Measurement comparisons in the CIPM MRA

CIPM MRA-D-05

Version 1.6

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1. Background

1.1. On the CIPM MRA

Paragraph 3 of the CIPM MRA defines the technical basis of the arrangement:

3.1 The technical basis of this arrangement is the set of results obtained in the course of time through key comparisons carried out by the Consultative Committees of the CIPM, the BIPM and the regional metrology organizations (RMOs), and published by the BIPM and maintained in the key comparison database[1]. Detailed technical provisions are given in the Technical Supplement to this arrangement.

3.2 Key comparisons carried out by Consultative Committees or the BIPM are referred to as CIPM key comparisons; key comparisons carried out by regional metrology organizations are referred to as RMO key comparisons; RMO key comparisons must be linked to the corresponding CIPM key comparisons by means of joint participants. The degree of equivalence derived from an RMO key comparison has the same status as that derived from a CIPM key comparison.

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2. Definitions

2.1. Key comparison

A key comparison is one of the set of comparisons selected by a Consultative Committee to test the principal techniques and methods in the field.

Note: Key comparisons may include comparisons of representations of multiples and sub-multiples of SI base and derived units as well as comparisons of artefacts.

[1] At present the key comparison data base (KCDB) is maintained by the KCDB office of the BIPM

2.1.1. CIPM key comparison

A CIPM key comparison is a key comparison executed in the framework of a Consultative Committee or by the BIPM. A CIPM key comparison leads to a key comparison reference value[2].

Note: BIPM key comparisons consist of series of successive bilateral comparisons between NMIs and the BIPM performed when the BIPM holds a unique facility (e.g. SIR for activity of radionuclides).

2.1.2. RMO key comparison

A RMO key comparison is a key comparison executed in the framework of a regional metrology organization.

2.1.3. Key comparison reference value

The key comparison reference value is the reference value resulting from the measurements taken in a CIPM key comparison, accompanied by its uncertainty (normally the standard uncertainty).

Only CIPM key comparisons (carried out by a Consultative Committee or the BIPM) result in a key comparison reference value. For a key comparison carried out by a regional metrology organization (RMO key comparison) the link to the key comparison reference value is obtained by reference to the results from those institutes which have also taken part in the CIPM key comparison.

Note: The method used to determine the key comparison reference value is part of the protocol of the comparison and is agreed by the Consultative Committee or by the appropriate working group to which the Consultative Committee has delegated this task.

2.1.4. Degrees of equivalence

The degree of equivalence relative to the key comparison reference value of a measurement standard or of a measurement result is the degree to which the measured value is consistent with the key comparison reference value. This is expressed quantitatively by two

[2] See 3.1 nomenclature of comparisons

terms: the deviation from the key comparison reference value and the expanded uncertainty of this deviation computed at a 95 % level of confidence (in practice, this is often approximated by using a coverage factor k equal to 2). 7KH ³JUDSK RI HTXLYDOHQFH´ VKR equivalence relative to the key comparison reference value.

The degree of equivalence between two measurement standards or two measurements results (also known as ³bilateral degree of equivalence´, or ³pair-wise degree of equivalence´) is expressed quantitatively by two terms: the deviation of one measured value with respect to the other, calculated as the difference between their respective deviations from the key comparison reference value and the expanded uncertainty of this deviation computed at a 95 % level of confidence (in practice, this is often approximated by using a coverage factor k equal to 2)[3].

The matrix of equivalence consists of the full set of degrees of equivalence. This may be published in the KCDB but in the event that it is not published, the details relating to its calculation are available in the final report.

2.2. Supplementary comparisons

A supplementary comparison is a comparison, usually carried out by an RMO to meet specific needs not covered by key comparisons (e.g. regional needs), for instance measurements of specific artefacts, or measurements of parameters not within the ³normal´ scope of the Consultative Committees.

Consultative Committees may however decide to run a supplementary comparison when there are only few participants capable of measuring the required quantity (none sharing the same RMO), when no link can be made to an RMO comparison or when the distribution of samples to measure is a constraint (for instance: measurements of radioactive matrix reference materials).

[3] In special cases, the CCs may decide that the degrees of equivalence be expressed in relative values, after normalization relatively to the key comparison reference value or the nominal value of the measurand.

2.3. Pilot studies

Pilot studies are a third category of comparison normally undertaken to establish PHDVXUHPHQW SDUDPHWHUV IRU D ³QHZ´ ILHOG RU LQVW, or as a training exercise. The results of pilot studies alone are not normally considered sufficient support for calibration and measurement capability[4] (CMC).

