

# The BIPM key comparison database (KCDB): technical aspects and data management

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## Abstract

The BIPM key comparison database (KCDB) is a Web application composed of a BIPM restricted-access back office, databases and administrative forms, and a front office, the KCDB website, publicly available on the Internet at <http://kcdb.bipm.org>. This is a pure BIPM product, built up thanks to the BIPM's staff and financial resources, in collaboration with an outside company. The back office makes it possible to build up pure html pages for the information and results of comparisons and to proceed to direct importation of the EXCEL files of Calibration and Measurement Capabilities (CMCs) into the appropriate tables of the databases. The data flow is continuous and the volume of data is huge: most of key comparison results involve tables including several thousands of characters, and the typical content of a CMC EXCEL file can be estimated to 500 cells. An important effort is also devoted to data saving. This paper points out some technical aspects of the KCDB work, and explains how the data is managed.

## Introduction

In 1999, the Comité International des Poids et Mesures (CIPM) drew up an arrangement for the “*mutual recognition of national measurement standards and of calibration and measurement certificates issued by national metrology institutes*”: the [CIPM MRA](#) (Mutual Recognition Arrangement) [1]. Its objectives are to provide international recognition of the realization of national standards, and to provide confidence in the measurement capabilities of participating laboratories.

Evidence for such a recognition is supported by data, such as results of measurements and descriptions of services offered to clients, approved by all parties. Such a data collection needs a tool that is easy to update and available to the wide public. This was realized through the creation of the BIPM key comparison database (KCDB), maintained at the Bureau International des Poids et Mesures (BIPM). Since 30 November 1999, it has represented the principal output of the CIPM MRA as available on the public internet network.

In practice, the KCDB is a Web application composed of a back office and a front office.

The back office is composed of:

- databases, which contain data,

- administrative forms, used to register data into the databases, and
- pre-production Websites, used to check the registered data before launch onto the public Web.

The front office is the KCDB Website, publicly available at <http://kcdb.bipm.org/>, and also designated as the production Website.

The information available from the KCDB is divided into four parts corresponding to the appendices of the text of the CIPM MRA (*Figure 1*) 1) the Appendix A is the list of the participating institutes, 2) the Appendix B contains information on key and supplementary comparisons, 3) the Appendix C contains Calibration and Measurement Capabilities (CMCs) declared by participants, and 4) the Appendix D lists the key comparisons.



Figure 1. KCDB Website Home Page: access to the four appendices.

The data contained in these four appendixes is of different nature, and needs dedicated treatment.

- Appendix A is a .pdf file maintained by the Director's office at the BIPM.
- Information in Appendix B and D is contained in a unique database, the Appendix B database, populated thanks to a complex administrative form.
- Data from Appendix C are primarily contained in EXCEL files that are directly imported in two databases, the Appendix C prototype and production databases.

At the BIPM, the KCDB office is responsible for maintaining the Appendix B and C databases and the complete Web system.

After a brief overview on the network installation at the BIPM, we describe the management of data published in Appendix B and C. Emphasis is given on the volume of data, the frequency of updates, and the saving process.

The technical work carried out daily at the KCDB office is the subject of 9 procedures approved in the framework of the BIPM Quality System since March 2004.

## 1. BIPM network

The global architecture of the BIPM network is shown on *Figure 2*. It is composed of a demilitarized zone (DMZ) and of an internal network. A firewall acts as a filter between the outside world-wide internet network and the DMZ. It also isolates the BIPM internal network from outside, but allows access to the DMZ from the internal network under authorized conditions.

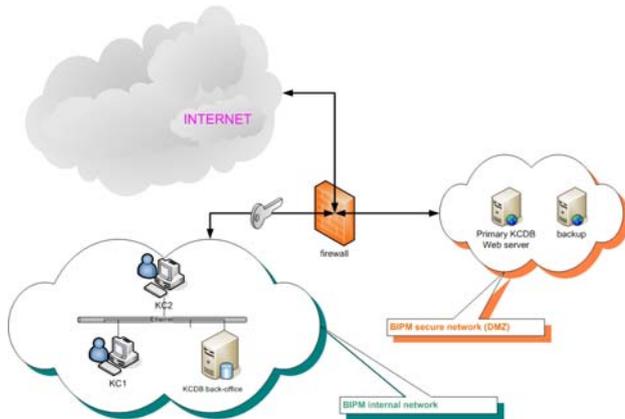


Figure 2. Global architecture of the BIPM network.

