00-18 (see Annex 6) which includes a checklist for review of Draft B reports.

In the case of a CCEM KC, the WGLF and the GT-RF are charged with examining draft B prior to its distribution to the CCEM for final approval. CCEM approval may be given by

correspondence on the recommendation of the WGLF or GT-RF. For RMO KCs, the chairperson of the RMO TCEM, together with the participants in the comparison, checks the draft B report and then forwards it to the relevant CCEM working group for further consideration.

Results of supplementary comparisons are checked by the chairpersons of the RMO TCEMs and then submitted to the CCEM Executive Secretary and the chair of WGLF or GT-RF to allow for a six-week period of comment and editorial control. If at the end of the period, no objections have been raised within the working group, the final report, accompanied by a statement that the control and comment procedure has been completed, will be sent by the RMO TCEM chair to the KCDB Office for publication in the KCDB.

9. Publication of the results and entry into the Key Comparison Database (KCDB)

For all KCs, the final report approved by the CCEM forms the basis for the entry of results into the KCDB. The results must be presented in EXCEL files according to a uniform template similar to that given in Annex 4; additional examples may be found in the KCDB. For KCs both the EXCEL files and the pdf version of the final report will be available in the KCDB. In addition, an abstract of the final report will be published in the *Technical Supplement* to *Metrologia*, a web-only service offered by *Metrologia* free of cost. The results of an AC will normally appear in the report of the associated KC but will not be tabulated and graphed in Appendix B. For SCs, normally no results will be presented in the KCDB except the final report. For PCs, final reports may be published in the *Technical Supplement* to *Metrologia* by sending the following to the Executive Secretary of the CCEM: (1) a copy of the report in pdf format; (2) the name of the organization having approved the final report; (3) the name and email address of the person having prepared the final report; (4) a 100 to 200-word abstract of the final report in Microsoft Word format.

With exception of the appendix containing the reference value and degrees of equivalence, the publication of the results in the Draft B Report may take place as soon as Draft B is agreed by the participants. There are different forms in which the results of a comparison may be published, depending on the wider significance of the information. The main publication channels are a scientific journal or the Conference Proceedings following presentation at a conference.

The results of comparisons are also used to control the impact of KCs and SCs on the calibration and measurement capabilities (CMCs) of the participating institutes published in Appendix C to the KCDB. For details, see Annex 3.

10. Evaluation of comparison data

Each CCEM key comparison yields a reference value, known as the Key Comparison Reference Value (KCRV). Although the KCRV is normally a close approximation to the corresponding SI value, it is possible that some of the values submitted by individual participants may be even closer.

The degree of equivalence (DoE) of each national measurement standard[1] describes to what degree a standard is consistent with the KCRV. It is expressed by the deviation from the KCRV and the uncertainty of this deviation at a 95% level of confidence. The degree of equivalence between pairs of national measurement standards[1] is expressed by the difference of their deviations from the KCRV and the uncertainty of this difference at a 95% level of confidence. It has been agreed by the CCEM, that in general tables of bilateral degrees of equivalence are no longer provided in the comparison reports. If possible, an equation for the calculation of the bilateral degrees of equivalence from the unilateral degrees of equivalence (from the KCRV) shall be provided.

Usually, the results of an RMO KC are linked to the KCRV established by the CCEM KCs by common participation of some institutes in both, CCEM and RMO comparisons. The uncertainty with which comparison data are propagated depends on the number of institutes taking part in the two comparisons and on the quality of the results reported by these institutes.

For details, see Annex 5.

[1] A national measurement standard refers to the highest measurement standard maintained by a laboratory, institute or organization listed in Appendix A of the MRA.

Chart for Organizing CCEM and RMO Comparisons

Abbreviations:
KC Key Comparison
AM Additional Measurements
SC Supplementary Comparison
PC Pilot Comparison

Note: Bilateral comparisons are treated similar to KCs and SCs
The Executive Secretary of the CCEM will automatically be involved in the activities of the WGLF, GT-RF and CCEM

No.	Action	CCEM Comparisons			RMO Comparisons		
		KC	AM	PC	KC	SC	PC
1	Member institutes of the CCEM or an RMO make a proposal for a new comparison	X	X	X	X	X	X
2	Proposals are discussed and agreed upon by WGLF or GT-RF	X	X	X			
3	Proposals are discussed and agreed upon by RMO TCEM				X	X	X
4	Pilot laboratory identified	X	X	X	X	X	X
5	Support group formed (not for bilateral comparisons)	X	X		X	X	
6	Proposals must be approved by CCEM	X	X				
7	Proposals must be approved by the chairperson of WGLF or GT-RF			X	X		
8	Proposals must be approved by the chairperson of the TCEM				X	X	X
9	Pilot laboratory sends an official invitation to the delegates of the CCEM or the contact persons of the RMO	X	X		X	X	
10	Pilot laboratory with the help of the support group prepares declaration form (DF) and technical protocol (TP)	X	X		X	X	
11	Pilot laboratory prepares technical protocol (TP)			X			X
12	DF and TP checked and approved by RMO TCEM chairperson and forwarded to WGLF or GT-RF				X		
13	DF and TP checked and approved by RMO TCEM chairperson and forwarded to the KCDB Manager for registration					X	
14	DF and TP reviewed and approved by chairperson of WGLF or GT-RF on behalf of the CCEM	X	X		X		

