

**Bureau International des Poids et Mesures**

**Consultative Committee  
for Mass and  
Related Quantities (CCM)**

8th Meeting (May 2002)

#### Note on the use of the English text

To make its work more widely accessible the International Committee for Weights and Measures publishes an English version of its reports.

Readers should note that the official record is always that of the French text. This must be used when an authoritative reference is required or when there is doubt about the interpretation of the text.

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**MEMBER STATES OF THE METRE CONVENTION AND  
ASSOCIATES OF THE GENERAL CONFERENCE**

as of 23 May 2002

**Member States of the Metre Convention**

Argentina	Korea (Dem. People's Rep. of)
Australia	Korea (Rep. of)
Austria	Malaysia
Belgium	Mexico
Brazil	Netherlands
Bulgaria	New Zealand
Cameroon	Norway
Canada	Pakistan
Chile	Poland
China	Portugal
Czech Republic	Romania
Denmark	Russian Federation
Dominican Republic	Singapore
Egypt	Slovakia
Finland	South Africa
France	Spain
Germany	Sweden
Greece	Switzerland
Hungary	Thailand
India	Turkey
Indonesia	United Kingdom
Iran (Islamic Rep. of)	United States
Ireland	Uruguay
Israel	Venezuela
Italy	Yugoslavia
Japan	

**Associates of the General Conference**

Chinese Taipei	Latvia
Cuba	Lithuania
Ecuador	Malta
Hong Kong, China	

## **THE BIPM AND THE METRE CONVENTION**

The International Bureau of Weights and Measures (BIPM) was set up by the Metre Convention signed in Paris on 20 May 1875 by seventeen States during the final session of the diplomatic Conference of the Metre. This Convention was amended in 1921.

The BIPM has its headquarters near Paris, in the grounds (43 520 m<sup>2</sup>) of the Pavillon de Breteuil (Parc de Saint-Cloud) placed at its disposal by the French Government; its upkeep is financed jointly by the Member States of the Metre Convention.

The task of the BIPM is to ensure worldwide unification of physical measurements; its function is thus to:

- establish fundamental standards and scales for the measurement of the principal physical quantities and maintain the international prototypes;
- carry out comparisons of national and international standards;
- ensure the coordination of corresponding measurement techniques;
- carry out and coordinate measurements of the fundamental physical constants relevant to these activities.

The BIPM operates under the exclusive supervision of the International Committee for Weights and Measures (CIPM) which itself comes under the authority of the General Conference on Weights and Measures (CGPM) and reports to it on the work accomplished by the BIPM.

Delegates from all Member States of the Metre Convention attend the General Conference which, at present, meets every four years. The function of these meetings is to:

- discuss and initiate the arrangements required to ensure the propagation and improvement of the International System of Units (SI), which is the modern form of the metric system;
- confirm the results of new fundamental metrological determinations and various scientific resolutions of international scope;
- take all major decisions concerning the finance, organization and development of the BIPM.

The CIPM has eighteen members each from a different State: at present, it meets every year. The officers of this committee present an annual report on

the administrative and financial position of the BIPM to the Governments of the Member States of the Metre Convention. The principal task of the CIPM is to ensure worldwide uniformity in units of measurement. It does this by direct action or by submitting proposals to the CGPM.

The activities of the BIPM, which in the beginning were limited to measurements of length and mass, and to metrological studies in relation to these quantities, have been extended to standards of measurement of electricity (1927), photometry and radiometry (1937), ionizing radiation (1960), time scales (1988) and to chemistry (2000). To this end the original laboratories, built in 1876-1878, were enlarged in 1929; new buildings were constructed in 1963-1964 for the ionizing radiation laboratories, in 1984 for the laser work, and in 1988 for a library and offices. In 2001 a new building for the workshop, offices and meeting rooms was opened.

Some forty-five physicists and technicians work in the BIPM laboratories. They mainly conduct metrological research, international comparisons of realizations of units and calibrations of standards. An annual report, the *Director's Report on the Activity and Management of the International Bureau of Weights and Measures*, gives details of the work in progress.

Following the extension of the work entrusted to the BIPM in 1927, the CIPM has set up bodies, known as Consultative Committees, whose function is to provide it with information on matters that it refers to them for study and advice. These Consultative Committees, which may form temporary or permanent working groups to study special topics, are responsible for coordinating the international work carried out in their respective fields and for proposing recommendations to the CIPM concerning units.

The Consultative Committees have common regulations (*BIPM Proc.-Verb. Com. Int. Poids et Mesures*, 1963, **31**, 97). They meet at irregular intervals. The president of each Consultative Committee is designated by the CIPM and is normally a member of the CIPM. The members of the Consultative Committees are metrology laboratories and specialized institutes, agreed by the CIPM, which send delegates of their choice. In addition, there are individual members appointed by the CIPM, and a representative of the BIPM (Criteria for membership of Consultative Committees, *BIPM Proc.-Verb. Com. Int. Poids et Mesures*, 1996, **64**, 124). At present, there are ten such committees:

1. the Consultative Committee for Electricity and Magnetism (CCEM), new name given in 1997 to the Consultative Committee for Electricity (CCE) set up in 1927;

2. the Consultative Committee for Photometry and Radiometry (CCPR), new name given in 1971 to the Consultative Committee for Photometry (CCP) set up in 1933 (between 1930 and 1933 the CCE dealt with matters concerning photometry);
3. the Consultative Committee for Thermometry (CCT), set up in 1937;
4. the Consultative Committee for Length (CCL), new name given in 1997 to the Consultative Committee for the Definition of the Metre (CCDM), set up in 1952;
5. the Consultative Committee for Time and Frequency (CCTF), new name given in 1997 to the Consultative Committee for the Definition of the Second (CCDS) set up in 1956;
6. the Consultative Committee for Ionizing Radiation (CCRI), new name given in 1997 to the Consultative Committee for Standards of Ionizing Radiation (CCEMRI) set up in 1958 (in 1969 this committee established four sections: Section I (X- and  $\gamma$ -rays, electrons), Section II (Measurement of radionuclides), Section III (Neutron measurements), Section IV ( $\alpha$ -energy standards); in 1975 this last section was dissolved and Section II was made responsible for its field of activity);
7. the Consultative Committee for Units (CCU), set up in 1964 (this committee replaced the “Commission for the System of Units” set up by the CIPM in 1954);
8. the Consultative Committee for Mass and Related Quantities (CCM), set up in 1980;
9. the Consultative Committee for Amount of Substance: metrology in chemistry (CCQM), set up in 1993;
10. the Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV), set up in 1999.