The personal computers of the KCDB office and the server “kcdb3”, which hosts the KCDB back office, are confined in a sub-domain of the BIPM internal network, accessible only through authentication processes.

These personal computers also share a common part of the BIPM server “si”, which serves as working space, and are thus primarily used as terminals.

The two front servers “kcdb1” and “kcdb2” are installed in the DMZ, and physically located in two different computer rooms at the BIPM. The KCDB front office is installed on the two front servers and are synchronized in real-time. This makes it possible to provide a continuous service to the internet user in case of failure of one of them.

The content of the servers kcdb1, kcdb2, kcdb3, and si, is saved every 24 hours by the BIPM Information Technology team according to procedures that are also approved in the framework of the BIPM Quality System. In addition, our team watches upon the maintenance of all pieces of hardware.

The KCDB Web application is a pure BIPM product, built up thanks to the BIPM’s staff and financial resources. The programming itself is made by an outside company, but its design is entirely controlled by the BIPM.

## 2. Appendix B

### 2.1. Content

A key or supplementary comparison is registered into [Appendix B](#) only when the BIPM KCDB office receives from the appropriate body, a Consultative Committee (CC) or a Regional Metrology Organization (RMO) a formal authorization to do so.

On 21 April 2005, 494 key comparisons and 118 supplementary comparisons [2] were registered.

The Appendix B has a search engine for the user at [http://kcdb.bipm.org/AppendixB/KCDB\\_ApB\\_search.asp](http://kcdb.bipm.org/AppendixB/KCDB_ApB_search.asp) allowing the access to the list of comparisons corresponding to a selection of search criteria. A unique identifier is attributed to each of them according to an agreed [nomenclature](#) [3]. Clicking on the identifier returns the page of information on the comparison. A link is provided to its final report and to its results (for key comparisons only) when they become available.

The information displayed by Appendix B is generally contained in the protocol of the comparison. It includes a brief description, the nominal values of the measurand and of the influence parameters, the dates of measurement, the status, the methods, the transfer standards, the pilot laboratory and the contact person’s name and address details, the list of participants, and any other comments of interest. An example is shown on *Figure 3*.

CCEM-K8	
Information	
Metrology area, branch	Electricity and Magnetism, DC Voltage and Current
Description	Comparison of DC voltage ratios
Time of measurement	1999 - 2001
Status	Approved for equivalence, <a href="#">Results available</a>
Reference(s)	<a href="#">Metrologia, 2003, 40, Tech. Suppl., 01001</a>
Measurand	DC voltage ratio: 1000 V / 10 V and 100 V / 10 V
Transfer device(s)	Datron 4902S standard divider, s/n 20335
Comparison type	Key comparison
Consultative Committee	CCEM (Consultative Committee for Electricity and Magnetism)
Conducted by	CCEM (Consultative Committee for Electricity and Magnetism)
Other designation(s)	CCE 97-2 (Comparison 97-2 of the former Consultative Committee for Electricity)
Comments	A subsequent comparison was decided between CEM, CSIR-NML and IEN. It is registered into the BIPM key comparison database under the identifier <a href="#">CCEM-K8.1</a> .

Figure 3. Information on key comparison CCEM-K8, as displayed by the Appendix B Website. Links (not shown here) are proposed to other pages (pilot laboratory, list of participants, results, etc.) from the left side of the page.

Measurements obtained by laboratories participating in a key comparison are interpreted in terms of equivalence as foreseen in the text of the [Technical Supplement to the CIPM MRA](#) [4], which introduces the notion of “degrees of equivalence” among the measurement standards of the participants. The resulting numbers and graphs (often designated as “results”) are published in the final report, and also displayed in Appendix B. A reference is subsequently inserted in the information page.

In practice the results of a key comparison, obtained for one value of the measurand or one value of an influence parameter, generally take the form of a four-sheet folder including 1) the laboratory individual measurements, 2) the equivalence statements, 3) the matrix of equivalence, and 4) the graph of equivalence.