15	Pilot laboratory or RMO TCEM chair send TP and DF to BIPM Database Manager for registration	X	X		X		
16	Pilot laboratory organizes and carries out the comparison	X	X	X	X	X	X
17	Participating institutes report the results at the latest 6 weeks after completion of measurements	X	X	X	X	X	X
18	Pilot laboratory prepares draft A report and sends it to the support group for review and comments	X	X		X	X	
19	Pilot laboratory sends the Draft A report to the participants for comments.	X	X		X	X	
20	Pilot laboratory prepares draft A report			X			X
21	Participating institutes send their comments to the pilot laboratory within the deadline given by the pilot laboratory	X	X	X	X	X	X
22	Pilot laboratory with the help of the support group prepares draft B report	X	X		X	X	
23	Pilot laboratory prepares final report			X			X
24	Draft B report approved by the RMO TCEM[1]				X	X	
25	Link to the CCEM KC approved by the RMO TCEM				X		
26	RMO TCEM chairperson forwards draft B reports to WGLF or GT-RF for further consideration				X		
27	RMO TCEM approves report, submits it to WGLF or GT-RF for editorial review (6 weeks) and then sends it to the KCDB office for publication					X	
28	Draft B report and link to the CCEM KC, if any, discussed and approved by WGLF or GT-RF	X	X		X		
29	Draft B report and link to the CCEM KC, if any, sent to CCEM for final approval	X			X		
30	After approval by the CCEM, pilot laboratory sends pdf file of final report, Word file of abstract and Excel file of KCDB entry to BIPM Database Manager	X			X		

31	Participants send statement on consistency between their comparison results and their CMCs to pilot laboratory after release of draft B	X			X	X	
32	Pilot laboratory sends Executive Report with statements from the participants to CCEM Executive Secretary.	X			X	X	
33	CCEM Executive Secretary send Executive Report to members of WGRMO.	X			X	X	
34	Pilot laboratory sends pdf file of final report and Word file of abstract to CCEM Executive Secretary			X			X

Suggested pattern for a technical protocol		
Section	**Paragraph**	**Principal content**
1 Introduction		Background and summary of the comparison; reason for carrying out the comparison
2 Travelling standard(s)	2.1 General requirements	Characteristics of the standard(s)
	2.2 Description of the standard(s)	Type, Sketch, Photos, Technical Data, Designation (make, type, serial number, size, weight, etc.)
	2.3 Quantities to be measured (optional quantities included)	Detailed description of each quantity and relevant parameters; ambient conditions of the measurement
	2.4 Method of computation of the KCRV/Reference value	A statement of how the KCRV/Reference value will be computed or a reference to the prescription that will be used
3 Organisation	3.1 Co-ordinator and members of the support group	Name, organisation and mail address
	3.2 Participants	List of participating institutes with persons responsible, details to be given in Annex A1. For RMO KCs the linking labs should be nominated
	3.3 Time schedule	Detailed circulation time schedule with clearly defined time slots for the participating laboratories (Annex A2); the procedure in case of unexpected delays should be given
	3.4 Transportation	Allowed time and means of transport, ATA carnet, informal note of confirmation for receipt and dispatch etc.
	3.5 Unpacking, handling, packing	In case of several items provide a parts list
	3.6 Failure of the travelling standard	Instructions what to do in this case
	3.7 Financial aspects, insurance	In general: each participant will pay the costs for measurement, transportation and customs formalities
4 Measurement instructions	4.1 Tests before measurements	Inspection and conditioning of the standards
	4.2 Measurement performance	Particular requirements for connecting and measuring, waiting times etc.
	4.3 Method of measurement	Typical methods, description of the methods

Suggested pattern for a technical protocol (cont'd)		
Section	**Paragraph**	**Principal content**
5 Uncertainty of measurement	5.1 Main uncertainty components, including sources and typical values	The Guidelines for CIPM Key Comparisons require a list of the main uncertainty contributions
	5.2 Scheme to report the uncertainty budget	The uncertainty must be calculated following the GUM: standard uncertainties, degrees of freedom, correlations, scheme for the evaluation of uncertainty (Annex A3)
6 Measurement report		Report should be sent to the pilot within 6 weeks from the end of the measurements, content and layout of the report should be specified by the pilot
7 Report of the comparison		Draft A and B, role of the support group; suggested method for calculating the reference value and comparing the results
References		most recent papers of interest for the planned comparison
Annexes	A1 Detailed list of participants	Organisation, country, contact person, mail and shipping addresses
	A2 Schedule of the measurements	Order of participants, allocated time-slots
	A3 Typical scheme for an uncertainty budget	For example in accordance with document EA-4/02 *Expression of the Uncertainty of Measurement in Calibration*
	A4 Layout of the measurement report	List of the required information, tables of results etc.
	A5 Confirmation note of receipt (optional)	Form to be filled in and sent by fax or email to the pilot laboratory to inform that the standard has arrived
	A6 Confirmation note of dispatch (optional)	Form to be filled in and sent to inform both the receiving laboratory and the pilot about the shipment of the standard