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3. Registration of comparisons in the KCDB and status report

Registration of comparisons must be made through the BIPM key comparison database office (KCDB Office), using the Key and supplementary comparison registration and progress form. Only key and supplementary comparisons are registered in the KCDB. Participants who are either i) signatories of the CIPM MRA, or ii) designated institutes for their country through the process of CIPM MRA-D-06, will be listed in the public website of the KCDB for the comparison.

During the course of a comparison that is registered in the KCDB, it is important that up-to-date information on the progress of the comparison be readily available. This implies that the participants, the KCDB Office, and the Consultative Committee (the President, the Executive Secretary, and the working group designated by the Consultative Committee for this task) should be regularly informed by the pilot institute of the status of the comparison. The progress of a comparison shall be reported to the KCDB office with the same form used for registration. Once the progress of the comparison is reported to the KCDB office, the updated status will be made public on the KCDB website.

3.1. Nomenclature of key comparisons

Upon registration with the KCDB Office, each key or supplementary comparison is identified by a unique nomenclature.[5]

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[4] See document CIPM MRA-D-04

[5] Some RMOs also use an internal identifier before the comparison is registered. This identifier may be kept in the KCDB and can be found using the website free form search engine.

The first part of the name identifies the comparison. A second part may be used to identify sub-sets of a particular comparison (see below).

x First, the body under the auspices of which the comparison is carried out. This can be:

  - Consultative Committee: CC
  - BIPM: BIPM.
  - Regional metrology organization designated by its acronym: AFRIMETS., APMP., COOMET., EURAMET., SIM., etc.

  The dot (.) is added for the BIPM and for the acronym of a regional metrology organization for clarity in reading the nomenclature.

x Second, the field of measurement, designated as in the titles of Consultative Committees:

  AUV for Acoustics, Ultrasound and Vibration;

  QM for Amount of Substance;

  EM for Electricity and Magnetism;

  RI for Ionizing Radiation;

  L for Length;

  M for Mass and related quantities;

  PR for Photometry and Radiometry;

  T for Thermometry;

  TF for Time and Frequency.

x Third, which applies only when the comparison is specifically chosen by a given Consultative Committee working group, part of the acronym of the working group preceded by a dot, for instance:

  .RF for the Working Group on Radio Frequencies of the CCEM;

  .M for the Working Group on Mass Standards of the CCM;

  .P for the Working Group on Pressure of the CCM;

  .F for the Working Group on Force of the CCM;

.D for the Working Group on Density of the CCM;

.H for the Working Group on Hardness of the CCM.

This also applies to the three sections of the CCRI (without the dot):

(I) for Section I;

(II) for Section II;

(III) for Section III;

as well as to the CCAUV:

.A for Acoustics;

.U for Ultrasound;

.V for Vibration;

.W for Underwater acoustics.

- Fourth, a hyphen (-).
- Fifth, a capital letter, K for key comparison, S for supplementary comparison and P for pilot study.
- Sixth, a number, generally in the successive order 1, 2, 3, etc.

The second part of the nomenclature may be omitted, but is useful to distinguish between several sub-comparisons of a key or supplementary comparison. It can take any form but should always be preceded by a dot (.). The most usual cases are:

- .a, .b, .c for several sub-comparisons, corresponding to different ranges of measurements of the same quantity;
- .Xy- . Z K L F K D S S H D U V I Q W K H I L H O G R I ionizing radiation for identifying the measurement of a specific radionuclide · Xy.
- .1, .2, .3 for subsequent bilateral comparisons to a key comparison.
- the year in which the comparison is initially registered in the KCDB.

Dots or hyphens can be added as desirable for clarity in this second part of the nomenclature.

Two or more key comparisons corresponding to the same description but carried out over two different time intervals must have different identifiers. Normally,

‡ 'HWDLOHG GHVFULSWLRQ RI WKH GHYLFHV PDNH
packaging, etc., and technical data needed for their operation.

‡ $GYLFH RQ KDQGOLQJ, WKH WUDYHOOLQJ VWDQGDU
packing and shipping to the next participant. This should include a complete list of the content of the package including handbooks, etc., and the weight and size of the whole package.

‡ $FWLRQ WR EH WDNHQ RQ UHFHLSW RI WKH
standards in a participating institute.

‡ $Q\ WHVWV WR EH FDUULHG RXW EHIRUH PHDVXUHF

‡Conditions of use of travelling standards during measurement.