The proceedings of the General Conference, the CIPM and the Consultative Committees are published by the BIPM in the following series:

- *Report of the meeting of the General Conference on Weights and Measures;*
- *Report of the meeting of the International Committee for Weights and Measures;*
- *Reports of the meetings of Consultative Committees.*

The BIPM also publishes monographs on special metrological subjects and, under the title *The International System of Units (SI)*, a brochure, periodically

updated, in which are collected all the decisions and recommendations concerning units.

The collection of the *Travaux et Mémoires du Bureau International des Poids et Mesures* (22 volumes published between 1881 and 1966) and the *Recueil de Travaux du Bureau International des Poids et Mesures* (11 volumes published between 1966 and 1988) ceased by a decision of the CIPM.

The scientific work of the BIPM is published in the open scientific literature and an annual list of publications appears in the *Director's Report on the Activity and Management of the International Bureau of Weights and Measures*.

Since 1965 *Metrologia*, an international journal published under the auspices of the CIPM, has printed articles dealing with scientific metrology, improvements in methods of measurement, work on standards and units, as well as reports concerning the activities, decisions and recommendations of the various bodies created under the Metre Convention.

## **LIST OF MEMBERS OF THE CONSULTATIVE COMMITTEE FOR MASS AND RELATED QUANTITIES**

as of 23 May 2002

### **President**

Dr M. Tanaka, member of the International Committee for Weights and Measures, National Metrology Institute of Japan, AIST, Tsukuba.

### **Executive Secretary**

Dr R.S. Davis, International Bureau of Weights and Measures [BIPM], Sèvres.

### **Members**

Bureau National de Métrologie, Institut National de Métrologie [BNM-INM], Paris.

Central Office of Measures/Główny Urząd Miar [GUM], Warsaw.

CSIR – National Measurement Laboratory [CSIR-NML], Pretoria.

D.I. Mendeleyev Institute for Metrology [VNIIM], Gosstandart of Russia, St Petersburg.

Istituto di Metrologia G. Colonnetti, Consiglio Nazionale delle Ricerche [IMGC-CNR], Turin.

Korea Research Institute of Standards and Science [KRISS], Daejeon.

National Institute of Metrology [NIM], Beijing.

National Institute of Standards and Technology [NIST], Gaithersburg.

National Measurement Laboratory, CSIRO [NML CSIRO], Lindfield.

National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology [NMIJ/AIST], Tsukuba.

National Physical Laboratory [NPL], Teddington.

National Research Council of Canada [NRC], Ottawa.

Nederlands Meetinstituut, Van Swinden Laboratorium [NMI VSL], Delft.

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

Slovak Institute of Metrology/Slovenský Metrologický Ústav [SMU], Bratislava.

Swedish National Testing and Research Institute [SP], Borås.

Swiss Federal Office of Metrology and Accreditation/Office Fédéral de Métrologie et d'Accréditation [METAS], Bern-Wabern.

The Director of the International Bureau of Weights and Measures [BIPM], Sèvres.

#### **Observers**

Centro Español de Metrología [CEM], Madrid.

Centro Nacional de Metrología [CENAM], Querétaro.

National Metrology Institute of Turkey/Ulusal Metroloji Enstitüsü [UME], Gebze-Kocaeli.

National Physical Laboratory of India [NPLI], New Delhi.

**Consultative Committee  
for Mass and Related Quantities**

**Report of the 8th Meeting**

(23-24 May 2002)

**to the International Committee for Weights and Measures**

## Agenda

- 1 Opening of the meeting; approval of the agenda; appointment of a rapporteur.
- 2 Reports of the working groups on mass and density:
  - 2.1 Mass standards;
  - 2.2 Density.
- 3 Report of the Working Group on Force.
- 4 Reports of the working groups on pressure:
  - 4.1 High pressure;
  - 4.2 Medium pressure;
  - 4.3 Low pressure;
  - 4.4 Joint meeting of the working groups on pressure.
- 5 Report of the Working Group on Gravimetry.
- 6 Report of the Working Group on the Avogadro Constant and progress of other work towards a possible new definition of the kilogram:
  - 6.1 Report of the Working Group on the Avogadro Constant;
  - 6.2 Progress of other work towards a possible new definition of the kilogram.
- 7 Report of the Working Group on Hardness.
- 8 Report of the Working Group on Fluid Flow.
- 9 Report of the *Ad Hoc* Working Group on Viscosity.
- 10 CCM key comparisons:
  - 10.1 Presentation of the database;
  - 10.2 Review of CCM key comparisons;
  - 10.3 Discussion of the document on the formalities required for CCM key comparisons.
- 11 RMO and JCRB activities regarding technical committees in the mass area:
  - 11.1 RMO key comparisons and the status of CMCs;
  - 11.2 Formalization of RMO key comparisons;
  - 11.3 News from the JCRB.

- 12 Work at the BIPM.
- 13 Working group membership and chairpersons:
  - 13.1 Working group membership;
  - 13.2 Changes in chairpersons.
- 14 Other business:
  - 14.1 Proposed websites;
  - 14.2 Special issue of *Metrologia*;
  - 14.3 Issues of transporting transfer standards;
  - 14.4 Date of next meeting.

## **1 OPENING OF THE MEETING; APPROVAL OF THE AGENDA; APPOINTMENT OF A RAPPORTEUR**

The eighth meeting of the Consultative Committee for Mass and Related Quantities (CCM) was held at the International Bureau of Weights and Measures (BIPM), at Sèvres, from 23 to 24 May 2002.

The following were present: A.K. Agarwal (NRC), N. Bignell (NML CSIRO), G. Chapman (NRC), N.G. Domostroeva (VNIIM), H. Durlík (GUM), K. Fujii (NMIJ/AIST), A. Germak (IMGC-CNR), M. Gläser (PTB), A. Gosset (BNM-LNE), J. Hjelmgren (SP), Z.J. Jabbour (NIST, SIM), C. Jacques (NRC), M. Lecollinet (BNM-INM), A. Lee (NIST), W.G. Lee (KRISS), P. Leggat (NPL), J.-C. Legras (BNM-LNE), G. Mattingly (NIST), A.P. Müller (NIST), G. Molinar (IMGC-CNR), A. Ooiwa (NMIJ/AIST), L.R. Pendrill (SP), M. Peters (PTB), T.J. Quinn (Director of the BIPM), P. Richard (METAS), I. Severn (NPL), R. Spurný (SMU), M. Tanaka (President of the CCM, NMIJ/AIST), I. van Andel (NMI VSL), Wang Chi (NIM), Zhang Yue (NIM).

Observers: A.K. Bandyopadhyay (NPLI), L.O. Becerra (CENAM), I. Field (CSIR-NML, SADC MET), I. Hernandez (CENAM), C. Kuzu (UME), M. Matilla Vicente (CEM), M. Patrascioiu (CSIR-NML).

