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A User's Guide to the Information in the Key Comparison Data Base

by A.J. Wallard and C. Thomas

Bureau International des Poids et Mesures, F-92312 Sèvres Cedex

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Abstract

The launch of the Mutual Recognition Arrangement by the International Committee for Weights and Measures (CIPM MRA) created a process within which calibration and measurement certificates from National Metrology Institutes (NMIs) which are signatories could be recognized and accepted worldwide. This process has become of great interest to regulators and accreditors. More recently, it has attracted the attention of international companies who wish to take advantage of the mutual recognition offered by these certificates by taking traceability to the International System of Units (the SI) through local NMIs. This latter aspect of the use to which the Key Comparison Data Base (KCDB) can be put has recently been made more straightforward as the result of a new search engine installed by the BIPM. The paper describes the current situation and shows how to access the relevant data. The paper will be complemented by a practical demonstration of the KCDB in the exhibition hall of the conference.

1. Introduction

In 1999, the International Committee for Weights and Measures (CIPM) drew up an arrangement for the mutual recognition of national measurement standards and of calibration and measurement certificates issued by National Metrology Institutes (NMIs), the CIPM MRA, with the objectives of:

- providing international recognition of national measurement standards maintained by NMIs;
- providing confidence in, and knowledge of, the measurement capabilities of participants for all users, including the regulatory and accreditation communities;
- providing the technical basis for acceptance, between countries, of measurements used to support the trade of goods and services, as a result of the world wide acceptance of certificates issued in the framework of the CIPM MRA, and thus
- ultimately reducing non-tariff or technical barriers to trade.

Such a structure constituted an important step towards improving the international metrology system and the overall traceability of measurements to the International System of Units (SI). As such, the CIPM MRA was welcomed by all sectors of the metrology community, by commercial and industrial companies, and by regulatory and accreditation bodies.

The CIPM MRA is an arrangement signed by metrology institutes. It can, however, have a positive impact only if quantitative information supporting international recognition is provided in an open and clear manner. Consequently, the CIPM MRA created a database, maintained by the BIPM and known as the "BIPM key comparison database" (BIPM KCDB). The KCDB openly displays, on the internet, data on international comparisons of the national measurement

standards maintained by participants in the CIPM MRA, and on the calibration and Measurements Capabilities (CMCs) declared by these institutes. The following section of this paper describes the content of the BIPM KCDB and its impact on the worldwide metrology system. The last section gives an overview of the search facilities provided by the BIPM KCDB website, especially the text-based semantic search engine, recently acquired by the BIPM. The paper will be complemented by a practical demonstration of the KCDB in the exhibition hall of the conference.

2. The BIPM key comparison database – definition and content

The BIPM key comparison database (KCDB) provides electronic support to the CIPM MRA. The expression "key comparison database" and the acronym "KCDB" are generic terms, which cover a complete web application maintained by the BIPM. It is based on two main databases and openly displayed on the internet through the KCDB home page at http://www.bipm.org/kcdb. All the information it contains is internationally recognized through the procedures described in the text of the CIPM MRA, and kept up to date.
Access is provided to three different types of information:

- a list of participants in the CIPM MRA,
- information on, and reports of, key and supplementary comparisons, including results interpreted in terms of equivalence for key comparisons, and
- the list of Calibration and Measurement Capabilities (CMCs) declared by the laboratories which participate in the CIPM MRA, and which are internationally recognized by all other participants.

2.1. Participants in the CIPM MRA

The participants in the CIPM MRA are metrology institutes:

- National Metrology Institutes (NMIs) from Member States of the Metre Convention or Associates of the General Conference on Weights and Measures (CGPM), and whose Directors have signed the CIPM MRA, and
- Designated Institutes (DIs) nominated by the signatory NMI as holding the national standards or facilities in the country, when these are not available at the NMI itself.

The list of participants in the CIPM MRA is officially maintained by the Director's Office at the BIPM. It is made available in the form of a .pdf file and of searchable html pages kept on the BIPM website. In March 2007, it included about 180 metrology laboratories from 45 member states and 20 Associates, plus two international organizations (IAEA and IRMM). A link to this list is made available from the KCDB home page.