Suggested pattern for a draft A or draft B report		
Section	**Paragraph**	**Principal content**
1 Introduction		Origin and scope of the comparison; aim of the comparison; relation with the corresponding CCEM comparison (for RMO KCs) or with pilot comparisons (if any).
2 Participants and organisation of the comparison	2.1 List of participants	List of all participants, with full name of the organisation, the acronym of the organisation and the state or economy; list of the standards measured by each laboratory if different standards were used.
	2.2 Comparison schedule	Sequence of participating institutes and dates of the measurements.
	2.3 Organisation of the comparison	Circulation method, timing and transport.
	2.4 Unexpected incidents	Report of organisational and transport problems, damage of standards etc, that have caused delays or changes of schedule (if any).
3 Travelling standard and measurement instructions	3.1 Description of the standard (s)	Description (with picture if useful), relevant technical data
	3.2 Quantities to be measured and conditions of measurement	Description of each quantity and parameter; conditions of the measurement (ambient conditions etc.); aimed accuracy and/or limit for participation (if any).
	3.3 Measurement instructions	Tests before measurements; measurement constraints; any specific instruction on how to carry out the measurements.
	3.4 Deviations from the protocol	Report of any deviation from the protocol, and the reason for this deviation.
4 Methods of measurement		A summary of the different methods used by the participating institutes. Details may be given in an Appendix.
5 Repeated measurements of the pilot institute, behaviour of the travelling standard(s)		From the measurements of the pilot institute the drift of the standard(s) and its(their) stability may be evaluated.

6 Measurement results	6.1 Results of the participating institutes	Values and corresponding standard uncertainty, ambient conditions. Refer to an Appendix for complete uncertainty budgets.
	6.2 Nomalization of the results	Elimination of the effects of drift and ambient conditions
	6.3 Calculation of the reference value and its uncertainty	Justify the method chosen. Co-variances must be taken into account.
	6.4 DoEs of the participating institutes with respect to the KCRV/Reference value	Tables of results and graphs (see Annex 5); replace, when possible, tables of DoEs of pairs of participants by an equation relating them to the DoEs with respect to the KCRV/Reference value
	6.5 Link to the CCEM KC and degrees of equivalence (for RMO KCs only)	Tables of results and graphs (Normally this will be reported in a separate document)
7 Withdrawals or changes of results		Information and explanations Possible adverse effect on CMC claims to be given in a separate comparison executive report, not part of the main report
8 Requests for follow up bilateral comparisons		if any
9 Summary and conclusions		Discussion of results compared to the aims of the comparison.
Appendices	A Degrees of equivalence (only for KCs)	"Raw" results; link to the KCRV; DoE with KCRV; bilateral DoEs; graphs. The scheme of existing DoE tables in the KCDB must be followed (see Annex 5).
	B Method of measurement	
	C Uncertainty budgets	
	D Optional measurements	If any
	E Comparison protocol	
	Others	If necessary

	Impact of comparisons on the calibration and measurement capabilities of a participating laboratory (CMCs)	Through the persons responsible for the comparison, the participating laboratories declare in writing that they have checked their results against their CMC claims and state whether or not these claims are supported by their results. If not, they describe the measures to be taken to remove this inconsistency. To be compiled by the pilot in a separate comparison Executive Report.

Key comparison CCEM-K4
MEASURAND : Capacitance **NOMINAL VALUE : 10 pF** **Pilot laboratory: NIST**

x_i: **result of measurements of capacitors S/N 108 and S/N 185, or S/N 190 and S/N 193, carried out by laboratory *i*, related to the fractional difference from the nominal value 10 pF, m_i, by: $x_i = x_0 \times (1 + m_i)$, with $x_0 = 10$ pF.**

The values assigned by the NIST to each capacitor are obtained by interpolation of the NIST measurement results to the measurement dates of the other laboratories.

u_i: **combined standard uncertainty of m_i, reported by laboratory *i***

Lab *i*	$m_i / 10^{-6}$ S/N 108 **S/N 190**	$m_{NIST} / 10^{-6}$ S/N 108 **S/N 190**	$(m_i - m_{NIST}) / 10^{-6}$ S/N 108 **S/N 190**	$m_i / 10^{-6}$ S/N 185 **S/N 193**	$m_{NIST} / 10^{-6}$ S/N 185 **S/N 193**	$(m_i - m_{NIST}) / 10^{-6}$ S/N 185 **S/N 193**	average $(m_i - m_{NIST}) / 10^{-6}$	$u_i / 10^{-6}$	Date of measurement
BIPM-1	**-40.625**	**-40.626**	**0.001**	**32.732**	**32.722**	**0.010**			97-11-16
BIPM-2	**-40.625**	**-40.590**	**-0.035**	**32.674**	**32.711**	**-0.037**			98-01-04
BIPM			**-0.017**			**-0.014**	-0.015	0.040	97-12-10
BNM-LCIE	-13.063	-12.847	-0.216	9.942	10.153	-0.211	-0.214	0.031	98-06-21
CSIRO-NML	-13.019	-13.058	0.039	10.362	10.325	0.037	0.038	0.033	96-03-29
MSL	-12.92	-12.912	-0.008	10.16	10.199	-0.039	-0.024	0.061	97-11-18
NIM	**-40.56**	**-40.486**	**-0.074**	**32.68**	**32.680**	**0.000**	-0.037	0.13	98-05-28
NMi-VSL	-13.79	-13.032	-0.758	9.48	10.259	-0.779	-0.768	0.6	97-03-01
NPL	-12.891	-13.067	0.176	10.524	10.298	0.226	0.201	0.047	96-08-28
NRC	-13.014	-13.058	0.044	10.325	10.289	0.036	0.040	0.16	96-11-01
PTB	-12.85	-12.863	0.013	10.15	10.166	-0.016	-0.002	0.045	98-03-08
VNIIM	-13.32	-12.999	-0.321	9.92	10.230	-0.310	-0.316	0.2	97-05-29

	measurements derived from R_{K-90}
	measurements derived from calculable capacitors
BIPM-1 & -2	**two BIPM measurements of the same capacitor on two different dates**

Note: bold numbers refer to the capacitors whose serial numbers are in bold.