‡ ,QVWUXFWLRQV IRU UHSRUWLQJ WKH UHVXOWV

‡Proposal for the method of determination of the key comparison reference value .

‡List of the principal components of the uncertainty budget to be evaluated by each participant, and any necessary advice on how uncertainties are estimated (this is based on the principles laid out in the ISO Guide to the Expression of Uncertainty in Measurement). In addition to the principal components of the uncertainty, common to all participants, individual institutes may add any others that they consider appropriate. Uncertainties are evaluated at a level of one standard uncertainty and information must be given on the number of effective degrees of freedom required for a proper estimation of the level of confidence.

‡Timetable for communicating the results to the pilot institute. Early communication helps to reveal problems with the travelling standard during the comparison.

‡)LQDQFLDO DVSHFWV RI WKH FRPSDULVRQ QRWL
institute is responsible for its own costs for the measurements, transport and any customs charges as well as any damage that may occur within its country. Overall costs of the organization of the comparison, including the supply of the transfer devices, are normally borne by the pilot institute.

‡ ,QVXUDQFH RI WUDQVIHU GHYLFHV LV not taking GHG E\
account of the responsibility of each participant for any damage within its country.

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4.5. Circulation of transfer standards and customs formalities

The pilot institute is responsible for organizing the circulation and transport of the standards and ensuring that the participants make proper arrangements for local customs formalities.

The equipment must be handled with care, i.e. only by qualified metrology personnel. It is desirable and in some cases essential that the transfer instruments be hand-carried. If this is not deemed essential, certain precautions must nevertheless be taken. As goods are usually delivered to a shipping department in an institute a warning note should be attached to the package indicating that the package should be opened only by laboratory personnel. The participating institutes are responsible for transport to the next institute according to the circulation scheme. The method of transport as defined in the instructions should be respected.

Before dispatching the package, each participant must inform the next participant and the pilot institute, giving transport details.

If an ATA carnet is used, it must be used properly. Upon each movement of the package the person organizing the transit must ensure that the carnet is presented to customs on leaving the country, and upon arrival in the country of destination. When the package is sent unaccompanied, the carnet must be included with the other forwarding documents so that the handling agent can obtain customs clearance. In no case should the carnet be packed with the device in the package. In some cases it is possible to attach the carnet to the package.

After arrival of the package, the participating institute should inform the pilot institute of this by completing and returning a form that is included in the package. Immediately after receipt, the participating institute should check for any damage of the standards, in particular scratches and rust, and report this to the pilot institute.

If a delay occurs the pilot institute should inform the participants and if necessary revise the time schedule or the order of circulation between countries.

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4.6. Reporting the results ofthe measurements

The participating institutes must report the results of the measurements to the pilot institute as soon as possible after this date and at the latest six weeks after the measurements

are completed. The measurement results, together with the associated uncertainties and any additional information required, should be reported in the format given in the instructions as part of the protocol, usually by completing the standard forms annexed to the instructions.

A result from a participant is not considered complete without an associated uncertainty, and is not included in the draft report unless it is accompanied by an uncertainty supported by a complete uncertainty budget. Uncertainties are drawn up following the guidance given in the technical protocol.

If, on examination of the complete set of results, the pilot institute finds results that appear to be anomalous, the corresponding institutes are invited to check their results for numerical errors but without being informed as to the magnitude or sign of the apparent anomaly. If no numerical error is found, the result stands, and the complete set is sent to all participants.

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4.7. Report of a CIPM key comparison

The pilot institute is responsible for writing the report of the key comparison. The report passes through a number of stages before publication, and these are referred to here as Draft A, Draft B and Final Report.

The first draft, Draft A, is prepared as soon as all the 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. However the results are not communicated if there are any outliers, until the participants concerned have been contacted to ensure that there are no arithmetic, typographical or transcription errors involved.

The participants may make comments on their own results and these may be modified if there were errors in the report of the result (typographical errors, different units, transcription errors from the institute report to the Draft A report). In the case of results that are discrepant with the reference value or are not consistent with their published CMCs, the participants are not allowed to withdraw their results from the report unless a reason not attributable to the performance of the laboratory can be assigned (for example, if an excessive drift or a malfunction is detected in the travelling standard). 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.

As the results may be changed due the reason explained above, Draft A (in all its versions) must be considered confidential and distributed among the participants only. As results may change, Draft A reports cannot be used as support for claiming CMCs.