2.2. Key and supplementary comparisons

A first database is maintained at the BIPM to keep records of international (key and supplementary) comparisons of national measurements standards maintained by participants. The corresponding information is made publicly available from the *"Key and supplementary*

comparisons" website[1]. These comparisons are selected and managed by the Consultative Committees (CCs) of the CIPM and by the Regional Metrology Organizations (RMOs).

The philosophy behind the design of these comparisons is to improve efficiency and reduce costs through a careful selection which decreases the number of items to be compared, but which gives confidence in a wide range of measurements.

2.2.1. Definitions

A "*key comparison*" is one of the set of comparisons selected by a Consultative Committee (CC) of the CIPM to test the principal techniques and methods in the field. Its protocol is agreed by the CC.

Key comparisons are denoted "*CIPM key comparisons*" if carried out by one of the CCs or by the BIPM, and "*RMO key comparisons*" if carried out by one of the RMOs within its region. An RMO key comparison can be initiated only if a CIPM (CC or BIPM) key comparison with the same protocol has already been decided.

The "*BIPM key comparisons*" are a series of bilateral comparisons between an NMI and the BIPM. These are special cases of CIPM key comparisons, and are especially useful when a facility is kept uniquely at the BIPM, for instance the International System of Reference (SIR) for use in measurements of radionuclides.

It is possible that participation in a key comparison reveal some problems in the measurement system involved in one or several laboratories. The CIPM MRA has foreseen the case of "*subsequent bilateral comparisons to key comparisons*", in order to give the opportunity to repeat measurements.

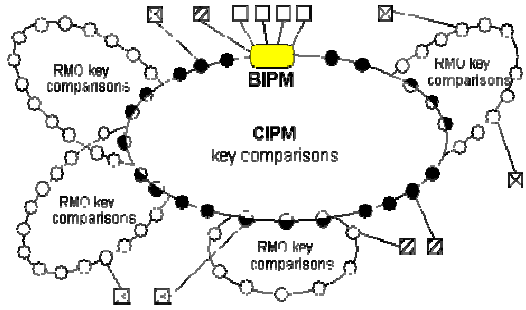
A "*supplementary comparison*" is one of the set of comparisons conducted by the RMOs to meet specific needs not covered by key comparisons, including comparisons to support confidence in calibration and measurement certificates.

Each comparison is concluded by the edition of a Final Report, which is reviewed and approved by the appropriate body (CC or RMO), posted onto the KCDB website, and also published as a *Metrologia Technical Supplement*. For key comparisons, numbers and graphs are also displayed from the KCDB website, as explained in next section.

2.2.2. Results of key comparisons

Key comparisons are organized to form families of comparisons, as shown in Figure 1. Each family is centred on a CIPM key comparison, to which RMO key comparisons and bilateral comparisons are linked.

[1] This part of the KCDB is often referred to as "*Appendix B of the CIPM MRA*".



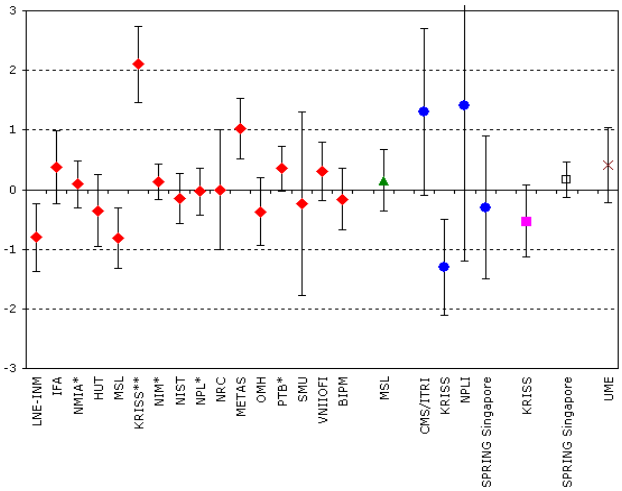
- Full circles: participants in CC key comparisons,
- Half full circles: participants in CIPM and RMO key comparisons,
- Empty circles: participants in RMO key comparisons only,
- Empty squares: participants in BIPM key comparisons,
- Crossed and hachured squares: participants in bilateral key comparisons

Figure 1. Organization of CIPM and RMO key comparisons.