Invited: L. Brito (IPQ), V. Gegevičius (VMT, COOMET), K. Iizuka (NMIJ/AIST), S.M. Lee (SPRING Singapore), V. Loayza (INMETRO), L. Nielsen (DFM, EUROMET), C.M. Sutton (MSL, APMP), M. Takamoto (NMIJ/AIST).

Also present: P. Giacomo (Director emeritus of the BIPM); M.-J. Coarasa, R.S. Davis (Executive Secretary of the CCM), H. Fang, C. Goyon-Taillade, A. Picard, C. Thomas, L. Vitushkin (BIPM).

Excused: W. Bich (IMGC-CNR).

Dr Tanaka, the President of the CCM, opened the meeting. The delegates and other attendees were introduced.

The appointment of Dr Quinn as a Fellow of the Royal Society led the committee to join with Dr Tanaka in issuing the following statement: "All those present at the eighth meeting of the CCM congratulate the BIPM Director, Dr T.J. Quinn, for being named Fellow of the Royal Society. The CCM has greatly benefitted from Dr Quinn's outstanding leadership in

metrology and science. We are therefore delighted, though not surprised, that the Royal Society has bestowed upon him this high honour.”

The agenda was accepted. Dr Severn was designated as rapporteur.

## **2 REPORTS OF THE WORKING GROUPS ON MASS AND DENSITY**

### **2.1 Mass standards**

A meeting of the Working Group on Mass Standards was held on 22 May 2002. In his report to the CCM Dr Gläser, the chairman of the working group, referred to the document CCM/02-05 which gives a review of the activities of the member institutes.

Dr Gläser gave a summary of the research activities currently under way in the member institutes. Investigations into surface contamination and the stability of masses are being carried out as follows: BIPM (ellipsometry), BNM (mirage effect and thermo-desorption mass spectrometry), NIST (a study of the stability of prototype kilograms), NPL (contamination of platinum iridium weights) and SP (time-of-flight secondary ion mass spectroscopy). Surface roughness is under investigation at the BNM-INM as part of EUROMET Project 551 and at the NIM. Susceptometers of the type developed at the BIPM have been used in two different comparisons: one between the BIPM, METAS, SP, the PTB and Mettler-Toledo; and a EUROMET one which was piloted by the PTB. Research into air density measurement is taking place at the BIPM, BNM-INM, NPL, PTB and the SP.

Key comparisons in mass are well advanced: CCM.M-K1 is complete; the draft B report for CCM.M-K2 has been accepted by the participants; the draft A report for CCM.M-K3 is in preparation, as are reports for comparisons CCM.M-K4 and -K5. The working group approved a new periodicity of ten years for key comparisons.

## 2.2 Density

The Working Group on Density met on 21 May 2002. The interim chairman, Dr Fujii, gave a report on the meeting. He referred to document CCM/02-10, which contains a full record of the density-related work carried out in the member institutes.

Five of the participants (IMGC, KRISS, METAS, NMIJ and PTB) in the key comparison CCM.D-K1 have made measurements. The circulation to the NRC and the NIST was delayed owing to technical problems but these measurements, along with those of two additional participants (CEM and CENAM), should be completed before the end of 2003.

The results of EUROMET.M.D-K1 were presented to the working group as well as a summary of the progress of EUROMET Project 627, which is a liquid density regional key comparison (EUROMET.M.D-K2). EUROMET.M.D-K1 will be linked, if technically possible, to CCM.D-K1.

Three more key comparisons were proposed: CCM.D-K2 (liquid density), CCM.D-K3 (density of a stainless steel weight) and CCM.D-K4 (hydrometers). A questionnaire will be sent to potential participants in CCM.D-K2 during 2002 and the comparison will start in 2003. The issue of who should be invited to participate in CCM.D-K2 was discussed. Dr Tanaka stated that officially this questionnaire should be circulated to all CCM members.

A new Standard Mean Ocean Water (SMOW) density table, covering the temperature range 0 °C to 40 °C, has been produced by the Water Density Task Group. Following approval by the working group and the CCM it was published in *Metrologia* in December 2001. The absolute measurement at the PTB of the density of water with known isotopic composition was also presented to the working group. It is anticipated that this work will be completed in the next two years.

There is considerable work in the field of air density. Direct gravimetric measurements by the BIPM, NMIJ, NPL and the PTB using artefacts of the same mass but different volumes exhibit a systematic offset from the CIPM approved formula for the calculation of air density (see section 12, below). Refractive index measurements, closely linked to the measurement of air density, are being made at the BIPM and the SP.

It was agreed that Dr Fujii should be appointed as chairman of the working group following Dr Tanaka's appointment as President of the CCM.

### **3 REPORT OF THE WORKING GROUP ON FORCE**

The Working Group on Force last met on 15-16 October 2001 at the NIST with details of the outcome being given in CCM/02-02. In his presentation to the CCM, Dr Peters, the chairman of the working group, commented that the only subject discussed was that of key comparisons. The key comparisons on force are based on a plan presented to the CCM in 1999. The schedule has changed slightly such that the 4 MN comparison (piloted by the NIST) will start in 2002, the 100 kN comparison (piloted by the NPL) will start in 2003 and the 1 MN comparison (piloted by the PTB) will start in 2004. All of the key comparisons will be completed by 2005.

The next meeting of the Working Group on Force will be held in South Africa in the spring of 2003. Plans for a torque key comparison will be discussed then.

### **4 REPORTS OF THE WORKING GROUPS ON PRESSURE**

#### **4.1 High pressure**

Dr Molinar reported that the Working Group on High Pressure met at the BIPM on 22 May 2002. He made reference to document CCM/02-04 which contains details of activities taking place in the member institutes. Many of these relate to the construction of new standards and mathematical modelling.

Much of the discussion at the working group meeting centred around key comparisons and the discussion of future strategy. Comparisons in the range 1 MPa to 7 MPa (CCM.P-K1.a, -K1.b and -K1.c) had already been approved for equivalence and their results published via the BIPM key comparison database.

EUROMET.M.P-K2 (measurements up to 4 MPa) has been linked to CCM.P-K1.c, reviewed and the data entered into the BIPM key comparison database. The EUROMET key comparison EUROMET.M.P-K3 has been divided into two parts: EUROMET.M.P-K3.a (up to 1 MPa) piloted by BNM-LNE and EUROMET.M.P-K3.b (up to 7 MPa) piloted by the NPL.

The measurements are complete for these comparisons and the reports are in preparation.

APMP-IC-2-97, which consists of one comparison up to 105 kPa and a second up to 4 MPa, has been reviewed and will be defined as two regional metrology organization (RMO) key comparisons: APMP.M.P-K6 (up to 105 kPa) and APMP.M.P-K1.c (up to 4 MPa). The pilot laboratory (NPLI) will prepare a report indicating the degrees of equivalence and linking the results to CCM.P-K6 and -K1.c.