On 21 April 2005, Appendix B displayed about 350 sets of results, covering the measurements obtained in 171 key comparisons. They are registered into Appendix B, and made publicly available via internet under the form of html folders (*Figure 4*).

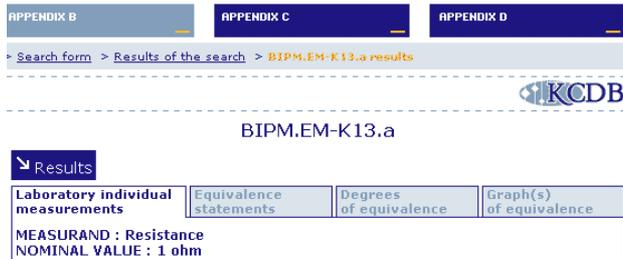


Figure 4. Access to the folder of a set of results as presented in Appendix B (example of BIPM.EM-K13.a, measurand value: 1 ohm).

A number of .pdf files are also posted in Appendix B, mainly full texts of final reports of key and supplementary comparisons, and also summary results of key comparisons.

## 2.2. Data volume and flow

The volume of the data contained in the Appendix B database can be roughly estimated to 15 mega bytes. Most of the information is saved in two tables of the database, one includes 612 lines (the total number of comparisons), and the other one 350 lines (the total number of set of results).

In addition, about 900 .pdf files of total size 180 mega bytes are posted in the Appendix B Website.

Data for Appendix B arrives every day at the KCDB office. This continuous flow mainly includes requests for registering new comparisons and updating the information on comparisons already registered. We manage to carry out the work in the hours following reception of the request. This type of updates is also made globally after a CC meeting for all of its comparisons.

On average we receive one approved final report of a key comparison each week, with the request to enter the corresponding sets of results. The registration of the data is made in close collaboration with the contact person, and is generally accomplished in a few weeks time. This work is facilitated if the contact person can provide an EXCEL file containing the numbers, because it avoids hand-typing. These numbers should, however, be checked in comparison with those contained in the final report.

## 2.3. Back Office

### 2.3.1. Structure

The Appendix B back office is composed of an ensemble of “administrative forms”, of a unique database, “the Appendix B database”, and of a pre-production Website. The back office is installed on the server kcdb3, and is accessible only from the computers located in the KCDB sub-domain of the BIPM internal network (see section 1) via a username and a password.

The administrative forms allow to enter information into the Appendix B database without typing directly in the fields of the tables of the database. This system is safe, and has a very sophisticated design able to handle with all possible requests we may receive.

### 2.3.2. General administrative form

The home page of the administrative form used for Appendix B is shown in Figure 5. Links are provided on the left side to sub-forms specially designed to create new items, modify existing items, and add news.



Figure 5. Home page of the Appendix B administrative form.

### 2.3.3. Sub-forms

Let’s take the example of a reference to an article in open literature.

The sub-form used to create a new reference is shown in Figure 6. Information are entered in the proposed fields, and are saved by clicking on “Save”.

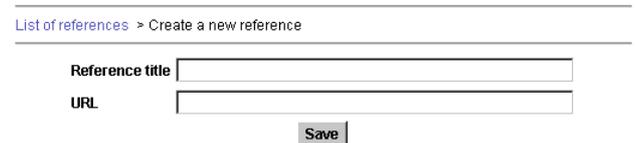


Figure 6. Sub-form used for the creation of a new reference.

The modification of the information concerning a reference is made in two steps: 1) searching the reference, and 2) enter the changes, as illustrated on Figure 7.

### Modify reference

Search a reference :

Reference title	Comparison
<a href="#">Metrologia, 2002, 39, Tech. Suppl., 01001</a>	CCEM-K2
<a href="#">Metrologia, 2003, 40, Tech. Suppl., 01001</a>	CCEM-K8
<a href="#">Metrologia, 2004, 41, Tech. Suppl., 01001</a>	EUROMET.EM-K8

Figure 7. Sub-form used for modifying a reference already registered in Appendix B. Inserting a chain of characters in the “Search a reference” box, and clicking on OK returns the full list of references corresponding to the search. Clicking on one of them lead to a sub-form including the information on the reference.