Measurements obtained by laboratories participating in a CIPM key comparison are interpreted in terms of equivalence as foreseen in the text of the Technical Supplement to the CIPM MRA. The resulting numbers and graphs (often designated as "*results*") are inserted in the Final Report, and also displayed in the KCDB website. They are composed of:

- the key comparison reference value, deduced through a statistical analysis of the results;
- the degree of equivalence of each national measurement standard, expressed quantitatively by two terms: its deviation from the key comparison reference value and the uncertainty of this deviation, at a 95 % level of confidence; and
- the graph of equivalence, which is a graphical representation of the set of degrees of equivalence (the zero-axis represents the key comparison reference value).

The next step is the linkage between two key comparisons of the same family, and thus the expansion of the results of the CIPM key comparison. It can be established only if there is a common participation of one or more members in the CIPM key comparison and the equivalent RMO key comparison. The linkage does not modify the value and the uncertainty of the CIPM key comparison reference value, which remains unique and unaltered for the whole family. It simply extends the set of degrees of equivalence and the graph of equivalence in order to give evidence of the comparability between institutes that have only participated in one of the exercises. The expanded uncertainty included in their degrees of equivalence is, however, generally higher than if they had been compared directly. An example is given in Figure 2.



The PR-K3.b family (luminous responsivity)

- Diamonds: CCPR-K3.b participants,
- Triangle : one value amended after the CC key comparison,
- Circles: APMP.PR-K3.b participants,
- Squares: participants in two subsequent bilateral comparisons

Figure 2. An example of the extension of a graph of equivalence.

2.2.3. Content of the database

On 5 April 2007, 720 comparisons were registered in the KCDB, among which there were:

- 567 key comparisons (78 from the BIPM, 288 from the CCs, and 201 from RMOs), and
- 153 supplementary comparisons.

On the same date, results were interpreted in terms of equivalence for 254 key comparisons, leading to the publication in the KCDB of the corresponding Final Reports and of about 800 graphs of equivalence. 76 Final Reports of supplementary comparisons were also available.

2.2.4. Impact

The interpretation of results in terms of equivalence requires that complete and documented uncertainty budgets are established by all of the participants. The output of the process is the elaboration of sets of degrees of equivalence, forming quantitative and objective information, which has been reviewed and approved. No attempt is given in the KCDB to judge the performance of any one participant relative to the others on a scale from "worst to best", but comparability between National Metrology Institutes (and Designated Institutes) is established on a solid footing, thus enhancing confidence at the highest level of metrological measurements. This comparability also constitutes a key item of information for the international approval of Calibration and Measurement Capabilities declared by NMIs.

2.3. Calibration and Measurement Capabilities (CMCs)

A second database is maintained at the BIPM to keep the list of Calibration and Measurement Capabilities (CMCs) declared and accepted by the institutes participating in the CIPM MRA. The corresponding information is made publicly available from the *"Calibration and Measurement Capabilities – CMCs"* website[2].

In the framework of the CIPM MRA, a Calibration and Measurement Capability (CMC) is defined as the ensemble of information given in a calibration or measurement certificate issued by a metrology institute. It corresponds to a service normally offered to all clients. A CMC is described by the measured quantity and its range, and is characterized by an uncertainty generally given at a 95 % level of confidence, together with the method or instrument used, the values of the influence parameters if any, and any other relevant information.

The CMC data registered in the KCDB are prepared by the institute, then peer-reviewed through intra- and inter-regional examination. They should be supported by information from some or all of the following sources [Document JCRB-14/06(2a)]:

- results of key and supplementary comparisons,
- documented results of past CC, RMO or other comparisons (including bilateral),
- knowledge of technical activities by other NMIs, including publications,
- on-site peer-assessment reports,
- active participation in RMO projects, and

[2] This part of the KCDB is often referred to as "*Appendix C of the CIPM MRA*".

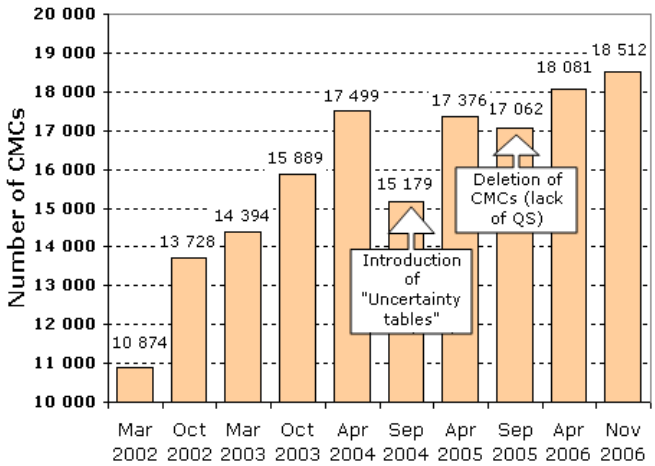
- any other available knowledge or experience.