CCM.P-K7, a high-pressure key comparison from 10 MPa to 100 MPa will start shortly. The PTB will pilot the comparison with results anticipated before the next CCM meeting. The completed EUROMET.M.P-K4 will link to this comparison as will SIM.M.P-K7.

A bilateral comparison between the PTB and the CENAM up to 100 MPa will be included on the BIPM key comparison database and designated SIM-EUROMET.M.P-BK4. Similarly, a trilateral comparison in the range 40 MPa to 200 MPa will be considered as a key comparison with the data to be sent for inclusion on the KCDB as soon as possible.

There are many older comparisons above 100 MPa. The results of these will be linked by the BNM-LNE, which will produce a summary of equivalence. The combined results will be considered to be CCM.P-K8. This comparison will not be repeated until after 2008.

It was agreed that Mr Legras of the BNM-LNE would become the new chairman of the Working Group on High Pressure due to the imminent retirement of Dr Molinar.

## **4.2 Medium pressure**

The interim chairperson, Mrs Leggat of the NPL, reported on the working group meeting that was held on 21 May 2002. Reference was made to document CCM-02/06. The working group meeting was dominated by discussion of key comparisons.

The NPL is piloting comparisons CCM.P-K6 and -K2 for gauge and absolute mode measurements, respectively, both covering the range 10 kPa to 120 kPa. Results from the final participant were received only two days prior to the working group meeting but a confidential presentation of results was made to the participants. It is clear from the results that there have been problems with the transfer standard, both in terms of its stability and observed differences between gauge and absolute mode operation. The NPL

sees similar problems with identical standards that have been bought since the comparison began and it was concluded that the transfer standard was probably inappropriate for a comparison of this type. It was decided that the comparison would not be repeated for several years.

It was agreed that Mrs Leggat should be appointed as the working group chairperson following the retirement of Mr Simpson.

#### 4.3 Low pressure

The Working Group on Low Pressure met on 21 May 2002. The interim chairman, Dr Miiller of the NIST, gave a summary of the meeting. Most of the activities of this working group have revolved around three key comparisons: CCM.P-K3, -K4 and -K5, all of which have been piloted by the NIST. Comparisons CCM.P-K4 (1 Pa to 1000 Pa absolute mode) and CCM.P-K5 (1 Pa to 1000 Pa differential mode) have been completed and the results published in the *Metrologia Technical Supplement*. These two comparisons used the same transfer standards, a combination of silicon resonance sensors and capacitance diaphragm gauges. In order to complete the comparison in eighteen months two nominally identical transfer standards were circulated, with one package going to Asia and the other to Europe. The transfer standards performed much better than those used in previous comparisons and have proved to be most robust. The comparisons looked at two principal measurement techniques and did not observe any relevant bias. Only one national metrology institute (NMI) submitted results that are considered to be outliers. Dr Quinn observed that the key comparisons had produced better results than anticipated. Dr Molinar commented that previous problems have arisen as a result of the pilot laboratory not using multiple devices and that the whole working group appreciated the hard work done by the NIST in producing the multi-sensor transfer standard.

The measurements for CCM.P-K3 ( $3 \times 10^{-6}$  Pa to  $9 \times 10^{-3}$  Pa) have been completed and a draft A report is in preparation. Two spinning rotor gauges and three ionization gauges have been used as transfer standards in this comparison. Unfortunately two of the three ionization gauges failed during the period of the comparison, but it is still possible to analyse the equivalence of the laboratories that took part.

There are several regional comparisons either under way or being planned that will link to the key comparisons. Comparison EUROMET.M.P-K1.a will link to CCM.P-K4 via the IMGC and the PTB while EUROMET.M.P-K1.b will link to CCM.P-K3 and -K4 via the same route. The APMP is planning a

comparison (APMP.M.P-K4) in the same range as CCM.P-K4 that will link to the CCM comparison via the KRISS and the NPLI. The measurements in a bilateral comparison between the CENAM and the PTB (SIM-EUROMET.M.P-BK3) will be completed before the end of August 2002.

Some consideration was given to the frequency with which comparisons should be repeated. It was decided that one low-pressure comparison every nine years is sufficient to demonstrate equivalence. A repeat of CCM.P-K9 ( $10^{-4}$  Pa to 1 Pa) may be proposed at the next CCM meeting.

It was agreed that Dr Miiller would become the new working group chairman following the retirement of Dr Tilford.

#### **4.4 Joint meeting of working groups on pressure**

Dr Molinar reported on the joint meeting of working groups on pressure, a meeting of which was held on 22 May 2002 at the BIPM. This meeting concentrated on coordinating the timetabling of key comparisons in the pressure field. It was decided that no more than one CCM pressure comparison would take place in a three-year period with the working group accepting that once degrees of equivalence of measurement standards are established over their operating ranges, they need only be checked periodically at a number of limited points. The existence of a robust quality system should be sufficient proof of continued equivalence over their full range. The importance of dialogue with RMOs to ensure a coherent timetable and links was discussed. It was decided that priority in the next three years would be given to the high-pressure comparison CCM.P-K7.

It was agreed that the next CCM Pressure Conference should take place in 2005. The NPL provisionally agreed to stage the event, provided that the U.K. Institute of Physics agrees to cooperate in its organization.

Two pressure-related conferences have been organized in 2003. The European Vacuum Congress, organized by the PTB and the German Vacuum Society, will take place during 23-26 June, while the IMEKO TC16 International Symposium, organized in association with the Chinese Society of Measurement, will take place in Beijing over the period 19-22 May.

## 5 REPORT OF THE WORKING GROUP ON GRAVIMETRY

The Working Group on Gravimetry was established by the CIPM in October 2001. It consists of fifteen members. Its chairman, Dr Vitushkin, reported on the activities of this new working group.

A comparison of absolute gravimeters (ICAG-2001), involving seventeen instruments from twelve countries, was held at the BIPM between June and August 2001. The links between the sites of the BIPM gravity network were compared using both absolute and relative gravimeters. This has allowed an investigation into different methods of data processing. The results have been analysed by a steering committee and a report is available on the BIPM website. A further paper is in preparation for submission to a special issue of *Metrologia* on gravimetry.

A workshop entitled “Instrumentation and Metrology in Gravimetry – IMG-2002” will be held at the European Centre for Geodynamics and Seismology in Luxembourg.

Future activities of the working group will include discussion of data processing to be used in comparisons, development of comparison protocols in conjunction with the International Gravity and Geoid Commission (IGGC) Working Groups, and a comparison of gravimeters on selected sites in different continents.

Dr Chapman questioned whether the Gal is a valid SI unit. Dr Quinn replied that it is not; however, we must accept the fact that the gravimetry community routinely use  $\mu\text{Gal}$  as a measurement unit.