Key comparison EUROMET.EM-K4
MEASURAND : Capacitance **NOMINAL VALUE : 10 pF** **Pilot laboratory: NPL**

$x_{i\text{-EUR}}$: result of measurements of capacitor S/N 01031 carried out by laboratory *i*, related to the fractional difference from the nominal value 10 pF, $m_{i\text{-EUR}}$, by: $x_{i\text{-EUR}} = x_0 \times (1 + m_{i\text{-EUR}})$, with $x_0 = 10$ pF.

$U_{i\text{-EUR}}$: expanded uncertainty ($k = 2$) of $m_{i\text{-EUR}}$, reported by laboratory *i*

Lab *i*	$m_{i\text{-EUR}}$ / 10^{-6}	$U_{i\text{-EUR}}$ / 10^{-6}	Date of measurement	$m_{i\text{R-EUR}}$ / 10^{-6}
NPL	-3.11	0.100	95-08-01	-3.20
	-1.88	0.100	98-08-05	-1.97
PTB	-2.93	0.10	95-11-05	-3.05
	-2.19	0.10	98-02-21	-2.05
NIST	-2.83	0.04	96-01-22	-2.90
	-2.21	0.04	97-08-18	-2.15
METAS	-3.0	62.0	96-03-15	-2.80
BEV	-2.3	1.4	96-05-14	-2.70
IEN	-2.29	0.8	96-07-17	-2.60
NMi-VSL	-3.04	1.2	96-10-13	-2.47
SP	-3.0	1.8	96-12-07	-2.40
CSIR-NML	-2.0	2.5	97-02-12	-2.32
BNM-LCIE	-2.12	0.052	97-05-13	-2.23
CSIRO-NML	-2.181	0.078	97-06-25	-2.19
MIKES/VTT	-3.05	1.5	97-09-23	-2.13
GUM	-2.5	0.8	97-11-03	-2.10
CEM	-2.1	3.0	97-12-15	-2.08
BIPM	-1.998	0.074	98-04-28	-2.02
CMI	-2.26	0.4	98-06-16	-2.01
UME	-1.69	1.6	98-09-22	-2.01

$m_{i\text{R-EUR}}$: value of reference referred to the date of measurement at laboratory *i* (see section 5.13.2 and subsequent graphs in the EUROMET.EM-K4 Final Report), based on a weighted mean of EUROMET.EM-K4 participants' measurements.
Its expanded uncertainty ($k = 2$) is 0.037×10^{-6} at all dates.

measurements derived from $R_{K\text{-}90}$
measurements derived from calculable capacitors

Key comparison CCEM-K4

MEASURAND : Capacitance **NOMINAL VALUE : 10 pF**

The key comparison reference value of CCEM-K4 is obtained from the weighted average of the results of the CCEM-K4 participants who derive their reference standard of capacitance by means of an independent realization of the farad from a calculable capacitor. It is chosen such that:

$x_R = x_0 \times (1 + m_R)$, with x_R = 10 pF exactly, that is, $m_R = 0$; the standard uncertainty of m_R is $u_R = 0.017 \times 10^{-6}$.

The degree of equivalence of each laboratory with respect to the reference value is given by a pair of terms: $D_i = (m'_i - m_R)$ and its expanded uncertainty (k = 2), U_i (see detailed calculation of U_i on page 17 of the CCEM-K4 Final Report), where m'_i is deduced from m_i by adding a constant factor chosen so that the reference value is a nominal 10 pF.

The degree of equivalence between two laboratories is given by a pair of terms: $D_{ij} = (D_i - D_j)$ and its expanded uncertainty (k = 2), U_{ij} (see detailed calculation of U_{ij} on page 17 of the CCEM-K4 Final Report).

Linking EUROMET.EM-K4 to CCEM.EM-K4

The input data for establishing the link between EUROMET.EM-K4 and CCEM-K4 are taken from the two previous tables.
In three cases, two EUROMET values are reported; the mean of the two values is used as the final result.

Seven laboratories (BIPM, BNM-LCIE, CSIRO-NML, NIST, NMi-VSL, NPL and PTB) participated in both comparisons.
Each was asked if its results should be used for the link and, if so, to provide a 1σ estimate of the uncertainty, r_l, corresponding to the imperfect reproducibility of its measurements during the time ellapsed between its measurements for the two comparisons.
One of the participant (BNM-LCIE) asked that its results not be used for the link.

The CCEM-K4 key comparison value and degrees of equivalence are unaltered by the linking procedure.