At the end of the review, they are approved by the Joint Committee of the RMOs and the BIPM (JCRB) for publication in the KCDB. In addition, since July 2005, all CMCs displayed by the KCDB website have been covered by an appropriate Quality System, approved by the RMO of the declaring institute. The consequence of this process is the international recognition by all participants in the CIPM MRA of the measurement and calibration services listed by each institute in the KCDB.

2.3.1. Content of the database

On 5 April 2007, the database contained some 19300 CMCs, among which about 3700 cover the field of Chemistry, 3400 the field of Ionizing Radiation, and 6000 the field of Electricity and Magnetism. This number is expected to increase since some metrology areas are not yet fully covered, especially Time and Thermometry. Figure 3 gives an overview of the number of CMCs recorded in the KCDB over the last five years. Detailed statistics on the number of CMCs approved per country and per metrology area are available from the KCDB statistics web page.

The effective number of uncertainty values published is estimated to be over 35000, as a consequence of the implementation of "*uncertainty tables*", which may be used to describe the range of uncertainty values that characterizes one given CMC. The column and row headings of the table contain the values taken by two physical quantities (or influence parameters) involved in the CMC. This facility, which makes it possible to deliver much more precise information, is extensively used in the field of Electricity.



Note : More than 800 CMCs were deleted from the KCDB in the period July – September 2005, because they were not covered by an approved QS. About 60 % of these were re-instated in the KCDB in April 2007.

Figure 3. Number of CMCs registered in the KCDB: evolution over the last five years.

2.3.2. Impact

The impact of the formal approval of information about CMCs can be summarized as follows:

- The NMI certificates supported by CMCs published in the KCDB are accepted worldwide by all participants at whatever accuracy is stated in the KCDB.
- The Calibration certificate statement of equivalence and the CIPM MRA Logo can be included in the certificate (see Figure 4 below).

- Commercial and industrial companies can use the services of any signatory if they need a calibration[3].This certificate will be accepted by all other signatories.
- The KCDB CMCs website is a tool that is useful for regulatory and accreditation bodies when they need to have information on uncertainty and traceability.

Calibration certificate statement
"This certificate is consistent with the capabilities that are included in Appendix C of the MRA drawn up by the CIPM. Under the CIPM MRA, all participating institutes recognize the validity of each other's calibration and measurement certificates for the quantities, ranges and measurement uncertainties specified in Appendix C."

CIPM MRA

Figure 4. The CIPM MRA Calibration certificate statement and the CIPM MRA Logo[4].

3. Searching the BIPM key comparison database

The KCDB home page gives access to both of the websites on "*Key and supplementary comparisons*", and on "*Calibration and Measurement Capabilities – CMCs*", as shown on Figure 5, and also to a number of useful links, including statistics, FAQs, a glossary, and the KCDB Newsletters page.

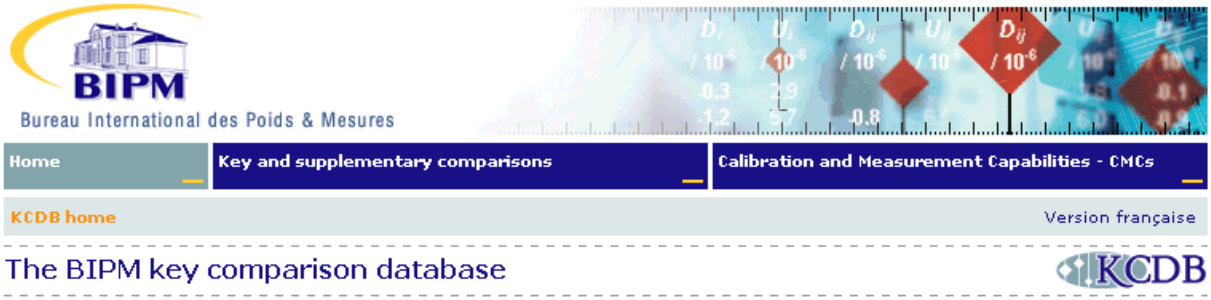


Figure 5: The BIPM KCDB home page.