Dr Tanaka asked whether key comparisons are open to non-NMIs. Dr Quinn responded by stating that for historical reasons NMIs do not tend to maintain gravimetric standards. In order to bring the measurements of this quantity into the Mutual Recognition Arrangement (MRA) it is necessary for the NMIs to designate an appropriate national institute for gravimetry. He also emphasized the importance of gravimetry to the watt-balance experiments for redefinition of the kilogram.

## **6 REPORT OF THE WORKING GROUP ON THE AVOGADRO CONSTANT AND PROGRESS OF OTHER WORK TOWARDS A POSSIBLE NEW DEFINITION OF THE KILOGRAM**

### **6.1 Report of the Working Group on the Avogadro Constant**

Dr Fujii presented a report (CCM/2002-13) that was prepared by Dr Becker, the chairman of the Working Group on the Avogadro Constant. A review of the status of the project was given and the technical issues faced by the participants outlined.

At the CIPM in October 2001 the necessity for better international coordination of the Avogadro project was discussed following a proposal from Dr Inglis. The new coordination concept was approved at the working group meeting in November 2001 prior to presentation to the meeting of directors of the NMIs in April 2002. Support for the proposal was agreed in principle but a more detailed research project plan is necessary to obtain final approval. The research plan will be discussed at the Working Group on the Avogadro Constant meeting to be held in June 2002. The coordination scheme will be discussed by the CIPM in October 2002.

### **6.2 Progress of other work towards a possible new definition of the kilogram**

Dr Richard presented a summary (CCM/2002-15) of other work towards a possible new definition of the kilogram.

#### **6.2.1 Voltage balance**

Work on the voltage balance at the FER (previously ETF, University of Zagreb) ceased in 2000, following a reduction and delay in funds and the death of Prof. Bego.

#### **6.2.2 Magnetic levitation**

A superconducting magnetic levitation project has been started at the MIKES in conjunction with the VNIIM and the VTT. A study into the materials used in the coil and levitating body has begun while a draft design has been produced and an interferometer is under construction.

The magnetic levitation experiment at the NMIJ expects to achieve electrical energy determination at the  $10^{-6}$  level and the mechanical energy determination may be achieved with this uncertainty by better position control of the float. A presentation of the work will be made at the CPEM in June 2002. There has been a significant reduction in the budget and number of staff able to work on this project.

#### 6.2.3 Ion accumulation

The PTB ion accumulation experiment has produced results with a relative uncertainty of 1.5 % and a deviation from previous data of 0.6 %. At the end of 2002 the experiment will switch from a gold ion source to a bismuth source in order to increase the ion current from its present level of 0.1 mA to 10 mA. This will lead to a considerable improvement in the measurement uncertainty.

#### 6.2.4 Watt balance

- NPL: The NPL apparatus is operating with a typical relative standard deviation of 3 parts in  $10^8$ . It has produced preliminary data on Planck's constant for presentation at the CPEM 2002.
- NIST: The NIST watt balance has been rebuilt in an isolated and shielded building with a fibreglass vacuum chamber. The coils and balance have been renewed with the exception of the wheel. It is expected that these modifications will produce greatly reduced uncertainties.
- METAS: The ratio of the mechanical watt and the electrical watt has been measured at 50 g and 100 g. The results will be presented at the CPEM 2002.
- BNM: A specification has been produced for this project, which was started in 2000. It is a collaboration between four BNM laboratories (INM/CNAM, LAMA, LNE and SYRTE/OP) all of which will be responsible for the features of the experiment that fall within their areas of expertise. The balance will utilize a 500 g test mass.

## **7 REPORT OF THE WORKING GROUP ON HARDNESS**

Dr Germak, chairman of the Working Group on Hardness, presented a summary of the group's activities. The last meeting was held in Turin in September 2001 so that it coincided with meetings of ISO TC164/SC3 and IMEKO TC5. The discussion centred on three main issues: comparisons, a common definition of Rockwell hardness scales in NMIs and the determination of uncertainty in hardness measurements.

The PTB is piloting CCM.H-K1 (comparison of Vickers hardness scales) in which ten laboratories are participating in the measurement of hardness on three hardness blocks. Temporary unavailability of some of the machines has delayed the comparison.

A supplementary comparison (CCM.H-S1.a... f), piloted by the MPA-NRW of Germany, will compare Rockwell hardness scales using a conical indenter. Results from seven of the ten participants agreed to within  $\pm 0.3$  Rockwell C Scale Hardness (HRC) when a common indenter was used, but only four of the participants obtained agreement to this level when using their own indenters. A draft B report will be issued in the summer of 2002.

The IMGC has been carrying out a study on Rockwell hardness with the aim of developing a procedure for the qualification of primary indenters. Geometrical characterization and performance comparisons of indenters have been performed with this in mind.

The NMIJ and the KRISS have proposed a joint pilot study on Martens hardness. A programme of work and a protocol will be prepared before the end of 2002.

A key comparison of Brinell hardness standards will commence in 2003 (CCM.H-K2). At the start of the comparison a survey of NMIs will be carried out to determine the range of measurements in which they are interested.

The new guidelines for the estimation of uncertainty in hardness measurement, EA10/16, were presented to the working group meeting. It will be used as a basis for calculations in future comparisons.

## **8 REPORT OF THE WORKING GROUP ON FLUID FLOW**

The chairman of the Working Group on Fluid Flow (WGFF), Dr Mattingly, presented a summary of WGFF plans approved at the third WGFF meeting held in April 2002. This working group, which was set up less than three years ago, has established a set of six specialist sub-groups to address six different measurement areas. The chairman of each sub-group (from the “initiating” laboratory), along with two assisting laboratories, is responsible for the organization of a key comparison in the metrology area for which the sub-group has responsibility. The three laboratories involved in organizing each comparison are from different RMOs (this is because interest in participating in these flow programmes comes essentially from members of the APMP, EUROMET and the SIM; provision has nevertheless been made to include NMIs from other regions) and have the additional responsibility of organizing the comparison in their own region, with specific transfer standards and test conditions. The prototype transfer standard is produced and evaluated in the initiating laboratory. Once the transfer standard is shown to be suitable, as judged by the WGFF Steering Committee (composed of the chairpersons of the sub-group, the RMO technical committees and the WGFF) this transfer standard is tested in the two assisting laboratories. Once the multi-laboratory tests have shown the transfer standard to be suitable, as judged by the WGFF Steering Committee, one to three clones are produced. These clones are then circulated in a timely manner by the initiating laboratory (which now becomes the pilot laboratory for the key comparison) and the two assisting laboratories (now the “pivot” laboratories) in parallel around the three RMOs. The resulting data sets are intended to produce an optimal basis for comparability of all the participating NMIs in all the RMOs.