Until all the participants have agreed on the report, it should be considered to be in Draft A stage, it being possible to have successive versions (D U D I W $ $ « H W F

In calculating the key comparison reference value, the pilot institute will use the method considered most appropriate for the particular comparison (normally that proposed in the protocol), subject to confirmation by the participants and, in due course, the key comparison working group and the Consultative Committee. After deciding the key comparison reference value and its uncertainty, the deviation from the reference value and the expanded uncertainty at a 95% level of confidence ($k = 2$ for infinite number of degrees of freedom) of the deviation are deduced for each of the individual results (degrees of equivalence). At this stage the participants may review the initial decision to include or not bilateral degrees of equivalence, subject to approval of the corresponding CC.

Once the final version of Draft A, which includes the proposed key comparison reference value and degrees of equivalence, is approved by the participants, the report is considered as Draft B. It must then be submitted for approval by the corresponding Consultative Committee. At this stage, the results are not considered confidential and can be used to support CMCs and can be used for presentations and publications, except for the key comparison reference value and the degrees of equivalence which must be considered confidential until they are approved by the Consultative Committee and published in the KCDB.

The working group on key comparisons is normally charged with examining Draft B prior to its distribution to all members of the Consultative Committee, to ensure that it meets all the requirements set by the committee. In the case of those Consultative Committees having permanent working groups dealing with specific areas of activity, the Consultative Committee may ask these working groups to undertake the functions of the key comparison working group.

Entry of the results, including the degrees of equivalence, into the KCDB must wait until Draft B has been approved by the Consultative Committee, at which point the Draft becomes the Final Report. At that stage, the mention ³'raft B´ in the title or contents should be replac H G E \ W K H P H Q W L.RQ ³) L Q D O 5 H S R U W´ Approval by the Consultative Committee may be given by correspondence on the recommendation of the working group on key comparisons. Each Consultative Committee will set its own procedures for approving the results of key comparisons in the most efficient and timely way possible.

In the event of disagreement concerning the results or the interpretation of the results of a key comparison, which cannot be resolved by the participants, by the key comparison working group or by the Consultative Committee, the matter is referred to the CIPM for a decision.

An institute that considers its result unrepresentative of its standards may request a subsequent separate bilateral comparison with the pilot institute or one of the participants. This should take place as soon as possible after the completion of the comparison in progress. The subsequent bilateral comparison is considered as a new and distinct comparison.

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5. RMO key comparisons

To allow the participation in key comparisons of all the NMIs and DIs of an RMO, the RMOs may organize their own key comparisons.

5.1. Participation in RMO key comparisons

Participation in RMO key comparisons is decided by the corresponding committees of the RMO, but only the results corresponding to NMIs or DIs from Member States of the BIPM or Associate States and Economies of the CGPM that have signed the CIPM MRA will appear in the tables of numbers (including the degrees of equivalence) and in the graphs (including the graphs of equivalence) published in the KCDB. The policy for reporting comparisons that involve participants who are non-signatories to the CIPM MRA is stated in paragraph 8.

As participation in CIPM key comparisons may be limited in number for technical reasons, it is recommended that if possible, RMO key comparisons be open to participation of NMIs of other regions.

The RMO key comparisons must be linked to the corresponding CIPM key comparisons by means of joint participants. This is mandatory to demonstrate global equivalence. To achieve this, it is recommended that at least two of the participants in the preceding CIPM key comparison participate also in the RMO key comparison.

5.2. Organization of RMO key comparisons

The RMO key comparisons must follow the same protocol as a preceding CIPM key comparison and must be approved in advance DV ³NH\´ E\ WKH FRUUHVSRQGL Committee. Instead of the method to determine a reference value, the RMO key comparison protocol must include the way in which the results will be linked to the corresponding CIPM key comparison reference value.

The mechanism for approval depends on the particular &RQVXOWDWLYH &RPP practice.

5.3. Reports of RMO key comparisons

The procedure for reporting an RMO key comparison is basically the same as that described in Section 4.7. Only key comparisons carried out by a Consultative Committee or the BIPM (CIPM key comparisons) lead to a key comparison reference value. For a key comparison carried out by an RMO, the link to the CIPM key comparison reference value is obtained by reference to the results from those institutes that have also taken part in the CIPM key comparison.