From October 1999 to March 2007, information was made available through directed search facilities allowing users to choose among a list of items or by downloading .pdf files. Some users, however, commented that searching information from the database of CMCs is sometimes difficult: one has first to select a metrology area, and then to choose from items presented under the format chosen for the Classification of Services drawn up for this metrology area. These items may be instruments, such as in dimensional metrology, or quantities, such as in electricity. This can be confusing and leads the visitor to simply download one or another global .pdf file from among those proposed, without using the search engine that would have delivered a well-targeted answer.

[3] An example on how the CIPM MRA assists international trade is given in the KCDB Newsletter No 6 from the experience of Dr Gun Woong Bahng, KRISS, Korea: "The CIPM MRA saved DSME up to $ 10 million".

[4] In April 2007 there were 55 laboratories authorized to use the CIPM MRA Logo in the measurement and calibration certificates of their services listed in the KCDB. Others who want to use it can do so by application to the BIPM.

To overcome this difficulty, and also to increase the visibility of the BIPM web system, a group composed of three BIPM staff - the Webmaster, the IT Manager and the KCDB Coordinator, studied the advantages of implementing a search facility that would be able to interpret a text-based inquiry. Several such search engines, all commercially available, were compared and the BIPM purchased new software in December 2005. Our new search engine was implemented on the KCDB and publicly launched on 6 March 2007. It takes the form of free-text boxes, into which the user types words, available from the websites which contain the information on comparisons and the CMCs. The previous directed search facilities are also maintained for sake of continuity.

The BIPM search engine is also implemented on the main BIPM website. It offers a search across the websites of all institutes participating in the CIPM MRA and a number of databases maintained at the BIPM, so promoting the BIPM website as the world's reference portal for metrology.

The BIPM search engine is a powerful tool with the advantages of full-text searching, and dynamically generated tables of contents based on each search results page, to allow an easy means of refining the search query, as shown in Figure 6.

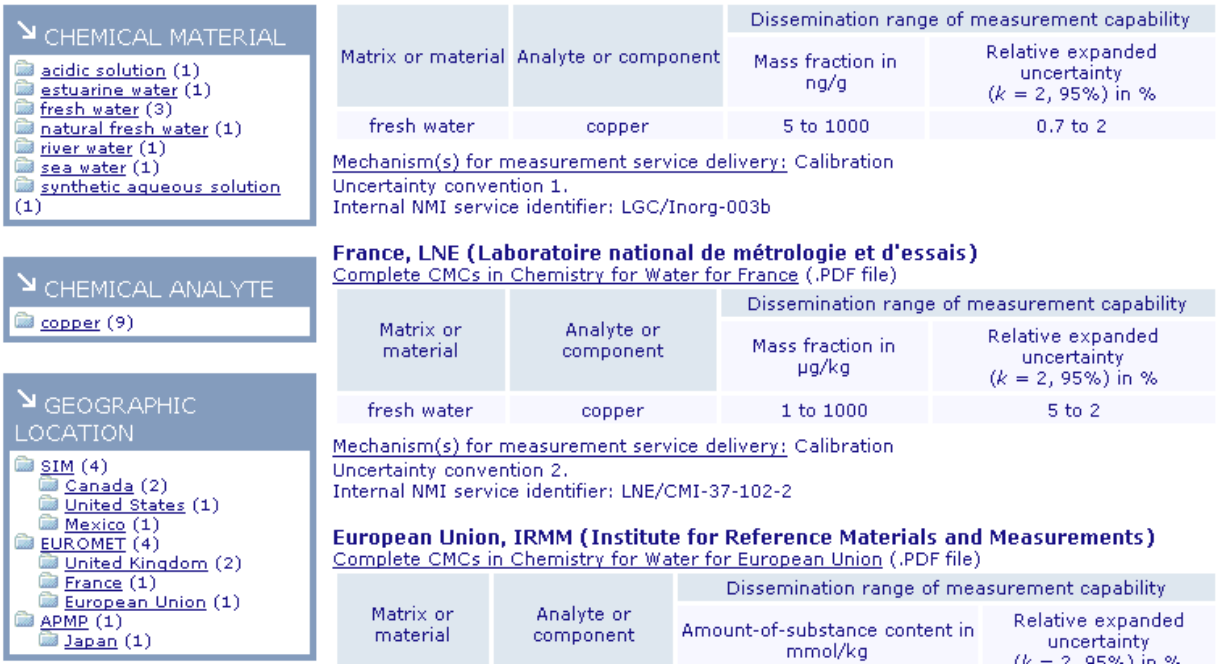


Figure 6: Results of the query "copper in water" entered in the free-text box implemented on the KCDB CMCs website. The right part of the screen displays some of the relevant CMCs. A number of contextual links are provided on the left and can be used to refine the search by geographic location of the declaring NMI, and by chemical material.