Dr Iizuka pointed out that it is essential that the RMOs are consulted and that their views are taken into account. Dr Mattingly confirmed that this has been done through the three WGFF meetings to date and through the circulation of the minutes from these meetings.

Dr Tanaka questioned whether it was possible to carry out a comparison of all RMOs in eighteen months. Dr Mattingly stated that it should be possible, using the original and cloned transfer standards in testing schedules closely monitored by the pilot laboratory.

## **9 REPORT OF THE *AD HOC* WORKING GROUP ON VISCOSITY**

Dr Davis, the Executive Secretary of the *Ad Hoc* Working Group on Viscosity (AHWGV) gave a brief description of the relationship between this group and the CCM. The issue of whether the activities of the working group should come under the auspices of the CCM was discussed. It was agreed that the CIPM must take clear and decisive action to decide the future of this activity at its meeting in October 2002.

A series of five viscosity key comparisons (CCM.V-K1.A, -K1.B1, -K1.B2, -K1.B3, -K1.C) piloted by the PTB is in progress. The AHWGV will discuss future CMCs in viscosity after this comparison has been concluded.

## **10 CCM KEY COMPARISONS**

### **10.1 Presentation of the database**

Dr Thomas gave a demonstration of the BIPM key comparison database (KCDB). The KCDB was introduced onto the BIPM website in November 1999. Prior to the meeting there were four hundred and nine comparisons on the database with seventy-seven of these relating to mass and derived quantities. Provisionally viscosity has been included in the mass area.

Appendix B of the database, which relates to results and information about each comparison, is being redesigned to make it easier to add comments. Dr Thomas pointed out that the contact person for each comparison should check the database regularly to make sure it is up to date. The results of a comparison go onto the database once they have been approved by the CCM. It is helpful if the results are sent to the BIPM in the form of an Excel spreadsheet along with any graphs. Dr Sutton asked whether there is a template available for submission of results. Dr Thomas confirmed that there are several.

Comparison results are no longer published in *Metrologia* unless they are of significant scientific interest, rather they are published in the *Metrologia Technical Supplement*. Once the results of a comparison arrive at the BIPM

for entry in the KCDB, *Metrologia* contacts the pilot laboratory to facilitate the publication of the report in the *Technical Supplement*.

## **10.2 Review of CCM key comparisons**

The details of specific key comparisons both proposed or in progress were discussed as part of the working group reports. However, there was discussion of some general principles associated with them.

The issue of RMO key comparisons being completed prior to the CCM key comparison was raised. There are several examples in the pressure field where there are completed EUROMET comparisons but no completed CCM activity. Dr Gläser commented that there should be no problem linking such comparisons to the CCM comparison when it is complete if the timescale is acceptable. Dr Quinn suggested that the reports relating to the regional comparisons could go on the database. This was agreed but Dr Thomas pointed out that it is only possible to calculate equivalence once the CCM key comparison has been finished.

## **10.3 Discussion of the document on the formalities required for CCM key comparisons**

The content of document CCM/2002-11 drawn up by the CCM working group chairpersons in October 2000 for the formalization of key comparison requirements was discussed. Several changes were agreed.

Dr Sutton commented that he felt there had been examples when laboratories with anomalous results in comparisons had not been given their full rights by pilot laboratories. Dr Gläser questioned whether it is necessary for all working group members to approve the draft B report. Dr Davis responded by saying that the working group is effectively the peer review process for publication in the *Metrologia Technical Supplement*. Dr Quinn commented that all members do not have to approve the draft B report. Agreement by consensus is acceptable so that one working group member cannot block the publication of a comparison.

## **11 RMO AND JCRB ACTIVITIES REGARDING TECHNICAL COMMITTEES IN THE MASS AREA**

### **11.1 RMO key comparisons and the status of CMCs**

Dr Thomas gave an overview of the contents of the BIPM key comparison database. In Appendix B, EUROMET has nineteen declared comparisons (including three supplementary comparisons). Prior to the CCM meeting there were no APMP, COOMET or SIM comparisons in Appendix B. However, this situation is expected to change shortly (refer to the KCDB for latest information). SADC MET.M.M-K5 has been declared, but unfortunately most participants are not members of the Metre Convention.

The importance of links between RMO key comparisons and the CCM comparisons was emphasized. Comparison EUROMET.M.P-K2, which is linked to CCM.P-K1.c, is at present the only example of this in mass-related metrology.

Dr Thomas then spoke about the status of CMC tables in Appendix C of the database. CMCs are only entered on the database after the JCRB's approval. In mass-related metrology only CMCs from the APMP have been entered on the database (refer to the KCDB for latest information).

#### **11.1.1 APMP activities**

Dr Sutton outlined comparison activities in the APMP region. A 1 kg comparison APMP.M.M-K1 has fifteen participants while two other mass comparisons are at the planning stage and will link to CCM.M-K2 and -K5. The NPLI is piloting a 1000 Pa absolute-mode comparison which will link to CCM.P-K4. The NMIJ is organizing a 100 MPa gauge-mode comparison linked to CCM.P-K7.

At the time of the meeting seven countries had CMC tables published in Appendix C of the database. In addition to these those from Japan and Malaysia had just been accepted. Chinese Taipei and Thailand had now submitted CMC tables to the APMP for review.

#### **11.1.2 COOMET activities**

Mr Gegevičius gave a summary of COOMET activities. Five members of COOMET have not yet signed the MRA. Three of these will do so in 2002 while the remaining two will sign it in 2003. Four COOMET members

(Bulgaria, Germany, Lithuania and Slovakia) have or will submit their CMCs through EUROMET rather than COOMET. The status of the CMC tables of member countries is shown on the COOMET website.

A recent structural change in COOMET has seen the establishment of committees for measurement standards, legal metrology, quality and training.

Three pressure comparisons are in progress and a new 1 kg mass comparison will begin in 2002. There are plans for comparisons in the submultiples of the kilogram and of force standards.

#### 11.1.3 SADC MET activities

SADC MET has twelve full-member countries and six affiliate members. Most of these countries are not signatories of the Metre Convention. Mrs Field outlined the current activities of SADC MET. A mass comparison SADC MET.M.M-K5) equivalent to CCM.M-K5 is under way. The PTB is cooperating in the provision of mass metrology training for all member countries.

#### 11.1.4 EUROMET activities

Dr Nielsen reported on EUROMET activities, many of which have been related to RMO key comparisons and CMC tables. There is comparison activity in virtually every mass-related field, including some in which there has not yet been a CCM key comparison.