The linking procedure consists of evaluating the correction d to apply to the result ($m_{l\text{-EUR}} - m_{l\text{R-EUR}}$) of a laboratory participating in EUROMET.EM-K4 only, so that the corrected result represents the best estimate of what would have been the result of this laboratory had it actually participated in CCEM-K4.
The correction d is obtained as the weighted average of the difference of the results $[(m'_l - m_R) - (m_{l\text{-EUR}} - m_{l\text{R-EUR}})]$ obtained by the 6 linking laboratories in both comparisons.
The weights are inversely proportional to the quantities $s_l^2 = t_l^2 + t_{l\text{-EUR}}^2 + 2r_l^2$, where t_l and $t_{l\text{-EUR}}$ are the standard transfer uncertainties in the CCEM-K4 and EUROMET.EM-K4 key comparisons.
The result is: $d = 0.007 \times 10^{-6}$ with a standard uncertainty, $u_d = 0.0202 \times 10^{-6}$.

The degree of equivalence of each laboratory participant in EUROMET.EM-K4 with respect to the reference value is given by a pair of terms: $D_l = [(m_{l\text{-EUR}} - mi_{\text{R-EUR}}) + d]$ and its expanded uncertainty ($k = 2$), U_l, based on the quadratic combination of u_R, u_d, $t_{l\text{-EUR}}$ and $U_{l\text{-EUR}}/2$ (see page 2 and Table 2 of the Linkage Report).

The complete matrix of equivalence is built up as explained on pages 2 and 3 and in Table 3 of the Linkage Report.

Key comparisons CCEM-K4 and EUROMET.EM-K4

MATRIX OF EQUIVALENCE

Lab *j* ⟹

Lab *i* ⇩

	D_i / 10^{-6}	U_i / 10^{-6}	BIPM D_{ij} / 10^{-6}	BIPM U_{ij} / 10^{-6}	BNM-LCIE D_{ij} / 10^{-6}	BNM-LCIE U_{ij} / 10^{-6}	CSIRO-NML D_{ij} / 10^{-6}	CSIRO-NML U_{ij} / 10^{-6}	MSL D_{ij} / 10^{-6}	MSL U_{ij} / 10^{-6}	NIM D_{ij} / 10^{-6}	NIM U_{ij} / 10^{-6}	NIST D_{ij} / 10^{-6}	NIST U_{ij} / 10^{-6}	NMi-VSL D_{ij} / 10^{-6}	NMi-VSL U_{ij} / 10^{-6}	NPL D_{ij} / 10^{-6}	NPL U_{ij} / 10^{-6}	NRC D_{ij} / 10^{-6}	NRC U_{ij} / 10^{-6}	PTB D_{ij} / 10^{-6}	PTB U_{ij} / 10^{-6}	VNIIM D_{ij} / 10^{-6}	VNIIM U_{ij} / 10^{-6}
BIPM	-0.018	0.105			0.20	0.12	-0.05	0.13	0.01	0.16	0.02	0.28	-0.02	0.11	0.75	1.20	-0.22	0.14	-0.06	0.34	-0.01	0.14	0.30	0.41
BNM-LCIE	-0.216	0.092	-0.20	0.12			-0.25	0.12	-0.19	0.15	-0.18	0.28	-0.21	0.10	0.56	1.20	-0.41	0.13	-0.25	0.33	-0.21	0.13	0.10	0.41
CSIRO-NML	0.035	0.069	0.05	0.13	0.25	0.12			0.06	0.15	0.08	0.27	0.04	0.09	0.81	1.20	-0.16	0.14	0.00	0.33	0.04	0.13	0.35	0.41
MSL	-0.026	0.124	-0.01	0.16	0.19	0.15	-0.06	0.15			0.01	0.29	-0.02	0.14	0.74	1.21	-0.22	0.17	-0.06	0.35	-0.02	0.16	0.29	0.42
NIM	-0.040	0.261	-0.02	0.28	0.18	0.28	-0.08	0.27	-0.01	0.29			-0.04	0.27	0.73	1.23	-0.24	0.29	-0.08	0.42	-0.04	0.28	0.28	0.48
NIST	-0.003	0.029	0.02	0.11	0.21	0.10	-0.04	0.09	0.02	0.14	0.04	0.27			0.77	1.20	-0.20	0.12	-0.04	0.33	0.00	0.11	0.32	0.40
NMi-VSL	-0.772	1.200	-0.75	1.20	-0.56	1.20	-0.81	1.20	-0.74	1.21	-0.73	1.23	-0.77	1.20			-0.97	1.21	-0.81	1.24	-0.77	1.20	-0.45	1.27
NPL	0.198	0.116	0.22	0.14	0.41	0.13	0.16	0.14	0.22	0.17	0.24	0.29	0.20	0.12	0.97	1.21			0.16	0.34	0.20	0.15	0.52	0.42
NRC	0.037	0.324	0.06	0.34	0.25	0.33	0.00	0.33	0.06	0.35	0.08	0.42	0.04	0.33	0.81	1.24	-0.16	0.34			0.04	0.34	0.36	0.52
PTB	-0.004	0.092	0.01	0.14	0.21	0.13	-0.04	0.13	0.02	0.16	0.04	0.28	0.00	0.11	0.77	1.20	-0.20	0.15	-0.04	0.34			0.31	0.41
VNIIM	-0.318	0.401	-0.30	0.41	-0.10	0.41	-0.35	0.41	-0.29	0.42	-0.28	0.48	-0.32	0.40	0.45	1.27	-0.52	0.42	-0.36	0.52	-0.31	0.41		
BEV	0.407	1.404	0.38	1.41	0.29	1.41	0.39	1.41	0.43	1.41	0.45	1.43	0.40	1.40	0.97	1.85	0.31	1.41	0.37	1.44	0.41	1.41	0.73	1.46
CEM	-0.013	3.002	-0.04	3.00	-0.13	3.00	-0.03	3.00	0.01	3.00	0.03	3.01	-0.03	3.00	0.55	3.23	-0.11	3.00	-0.05	3.02	-0.01	3.00	0.31	3.03
CMI	-0.243	0.412	-0.27	0.42	-0.36	0.42	-0.26	0.42	-0.22	0.43	-0.20	0.49	-0.26	0.41	0.32	1.27	-0.34	0.42	-0.28	0.52	-0.24	0.42	0.08	0.57
CSIR-NML	0.327	2.502	0.30	2.50	0.21	2.50	0.31	2.50	0.35	2.50	0.37	2.52	0.32	2.50	0.89	2.78	0.23	2.50	0.29	2.52	0.33	2.50	0.65	2.53
GUM	-0.393	0.806	-0.42	0.81	-0.51	0.81	-0.41	0.81	-0.37	0.82	-0.35	0.85	-0.41	0.81	0.17	1.45	-0.49	0.81	-0.43	0.87	-0.39	0.81	-0.07	0.90
IEN	0.317	0.806	0.29	0.81	0.20	0.81	0.30	0.81	0.34	0.82	0.36	0.85	0.31	0.81	0.88	1.45	0.22	0.81	0.28	0.87	0.32	0.81	0.64	0.90
METAS	-0.193	62.000	-0.22	62.00	-0.31	62.00	-0.21	62.00	-0.17	62.00	-0.15	62.00	-0.21	62.00	0.37	62.01	-0.29	62.00	-0.23	62.00	-0.19	62.00	0.13	62.00
MIKES/VTT	-0.913	1.504	-0.94	1.51	-1.03	1.51	-0.93	1.51	-0.89	1.51	-0.87	1.53	-0.93	1.50	-0.35	1.92	-1.01	1.51	-0.95	1.54	-0.91	1.51	-0.59	1.56
SP	-0.593	1.802	-0.62	1.81	-0.71	1.80	-0.61	1.81	-0.57	1.81	-0.55	1.82	-0.61	1.80	-0.03	2.17	-0.69	1.81	-0.63	1.83	-0.59	1.81	-0.27	1.85
UME	0.327	1.602	0.30	1.61	0.21	1.61	0.31	1.61	0.35	1.61	0.37	1.62	0.32	1.60	0.89	2.00	0.23	1.61	0.29	1.63	0.33	1.61	0.65	1.65