The sub-forms used for creating a new comparison and modifying the information already registered is more complex: additional links are provided to attribute a number of items entered independently to the comparison, for instance a reference, a contact person, a list of participants, etc. (Figure 8).



The pair-wise degrees of equivalence are given as "Lab *i* - Lab *j*"

Select Lab *j*

Lab <i>i</i>	$D_i$	$U_i$	$D_{ij}$	$U_{ij}$
	/ 10 <sup>-8</sup>	/ 10 <sup>-8</sup>	/ 10 <sup>-8</sup>	/ 10 <sup>-8</sup>
CEM	-8.0	18.0	-19.0	26.9
JV	2.7	12.4	-8.3	23.5
CMI	11.0	20.0		
INPL	18.0	30.0	7.0	36.0
KRISS	3.1	8.4	-7.9	21.6
NML(IE)*	-7.1	46.0	-18.1	50.1

Figure 10.c. Presentation of the matrix of equivalence of Figure 10.a in the KCDB Appendix B Website (degrees of equivalence of each participant relative to the key comparison reference value and pair-wise degrees of equivalence relative to the Czech institute of metrology CMI).

Clicking on "Save" at the bottom of anyone of the administrative forms saves the data into the database.

### 2.3.5. Pre-production Website

The Appendix B pre-production Website is an access-restricted Website installed on the server kcdb3, which uses the same programming as the production Appendix B Website open to the public.

It displays the data entered in the Appendix B database via the administrative form, and thus makes it possible to check the conformity of the information by comparison with the documents sent to the KCDB office (mail requesting the registration of new comparisons, final reports of key comparisons, etc.), and the appearance on the screen (style, colours, etc.).

## 2.4. Publication on the Web

Clicking on "Online" at the bottom of anyone of the administrative forms launches the data onto the public Web.

All files inserted in the Mini-Word windows via hyperlinks (final reports, summary reports, images, etc.) must also be pushed onto the front servers kcdb1 and kcdb2. This is realized using a file transfer facility installed on kcdb3.

A last check of the data as returned from the servers kcdb1 and kcdb2, and the insertion of a set of news (see Figure 5) end the process: new information is available to the wide public via Internet.

## 2.5. Data saving

The files used in the process of publishing data via Appendix B (.pdf files, EXCEL files, images, etc.) are saved on the server kcdb1, kcdb2, and kcdb3.

## 3. Appendix C

### 3.1. Content

[Appendix C](#) give the list of Calibration and Measurement Capabilities (CMCs) declared and accepted by the institutes participating in the CIPM MRA.

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 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 Appendix C are prepared by the institute in EXCEL files of pre-defined format, then peer-reviewed through intra- and inter-regional examination, and finally approved by the Joint Committee of the RMOs and the BIPM (JCRB) [5].

On 21 April 2005, Appendix C contained about 17000 CMCs, among which about 3000 cover the field of Chemistry, 3000 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 Frequency, and Thermometry.

The effective number of uncertainty values published via Appendix C is, however, estimated to be much higher (over 35000). This is the 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.

An example of one CMC as published in Appendix C is shown in Figure 11.

**Austria, BEV (Bundesamt für Eich- und Vermessungswesen)**

[Complete CMCs in for Austria \(.PDF file\)](#)

AC current up to 100 A: meters, AC ammeter, multimeter, multifunction transfer standard, 0.005 A to 20 A  
 Relative expanded uncertainty ( $k = 2$ , level of confidence 95%) in  $\mu\text{A/A}$ : 60 to 330  
 Comparison with reference setup  
 Frequency: 40 Hz to 100 kHz  
 Internal NMI service identifier: BEV/35  
[Uncertainty table](#)

Figure 11. Appendix C: example of a CMC declared by Austria in the field of Electricity. The range of uncertainty is detailed in the uncertainty table obtained by clicking on the proposed link.

A number of .pdf files are also posted on Appendix C.

### 3.2. Data volume and flow

The volume of the data contained in Appendix C can be roughly estimated to 20 mega bytes. It grows up much faster than the volume of data of Appendix B. In addition, about 400 .pdf files of total size 30 mega bytes are posted in the Appendix C Website.

The content of Appendix C is updated several times a week: addition of newly approved CMCs, deletion of CMCs that correspond to services no more available or not covered by an appropriate Quality System, increase of uncertainty values, additional information on a given CMC, etc.