Dr Nielsen outlined some of the difficulties that have been faced in the review of EUROMET CMC tables. The main problems were identified as harmonization between RMOs being too late, delays in inter-regional reviews, differences in the interpretation of acceptance criteria in the absence of key comparisons and laboratories claiming smaller uncertainties than had been achieved in key comparisons. Dr Quinn confirmed this last point by commenting that some examples had been seen where CMC uncertainties were five times smaller than those quoted in key comparisons. Dr Nielsen raised the suspicion that in some cases laboratories look at how close their comparison result is to the reference value and revise their uncertainty budget to produce a smaller number that is still equivalent. Dr Gläser expressed the view, which Dr Quinn supported, that if there has been a key comparison the corresponding CMC table entries should not be lower than the uncertainties quoted by that NMI in the comparison and they should be consistent with the results of the comparison.

There have been some problems in the acceptance of EUROMET force CMCs by the APMP owing to some entries having lower uncertainties than that which the APMP experts believe to be state-of-the-art. Mr Gosset commented that the force CMCs relate to the uncertainty in generated force, not the force measured by an instrument. Dr Nielsen responded by saying that in all other areas EUROMET had agreed that the CMC entries would include a contribution for the performance of the device under test (taken to be the best device presently on the market). Dr Quinn supported this policy. Mr Gosset reminded the committee that comparison results and uncertainties are limited by the performance of the transfer standard and that if the pilot laboratory is not able to achieve state-of-the-art uncertainties, the best possible uncertainty cannot be attained. Dr Sutton said that CCM experts should offer guidance on what is the best attainable uncertainty in a particular field.

#### 11.1.5 SIM activities

Dr Zabbour presented an overview of SIM comparison activities and then reviewed the status of the SIM CMC submission.

There are four mass comparisons under way, including three bilateral comparisons in the range 200 mg to 2 kg where CCM members are being used to provide the link to reference values. Five force comparisons are in progress. There are RMO key comparisons in the pressure and vacuum field as well as several ongoing supplementary and bilateral comparisons. The NIST will pilot a high-pressure regional key comparison to support CCM.P-K11 while a solid density comparison using stainless steel 1 kg weights as standards is also planned.

The SIM CMC tables were initially submitted in May 2001. They were resubmitted in the week prior to the CCM meeting (see KCDB).

#### 11.2 Formalization of RMO key comparisons

Dr Samuel, Executive Secretary of the JCRB, gave a presentation of the JCRB pages on the BIPM website. There is publicly available material relating to the modification of CMC tables. RMO technical committees have access to password-controlled pages that show JCRB committee details. A third set of pages offers members of the JCRB access to working documents. It is intended that these pages should improve the efficiency of CMC table review.

Dr Thomas reminded the delegates that RMO key comparisons may only be entered into the database once they have received approval from the appropriate CCM working group. Dr Quinn said that the reason for this is to ensure future linkage of comparisons.

### **11.3 News from the JCRB**

Dr Quinn gave a brief overview of JCRB activities. A report summarizing the last meeting is available on the BIPM website. The members of the JCRB were in favour of calibration certificates containing a reference to the MRA and CMCs. A initial draft of this was produced in English with a French version that is more explicit in its wording being provided in collaboration with Dr Énard of the BNM. A more detailed English version has now been produced to correspond to the French version.

The initial period of operation of the MRA will end in October 2003 at the time of the twenty-second CGPM. NMIs whose quality systems do not meet the requirements of the MRA may have their CMC tables deleted. Dr Peters commented that he felt that parts of the associated document, JCRB-8/13(1), are not consistent with self-declaration of quality systems. Dr Lee also expressed some reservations. Dr Quinn stated that this was not the intent of the document.

## **12 WORK AT THE BIPM**

Dr Davis gave a summary of work in the Mass section of the BIPM. Fourteen national prototypes of the kilogram have been returned to the BIPM for calibration since the third verification. The BIPM mass standards have also been maintained. As the time since the third verification increases, so does the uncertainty in the 1 kg standards. At present the uncertainty in the BIPM standards is approximately 4 µg. Dr Davis emphasized the variability in the mass increase of prototypes following cleaning and illustrated the fact that it is dubious to base the mass gain profile of a particular standard on that of the average data without having supporting evidence.

The BIPM and the PTB have been carrying out joint research into the direct measurement of air density using artefacts. It appears that there is a

systematic offset from the CIPM equation of 1981 and 1991 which is of the order 1 part in  $10^4$ . One possibility is that the accepted amount concentration of argon in the atmosphere might be in error. A modern value for this parameter is being sought. The CCQM may assist in this work as part of a pilot study that is measuring the amount of carbon dioxide mixed with nitrogen and argon. Dr Davis asked for and received the support of the CCM in pursuing this matter with the appropriate CCQM working group.

A new hydrostatic weighing apparatus, designed and built by Dr Spurný, has been installed at the BIPM. The long-term standard deviation of the apparatus is approximately  $2 \times 10^{-6}$  when using distilled water as the reference standard of density.

There has also been further work with the BIPM susceptometer and a quality system has been introduced.

## **13 WORKING GROUP MEMBERSHIP AND CHAIRPERSONS**

### **13.1 Working group membership**

Working group membership was discussed with many laboratories having applied for membership. The Directory of Consultative Committees, available on demand from the BIPM and on the BIPM website, contains a list of members.

### **13.2 Changes in chairpersons**

Dr Tilford, chairman of the Working Group on Low Pressure, and Mr Simpson, chairman of the Working Group on Medium Pressure, have retired and resigned from their CCM roles. Colleagues from the NIST and the NPL were asked to convey the CCM's best regards to them and to thank them for their contributions. Dr Miiller was appointed chairman of the Working Group on Low Pressure while Mrs Leggat was appointed chair of the Working Group on Medium Pressure. Dr Molinar also announced his resignation as chairman of the Working Group on High Pressure due to his imminent retirement. The CCM thanked him for his scientific contribution to pressure metrology, his broad-minded outlook and his contribution to the Joint Working Group on Pressure. Mr Legras was appointed as Dr Molinar's

successor. Dr Fujii replaced Dr Tanaka as chairman of the Working Group on Density following Dr Tanaka's appointment as President of the CCM.

## **14 OTHER BUSINESS**

### **14.1 Proposed websites**

Dr Picard has created a website for the Working Group on the Avogadro Constant. This makes for better coordination and more effective administration. It was proposed by Dr Wallard that the BIPM could create a site for the CCM and its working groups. First it will be necessary to define the needs of such a site. After this, the BIPM will undertake to organize and maintain it.

### **14.2 Special issue of *Metrologia***

A special issue of *Metrologia* relating to "Mass and Density" will possibly be published in 2003.

### **14.3 Issues of transporting transfer standards**

Dr Gläser raised the issue of the problems of transporting transfer standards by air. Increased security, particularly in the United States, means that security personnel systematically control transfer standards prior to air transportation but this sometimes involves rough handling. It was agreed that each working group chair should nominate one person to work with Dr Gläser in trying to solve this problem.