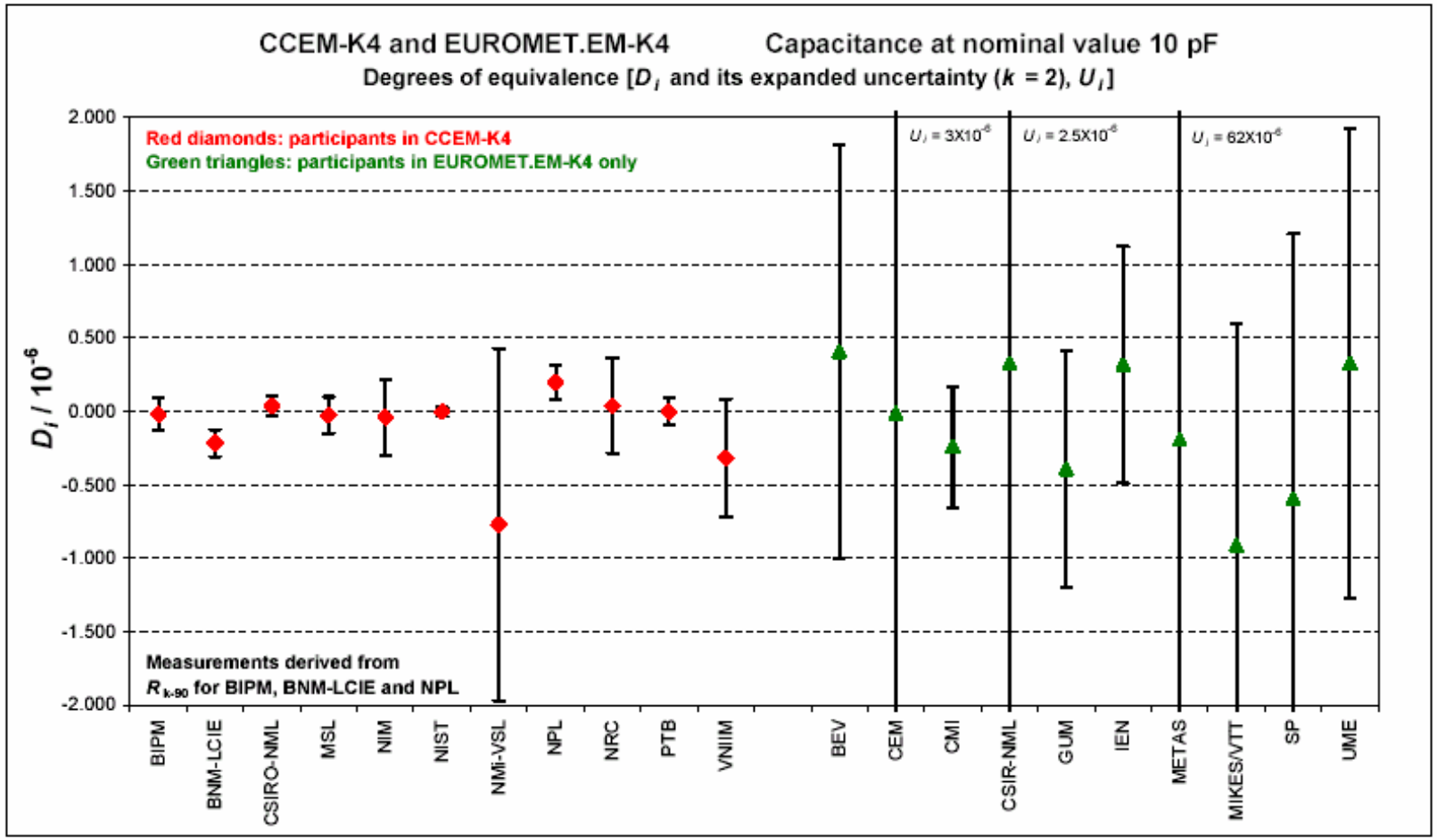
Key comparisons CCEM-K4 and EUROMET.EM-K4