In the following we show some characteristics of the new BIPM search engine through a number of illustrative examples which the reader is encouraged to experience.

3.1. Relevance of the results

The search engine parameters are chosen so the answers are all appropriate (minimization of the noise) and no appropriate answers are missing (minimization of gaps in the information). For instance, the query '**AC-DC**'[5] in the database of CMCs returns about 1000 answers, all relevant to AC-DC voltage and current transfer at all frequencies.

3.2. Refining results

The links generated dynamically on the left of the screen can be used to refine the search by selecting or deleting one or several item(s) among the proposed lists. It is always possible to come back to the previous screen by clicking again on the same link. In the example '**AC-DC**', it is possible to choose an RMO or an NMI, and measurements at radio-frequencies for instance.
Note that this type of surfing requires only a few clicks, and no *a-priori* knowledge.

3.3. Finding comparisons corresponding to a specified theme

It is now possible to search for comparisons involving a specified theme: '**natural gas**' for instance returns key and supplementary comparisons in Chemistry and Fluid Flow.

3.4. Making statistics

Any type of statistics based on numbers of CMCs or on comparisons corresponding to specified properties is now facilitated. For instance, searching for '**key**' and refining by selecting the statuses '**Report in progress**' and '**Measurements completed**' returns those key comparisons that are about to be finished. Another example may be '**Electricity and Magnetism United States**' which would return all CMCs declared by that country and relevant to that metrology area.

3.5. Approximation, exact wording search

An approximation of two letters on the entry is allowed. It follows that the plural is automatically taken into account: the queries '**flowmeter**' and '**flowmeters**' are thus equivalent. Exact wording search is possible by using quotes: the queries '**"VNIIM"**' and '**"VNIIMS"**' (two Russian metrology institutes) are not equivalent.

3.6. Vocabulary, use of acronyms

A vocabulary is implemented on the search engine, which makes it possible to find information relevant to synonyms of the entry. It is intended to be especially useful when acronyms are searched: for instance '**DVM**' for digital voltmeters.

[5] Note that if the entry includes a slash ("/"), the search engine understands it as a separator and considers only the first part of the entry. It would thus dramatically truncate the answer. The use of a slash is thus not recommended. The search engine is set up on the KCDB website in such a way that the sign "-" and the hyphen are understood as the word "and".

3.7. Searching a given Certified Reference Material or a given NMI service

Though the KCDB is by no means a catalogue of Certified Reference Materials (CRMs), a number of CMCs, especially in Chemistry, are based on the use of CRMs for dissemination of traceability. It is now possible to call for a given CRM, for instance '**CASS-4**', and access all measurements that this particular CRM supports (in this case, a number of analytes measured in sea water by Canada). It is also possible to have a direct access to a specified NMI service known by its identifier, for instance '**PTB 94a**' available from the German NMI.

4. Conclusions

The worldwide metrology system is well supported by the Mutual Recognition Arrangement drawn up by the CIPM and its electronic support, the BIPM key comparison database. The process put in place helps ensure traceability to the SI, of measurements stated on calibration certificates. It provides a means to validate the traceability and the uncertainty claims of commercial and industrial companies and of laboratories worldwide which have been accredited to ISO/IEC 17025 or, in the case of reference materials, to ISO Guide 34.

Ensuring the maintenance and the update of the KCDB, and providing access to its content, are essential and continuous tasks for the BIPM, which are central to its fundamental mission. The BIPM invites feedback from the KCDB visitors, in order to further improve its service to the widest possible user community.

Acknowledgements

Claudine Thomas extends warm thanks to Janet Miles, the BIPM webmaster, and to Laurent Le Mée, the BIPM IT Manager, for helpful collaboration in implementing the BIPM search engine on the KCDB website.