### **14.4 Date of next meeting**

The next CCM meeting will held in May 2005. It is anticipated that the next working group chairpersons' meeting will take place in November 2003.

I. Severn, Rapporteur  
revised November 2002

**APPENDIX M 1.****Working documents submitted to the CCM at its 8th meeting**

(see the list of documents on page 43)

## LIST OF ACRONYMS USED IN THE PRESENT VOLUME

### 1 Acronyms for laboratories, committees and conferences

AHWGV	<i>Ad Hoc</i> Working Group on Viscosity
AIST*	National Institute of Advanced Industrial Science and Technology, see NMIJ/AIST
APMP	Asia/Pacific Metrology Programme
BIPM	International Bureau of Weights and Measures/Bureau International des Poids et Mesures
BNM	Bureau National de Métrologie, Paris (France)
BNM-CNAM	Bureau National de Métrologie, Conservatoire National des Arts et Métiers, Paris (France)
BNM-INM	Bureau National de Métrologie, Institut National de Métrologie, Paris (France)
BNM-LNE/LAMA	Bureau National de Métrologie, Laboratoire National d'Essais, Laboratoire André-Marie Ampère, Paris (France)
BNM-SYRTE	Bureau National de Métrologie, Systèmes de Référence Temps Espace, Paris (France)
CCM	Consultative Committee for Mass and Related Quantities/Comité Consultatif pour la Masse et les Grandeurs Apparentées
CCQM	Consultative Committee for Amount of Substance: metrology in chemistry/Comité Consultatif pour la Quantité de Matière: métrologie en chimie
CEM	Centro Español de Metrología, Madrid (Spain)
CENAM	Centro Nacional de Metrología, Mexico (Mexico)
CGPM	General Conference on Weights and Measures/Conférence Générale des Poids et Mesures
CIPM	International Committee for Weights and Measures/Comité International des Poids et Mesures
CNAM	Conservatoire National des Arts et Métiers, Paris (France), see BNM-CNAM

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\* Organizations marked with an asterisk either no longer exist or operate under a different acronym.

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COOMET	Cooperation in Metrology among the Central European Countries
CPEM	Conference on Precision Electromagnetic Measurements
CSIR-NML	Council for Scientific and Industrial Research, National Metrology Laboratory, Pretoria (South Africa)
CSIRO*	see NML CSIRO
DFM	Danish Institute of Fundamental Metrology, Lyngby (Denmark)
ETF*	Elektrotehnicki Fakultet/Faculty of Electrical Engineering, Zagreb (Croatia), see FER
EUROMET	European Collaboration in Measurement Standards
FER	(formerly the ETF) Fakultet Elektrotehnike i Računarstva/Faculty of Electrical Engineering and Computing, University of Zagreb, Zagreb (Croatia)
GUM	Główny Urząd Miar/Central Office of Measures, Warsaw (Poland)
ICAG	International Conference of Absolute Gravimeters
IGGC	International Gravity and Geoid Commission
IMEKO	International Measurement Confederation
IMG	Instrumentation and Metrology in Gravimetry
IMGC	Istituto di Metrologia G. Colonnetti, Turin (Italy)
IMGC-CNR	Istituto di Metrologia G. Colonnetti, Consiglio Nazionale delle Ricerche, Turin (Italy)
INM*	Institut National de Métrologie, Paris (France), see BNM-INM
INMETRO	Instituto Nacional de Metrologia, Normalização e Qualidade Industrial, Rio de Janeiro (Brazil)
IPQ	Instituto Português da Qualidade, Lisbon (Portugal)
ISO	International Organization for Standardization
JCRB	Joint Committee of the Regional Metrology Organizations and the BIPM
KRISS	Korea Research Institute of Standards and Science, Taejeon (Rep. of Korea)
LAMA	Laboratoire André-Marie Ampère, see BNM-LNE/LAMA
LNE*	Laboratoire National d'Essais, Paris (France), see BNM-LNE

METAS	(formerly the OFMET) Office Fédéral de Métrologie et d'Accréditation, Wabern (Switzerland)
MIKES	Mittatekniikan Keskus/Centre for Metrology and Accreditation, Helsinki (Finland)
MPA-NRW	Materialprüfungsamt Nordrhein-Westfalen, Dortmund (Germany)
MRA	Mutual Recognition Arrangement
MSL	Measurement Standards Laboratory of New Zealand, Lower Hutt (New Zealand)
NIM	National Institute of Metrology, Beijing (China)
NIST	National Institute of Standards and Technology, Gaithersburg (United States)
NMI	National Metrology Institute
NMIJ/AIST	National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology, Tsukuba (Japan)
NMi VSL	Nederlands Meetinstituut, Van Swinden Laboratorium, Delft (The Netherlands)
NML CSIRO	National Measurement Laboratory, CSIRO, Lindfield (Australia)
NPL	National Physical Laboratory, Teddington (United Kingdom)
NPLI	National Physical Laboratory of India, New Delhi (India)
NRC	National Research Council of Canada, Ottawa (Canada)
NRLM*	National Research Laboratory of Metrology, Tsukuba (Japan), see NMIJ/AIST
OFMET*	Office Fédéral de Métrologie/Eidgenössisches Amt für Messwesen, Wabern (Switzerland), see METAS
OP	Observatoire de Paris, Paris (France)
PSB*	Singapore Productivity and Standards Board, Singapore (Singapore), see SPRING
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig and Berlin (Germany)
RMO	Regional Metrology Organization
SADCMET	Southern African Development Community Cooperation in Measurement Traceability
SIM	Sistema Interamericano de Metrología

SMU	Slovenský Metrologický Ústav/Slovak Institute of Metrology, Bratislava (Slovakia)
SP	Sveriges Provnings- och Forskningsinstitut/Swedish National Testing and Research Institute, Borås (Sweden)
SPRING	(formerly the PSB) Standards, Productivity and Innovation Board, Singapore (Singapore)
SYRTE*	Systèmes de Référence Temps Espace, see BNM-SYRTE
UME	Ulusal Metroloji Enstitüsü/National Metrology Institute, Marmara Research Centre, Gebze-Kocaeli (Turkey)
VMT	State Metrology Service, Vilnius Metrology Center, Vilnius (Lithuania)
VNIIM	D.I. Mendeleyev Institute for Metrology of Gosstandart of Russia, St Petersburg (Russian Fed.)
VSL*	Van Swinden Laboratorium, Delft (The Netherlands), see NMI VSL
VTT	Centre for Metrology and Accreditation, Technical Research Centre of Finland, Espoo (Finland)
WGFF	CCM Working Group on Fluid Flow

## 2 Acronyms for scientific terms

CMC	Calibration and Measurement Capabilities
HRC	Rockwell C Scale Hardness
KCDB	BIPM Key Comparison Database
SI	International System of Units
SMOW	Standard Mean Ocean Water