MATRIX OF EQUIVALENCE (Continued)

Lab *j* ⟹

Lab *i* ⇩

Lab *i*	D_i / 10^{-6}	U_i / 10^{-6}	BEV D_{ij} / 10^{-6}	BEV U_{ij} / 10^{-6}	CEM D_{ij} / 10^{-6}	CEM U_{ij} / 10^{-6}	CMI D_{ij} / 10^{-6}	CMI U_{ij} / 10^{-6}	CSIR-NML D_{ij} / 10^{-6}	CSIR-NML U_{ij} / 10^{-6}	GUM D_{ij} / 10^{-6}	GUM U_{ij} / 10^{-6}	IEN D_{ij} / 10^{-6}	IEN U_{ij} / 10^{-6}	METAS D_{ij} / 10^{-6}	METAS U_{ij} / 10^{-6}	MIKES/VTT D_{ij} / 10^{-6}	MIKES/VTT U_{ij} / 10^{-6}	SP D_{ij} / 10^{-6}	SP U_{ij} / 10^{-6}	UME D_{ij} / 10^{-6}	UME U_{ij} / 10^{-6}
BIPM	-0.018	0.105	-0.38	1.41	0.04	3.00	0.27	0.42	-0.30	2.50	0.42	0.81	-0.29	0.81	0.22	62.00	0.94	1.51	0.62	1.81	-0.30	1.61
BNM-LCIE	-0.216	0.092	-0.29	1.41	0.13	3.00	0.36	0.42	-0.21	2.50	0.51	0.81	-0.20	0.81	0.31	62.00	1.03	1.51	0.71	1.80	-0.21	1.61
CSIRO-NML	0.035	0.069	-0.39	1.41	0.03	3.00	0.26	0.42	-0.31	2.50	0.41	0.81	-0.30	0.81	0.21	62.00	0.93	1.51	0.61	1.81	-0.31	1.61
MSL	-0.026	0.124	-0.43	1.41	-0.01	3.00	0.22	0.43	-0.35	2.50	0.37	0.82	-0.34	0.82	0.17	62.00	0.89	1.51	0.57	1.81	-0.35	1.61
NIM	-0.040	0.261	-0.45	1.43	-0.03	3.01	0.20	0.49	-0.37	2.52	0.35	0.85	-0.36	0.85	0.15	62.00	0.87	1.53	0.55	1.82	-0.37	1.62
NIST	-0.003	0.029	-0.40	1.40	0.03	3.00	0.26	0.41	-0.32	2.50	0.41	0.81	-0.31	0.81	0.21	62.00	0.93	1.50	0.61	1.80	-0.32	1.60
NMi-VSL	-0.772	1.200	-0.97	1.85	-0.55	3.23	-0.32	1.27	-0.89	2.78	-0.17	1.45	-0.88	1.45	-0.37	62.01	0.35	1.92	0.03	2.17	-0.89	2.00
NPL	0.198	0.116	-0.31	1.41	0.11	3.00	0.34	0.42	-0.23	2.50	0.49	0.81	-0.22	0.81	0.29	62.00	1.01	1.51	0.69	1.81	-0.23	1.61
NRC	0.037	0.324	-0.37	1.44	0.05	3.02	0.28	0.52	-0.29	2.52	0.43	0.87	-0.28	0.87	0.23	62.00	0.95	1.54	0.63	1.83	-0.29	1.63
PTB	-0.004	0.092	-0.41	1.41	0.01	3.00	0.24	0.42	-0.33	2.50	0.39	0.81	-0.32	0.81	0.19	62.00	0.91	1.51	0.59	1.81	-0.33	1.61
VNIIM	-0.318	0.401	-0.73	1.46	-0.31	3.03	-0.08	0.57	-0.65	2.53	0.07	0.90	-0.64	0.90	-0.13	62.00	0.59	1.56	0.27	1.85	-0.65	1.65
BEV	0.407	1.404			0.42	3.31	0.65	1.46	0.08	2.87	0.80	1.62	0.09	1.62	0.60	62.02	1.32	2.05	1.00	2.28	0.08	2.13
CEM	-0.013	3.002	-0.42	3.31			0.23	3.03	-0.34	3.91	0.38	3.11	-0.33	3.11	0.18	62.07	0.90	3.36	0.58	3.50	-0.34	3.40
CMI	-0.243	0.412	-0.65	1.46	-0.23	3.03			-0.57	2.53	0.15	0.90	-0.56	0.90	-0.05	62.00	0.67	1.56	0.35	1.85	-0.57	1.65
CSIR-NML	0.327	2.502	-0.08	2.87	0.34	3.91	0.57	2.53			0.72	2.63	0.01	2.63	0.52	62.05	1.24	2.92	0.92	3.08	0.00	2.97
GUM	-0.393	0.806	-0.80	1.62	-0.38	3.11	-0.15	0.90	-0.72	2.63			-0.71	1.14	-0.20	62.01	0.52	1.70	0.20	1.97	-0.72	1.79
IEN	0.317	0.806	-0.09	1.62	0.33	3.11	0.56	0.90	-0.01	2.63	0.71	1.14			0.51	62.01	1.23	1.70	0.91	1.97	-0.01	1.79
METAS	-0.193	62.000	-0.60	62.02	-0.18	62.07	0.05	62.00	-0.52	62.05	0.20	62.01	-0.51	62.01			0.72	62.02	0.40	62.03	-0.52	62.02
MIKES/VTT	-0.913	1.504	-1.32	2.05	-0.90	3.36	-0.67	1.56	-1.24	2.92	-0.52	1.70	-1.23	1.70	-0.72	62.02			-0.32	2.35	-1.24	2.20
SP	-0.593	1.802	-1.00	2.28	-0.58	3.50	-0.35	1.85	-0.92	3.08	-0.20	1.97	-0.91	1.97	-0.40	62.03	0.32	2.35			-0.92	2.41
UME	0.327	1.602	-0.08	2.13	0.34	3.40	0.57	1.65	0.00	2.97	0.72	1.79	0.01	1.79	0.52	62.02	1.24	2.20	0.92	2.41		