The KCDB office downloads the CMCs EXCEL files from the access-restricted JCRB Website as soon as they are posted for approval. Since the approval process takes at least 3 weeks, it is possible to prepare in advance the publication, which greatly facilitates the organization of the work.

### 3.3. Back office

#### 3.3.1. Structure

The Appendix C back office is composed of an administrative form, of two databases, “the Appendix C prototype database” and “the Appendix C production database”, and of a prototype Website. The back office is installed on the server kcdb3, and is accessible only from the computers located in the KCDB sub-domain of the BIPM internal network (see section 1).

#### 3.3.2. Administrative form

The Appendix C databases are populated by direct importation of the EXCEL files of CMCs, via dedicated facilities named “modules of importation”. Their role is to place the content of each EXCEL cell in the appropriate field of the appropriate table of the databases.

As mentioned above, the CMCs EXCEL files have a pre-defined format corresponding to 3 different templates chosen to accommodate the information according to the metrology area they cover:

- General Physics, for Acoustics, Ultrasound, and Vibration (AUV), Electricity and Magnetism (EM), Length (L), Mass and Related Quantities (M), Photometry and Radiometry (PR), Thermometry (T), and Time and Frequency (TF);
- Ionizing radiation (RI); and
- Chemistry (QM).

We thus need 3 different tables in each of the Appendix C databases, and 3 different modules to populate them.

The administrative form is shown on *Figure 12*.

#### Appendix C - Prototype

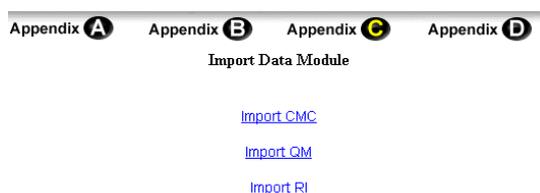
[Appendix C Prototype - Front](#)  
[Appendix C Prototype - Importation AppC](#)

#### Appendix C - Production

[Appendix C Production- Front](#)  
[Appendix C Production - Importation AppC](#)

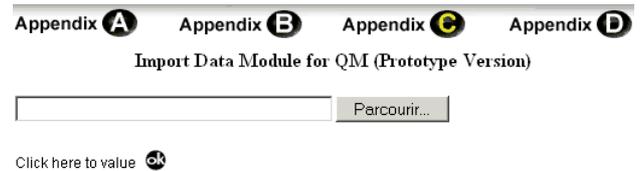
*Figure 12. Appendix C administrative form: access to the prototype and production Websites, and to the modules of importation.*

Clicking on “Appendix C Prototype – Importation AppC” leads to the page shown on *Figure 13*.



*Figure 13. Access to the individual modules of importation. Each of the 3 links that are proposed populates 3 different tables of the databases, dedicated to General Physics, Chemistry, and Ionizing Radiation.*

Clicking on one of the link allows to choose the EXCEL file to be imported, and to import it into one of the database as shown on *Figure 14*.



*Figure 14. Importation of an EXCEL file of CMCs in the field of Chemistry into the Appendix C prototype database. “Parcourir” allows to select the file to be imported. Clicking on “OK” launches the importation. When the importation is finished, the message “Data file imported” appears in this page.*

#### 3.3.3. The importation process

Each module of importation is designed to import CMCs declared for one unique metrology area “MA” and by one unique country “CO”. It proceeds as follows:

- 1) It places the CMCs corresponding to “MA” and “CO” in a temporary table of the database.
- 2) It searches for all CMCs corresponding to “MA” and “CO” already present in the appropriate table of the database.
- 3) If any, it deletes these CMCs from this table.
- 4) It imports the CMCs corresponding to “MA” and “CO” placed in the temporary table into the appropriate table.

It is thus a substitution, which requests that all CMCs covering one metrology area and declared by one country are collected in one single CMC EXCEL file. The corresponding files are often designated as the “master CMCs files” and are named “MA\_CO.xls”. They are all made available at any time in the part “Get Published CMCs” of the access-restricted JCRB Website. They are also converted in .pdf files named “MA\_CO.pdf”, which are made available from the Appendix C Website.