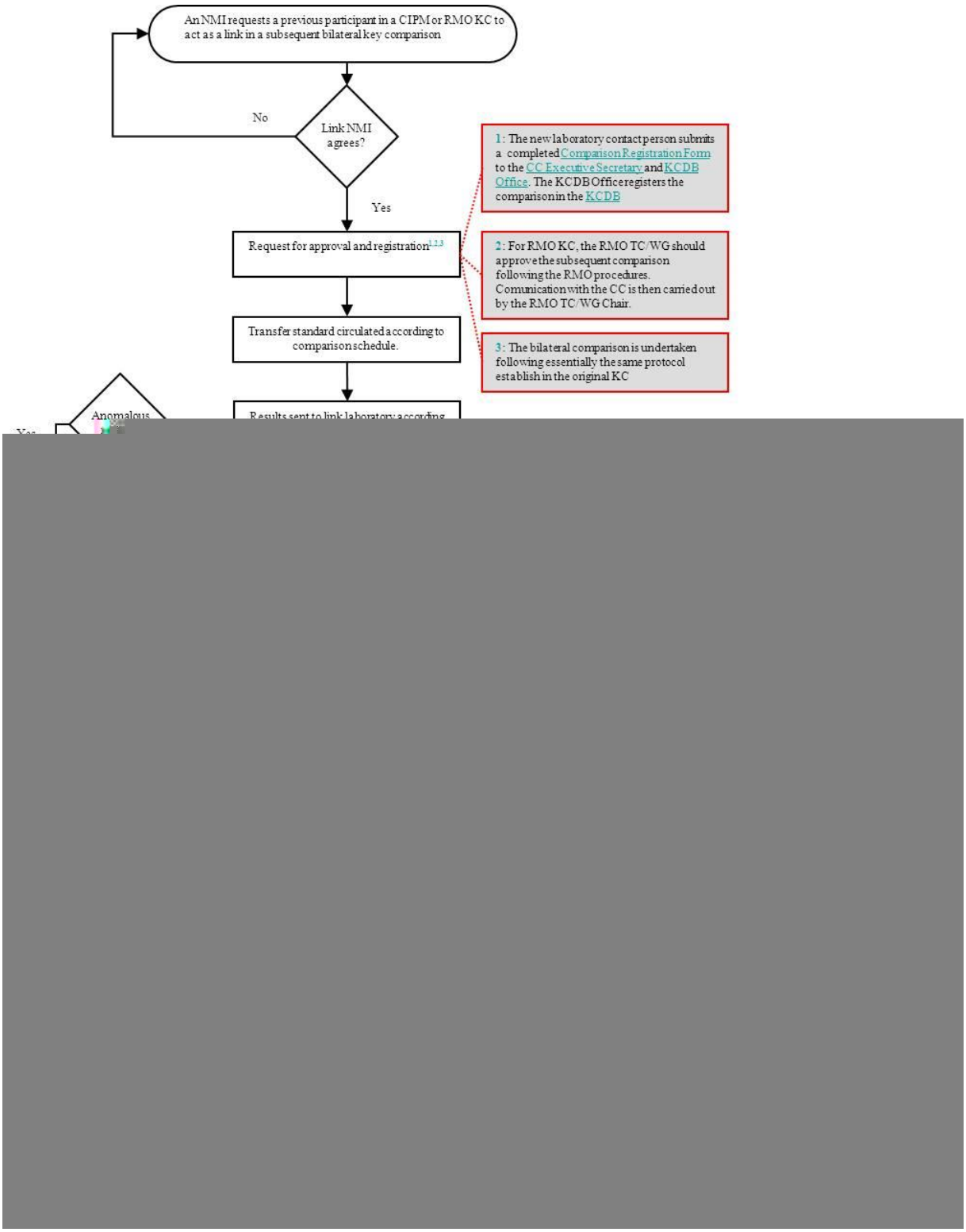
The complete results of the linked RMO key comparison are shown in exactly the same form in the pages of the original CIPM key comparison in the KCDB. However, the link IRU ³SDUWLFLSDQWV´ LQ WKH SDJH IRU WKH 502 FRPSL participated in this exercise.

The degree of equivalence relative to the CIPM key comparison reference value derived from an RMO key comparison has the same status as that derived from a CIPM key comparison.

6. Subsequent bilateral key comparisons

Subsequent bilateral key comparisons are normally carried out for one of the following reasons:

After completing a key comparison, an institute that considers its result unrepresentative of its standards may request a subsequent bilateral comparison with one of the other participants.

An institute that was not ready to participate at the time a key comparison was conducted may request a subsequent bilateral comparison with one of the

Appendix 2 ±Flowchart of subsequentbilateral comparisons