The BIPM key comparison database, August 2002 7/8

Evaluation of key comparison data

Annex 5 describes methods for the evaluation of key comparison data, which may be applied to supplementary comparisons and pilot comparisons as well. An important part of such an evaluation is the determination of a key comparison reference value (KCRV) and its associated uncertainty, and the degrees of equivalence (DoEs) of and between national measurement standards[1]. "National measurement standard" is interpreted as the result of the measurement made by the respective participating laboratory, institute or organization listed in Appendix A of the MRA of a travelling standard. In cases where BIPM is one of the participants the term "National measurement standard" has to be applied in the wider sense.

The degree of equivalence of each national measurement standard[1] is expressed quantitatively by two terms:

- its deviation from the key comparison reference value
- the uncertainty of this deviation at the 95 % level of confidence

The degree of equivalence between pairs of national measurement standards[1] is expressed quantitatively by two terms:

- the difference of their deviations from the key comparison reference value
- the uncertainty of this difference at the 95 % level of confidence

In case the DoEs between pairs of national measurement standards[1] could be calculated in a simple manner from the DoEs of each national measurement standard[1], it is not obligatory to report the pairwise DoEs in the comparison report and/or the EXCEL file of the KCDB.

The *BIPM Director's Advisory Group on Uncertainties* is developing guidance documents for the evaluation of key comparison data which are intended to be as simple as possible consistent with the degree of rigour demanded by the activity. The currently available guidelines may be said to apply to the simplest situation, viz. the straightforward circulation around all the participants of a single travelling standard having good short-term stability.

It is intended subsequently to develop guidelines that apply to other types of key comparisons, some of the most important of which have one or more of the following features:

- mutual dependencies among some or all of the institutes' measurements
- travelling standards not possessing good short-term stability
- patterns for the comparison that are different from the simple circulation of a travelling standard
- several travelling standards circulated (and to be treated) together
- travelling standards to be measured at each of a number of stipulated values of a parameter, such as wavelength or frequency
- KCRVs deduced other than from the results of participant's measurements

The CCEM also intends to provide guidelines for linking key comparisons carried out under the auspices of the CIPM (CC or BIPM key comparisons) and those operated by the RMOs.

Guidelines presently available:

- M. Cox, The evaluation of key comparison data, *Metrologia*, 2002, **39**, 589-595. Describes the circulation around all the participants of a single travelling standard having good short-term stability

[1] A national measurement standard refers to the highest measurement standard maintained by a laboratory, institute or organization listed in Appendix A of the MRA.

References used in this document		
CIPM MRA-D-05		Measurement comparisons in the CIPM MRA, March 2016
CIPM MRA-G-04		CIPM MRA Guidelines for Authorship of Key, Supplementary and Pilot Study Comparison Reports, October 2011
		Key and supplementary comparison registration and progress form, May 2016
Metrologia, 2002, **39**, 589-595	M. Cox	The evaluation of key comparison data
		CCEM Strategic Plan, 26 March 2014
CCEM/00-18	C. Thomas J. de Vreede B. Field	Checklist for review of Draft B Reports of CCEM Comparisons