Let’s take the example of the CMCs declared by United Kingdom in the field of Ionizing Radiation. The file “RI\_GB.xls” (the country is identified by its ISO code) was first imported on 15 September 2003. At that time, it only included CMCs covering Radioactivity only. Another set of CMCs from United Kingdom covering Dosimetry was approved on 01 March 2005. If we had imported this set it would have suppressed the Radioactivity CMCs from the database. So, the new set was inserted in the master file “RI\_GB.xls”, thus turning the previous one to archives. The new file was imported on 11 March 2005.

A look at the file “EM\_RU.xls” indicates that it covers the CMC claims from 5 Russian laboratories, all showing competence in different branches of Electricity and Magnetism.

#### 3.3.4. Building up the file to import

The modules of importation are slightly instable and operate correctly only with very clean EXCEL files. The master EXCEL files, however, generally include information that must not be imported in the databases (notes, dates, review comments, etc.). We thus copy and

paste the active part of the master EXCEL file in a new EXCEL file in order to be sure that no spurious characters may alter the importation.

We take this opportunity to insert html codes for special attributes such as italics, subscripts, superscripts, etc., and also images to replace special characters such as Greek letters. This new file is the one which is imported.

### **3.3.5. Prototype Website**

The Appendix C prototype Website is an access-restricted Website installed on the server kcdb3, which uses the same programming as the production Appendix C Website open to the public.

It returns the data as imported in the Appendix C prototype, and thus makes it possible to check that the importation process has not altered the file. The checking process consists in selecting the appropriate items in the Appendix C search engine in order to return the CMC information, and to read it by comparison with the CMCs file as it was posted in the JCRB Website for formal approval. This work is very time-consuming, but guarantees the quality of the publication.

### **3.4. Publication on the Web**

Importing the EXCEL files into the Appendix C production database launches the data onto the public Web.

The corresponding .pdf files must also be pushed onto the front servers kcdb1 and kcdb2, using a file transfer facility installed on kcdb3.

A last check of the data as returned from the servers kcdb1 and kcdb2, and the insertion of a set of news (see *Figure 5*) end the process: new information is available to the wide public via Internet.

### **3.5. Data saving**

The EXCEL files used in the process of importing data in the database are saved on the KCDB common part of the server si, and the .pdf files are saved on the servers kcdb1, kcdb2, and kcdb3.

## **Conclusions**

The back office put in place for the KCDB Web application is sophisticated, and well adapted to the purpose. Populating the database is facilitated thanks to dedicated tools such as EXCEL macros, the Mini-Word facility, and the modules of importation of EXCEL files.

It remains that the whole process is time-consuming because the information should be checked in order to ensure its conformity with the content of the files formally accepted (final reports of comparisons, files of CMC claims, etc.). Much effort is devoted on the exactness of data, which gives this very special “metrological touch” to the KCDB Website.

The KCDB office is always working towards improving the system, especially the Front Office, in order to give a better access to information. With this in view, we are currently studying the implementation of a commercial semantic “Google-type” search engine, operating with key words freely typed in by the user. Further implementation in the Appendix C Website will necessitate that thesaurus of scientific words used in the CMCs be drawn up in collaboration with experts in each field, and also the development of an appropriate programming for the Web return.

## **References**

[1] CIPM MRA, information available at:

<http://www.bipm.org/en/convention/mra/>

[2] C. Thomas, paper S-11, NMIJ-BIPM Workshop on the impact of Information Technology, Satellite Workshop on Key Comparison Data Evaluation, May 2005.

[3] Nomenclature of key and supplementary comparisons, available at:

<http://www.bipm.org/utls/en/pdf/nomenclature.pdf>

[4] Technical supplement to the CIPM MRA, text available at:

[http://www.bipm.org/utls/en/pdf/mra\\_techsuppl2003.pdf](http://www.bipm.org/utls/en/pdf/mra_techsuppl2003.pdf)

[5] JCRB, information available at:

<http://www.bipm.org/en/committees/jc/jcrb/>

The main BIPM Website and the KCDB Website are available at:

<http://www.bipm.org> and <http://www.bipm.org/kcdb> (or <http://kcdb.bipm.org>) respectively.

The full names of the laboratories cited by their acronyms can be found in the KCDB Appendix A at:

<http://www.bipm.org/utls/en/pdf/signatories.pdf>