

Bureau International des Poids et Mesures

Director's Report on the Activity and Management of the International Bureau of Weights and Measures

(1 July 2006 – 30 June 2007)

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 these 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 AND ASSOCIATES OF THE GENERAL CONFERENCE

as of 30 June 2007

Member States

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	Serbia and Montenegro
Egypt	Singapore
Finland	Slovakia
France	South Africa
Germany	Spain
Greece	Sweden
Hungary	Switzerland
India	Thailand
Indonesia	Turkey
Iran (Islamic Rep. of)	United Kingdom
Ireland	United States
Israel	Uruguay
Italy	Venezuela
Japan	

Associates of the General Conference

Belarus	Kenya
CARICOM	Latvia
Chinese Taipei	Lithuania
Costa Rica	Macedonia (the FYR of)
Croatia	Malta
Cuba	Moldova
Ecuador	Panama
Estonia	Philippines
Hong Kong, China	Slovenia
Jamaica	Ukraine
Kazakhstan	Viet Nam

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 m²) 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.

The task of the BIPM is to ensure worldwide unification of 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 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. 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 (CEM), 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 γ -rays, electrons), Section II (Measurement of radionuclides), Section III (Neutron measurements), Section IV (α -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 and the CIPM 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.*

The CIPM decided in 2003 that the reports of meetings of the Consultative Committees should no longer be printed, but would be placed on the BIPM website, in their original language.

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.

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INTERNATIONAL BUREAU OF WEIGHTS AND MEASURES**

on 30 June 2007

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1 Head of special projects.

2 Also Publications.

3 Also site maintenance.

Director's Report
on the Activity and Management
of the International Bureau
of Weights and Measures
(1 July 2006 – 30 June 2007)

1 INTRODUCTION

1.1 General introduction and summary of scientific work

The BIPM has had an eventful year. We have made significant progress in a number of scientific projects to improve and enhance our international reference facilities and the provision of services such as International Atomic Time (TAI). At the same time, there have been a large number of meetings of Consultative Committees (CCs), working groups and workshops. We have maintained our liaison with intergovernmental organizations and international bodies and have consolidated a number of joint activities, notably with the aim of increasing awareness and appreciation of the International System of Units (SI) and the associated concepts of traceability and uncertainty in measurement. This sets a sound basis for future work and collaboration, and should open up opportunities for National Metrology Institutes (NMIs) to respond through similar activities at the national level.

This annual report summarises a number of the main activities carried out at the BIPM and then goes on to give more detail of the scientific work.

1.2 The International System of Units (SI)

During the past few months there have been several scientific developments and meetings on possible redefinitions of base units of the SI, stimulated by the progress on a number of experiments which could lead to a redefinition of the kilogram. New results from the watt balance experiments and encouraging progress on the International Avogadro Coordination project now seem likely to provide an opportunity for the General Conference on Weights and Measures (CGPM) to take decisions on a redefinition of the kilogram in 2011.

Stimulated by, and directly linked to the kilogram redefinition, there is also likely to be a simultaneous redefinition of the base units for electric current, and amount of substance. A redefinition of the kelvin is also likely, based on a fixed value of the Boltzmann constant k . The CIPM has encouraged CCs to consider the effects of these redefinitions and a number of CCs have set up specific working groups to discuss these issues and to develop a strategy for their implementation. As the redefinitions place more of the base units of the SI on fixed values of fundamental constants of physics, there will be a need for guidance on how to realize them in practice. The example being followed

is that of the redefinition of the metre in 1983 based on a fixed value for the speed of light in vacuum. The approach adopted in this case was the creation of a *Mise en pratique*, or set of instructions and recommendations for a practical and universally followed way of realizing the definition. The *Mise en pratique* for the metre has stood the test of time and has been modified with the advent of new measurements, notably of laser-based measurement standards. The various CCs are following this approach and are preparing drafts to be finalized in the coming few years.

The Consultative Committee for Mass and Related Quantities (CCM) held a special meeting with representatives of the electrical community in February 2007. This made considerable progress towards a common position, which would allow the kilogram to be redefined in such a way (by fixing the value of the Planck constant, h) that the present representations of the volt and ohm would become genuine SI realizations firmly based on fundamental constants, rather than be based on conventional values.

Several communities came together at the meeting of the Consultative Committee for Units (CCU) in June 2007 and reached the conclusion that a kilogram redefinition based on the Planck constant was to be preferred to one based on the Avogadro constant, N_A . The CCU agreed with the Consultative Committee for Electricity and Magnetism (CCEM) that a definition of the ampere should be based on a fixed value of the elementary charge, e . The thermometry community reported that they expected new results for the Boltzmann constant in the next few years, which will allow a redefinition of the kelvin in 2011.

It is highly unlikely that these redefinitions will influence the vast majority of measurements made for industrial or scientific purposes; they will enhance the SI and bring benefits to metrologists and to the fundamental constant community through, in general, a reduction in uncertainties associated with the CODATA values. The CIPM and the CCs nevertheless believe that there needs to be an awareness campaign in the scientific and the industrial measurement community in order to alert them to these changes and their implications. Much of this effort will fall to NMIs at a national level.

1.3 The CIPM Mutual Recognition Arrangement (MRA)

The CIPM MRA continues to grow in strength as more new or revised calibration and measurement capabilities (CMCs) are entered into the BIPM key comparison database (KCDB). The KCDB itself has also been enhanced

so as to make it easier to search for data, using a semantic search facility and to interpret text-based inquiries. These facilities will make it easier for assessors of accredited laboratories to check the details of their traceability to national realizations of the SI and to access the graphs of equivalence. The BIPM is taking every opportunity to promote the new facility through presentations, live demonstrations and the *KCDB Newsletter*.

1.4 Member States and Associates

The number of Member States which are signatories to the Metre Convention remains static at 51. However, there has been a rise in the number of Associate States and Economies of the General Conference to 22, with the accession of the Former Yugoslav Republic of Macedonia (FYROM) and Moldova during the year. The BIPM is in touch with a number of other States which have declared their intention to become Associates as well as with some current Associates which are considering becoming Member States.

1.5 NMI Directors' Meeting

Over 70 Directors from NMIs in Member States and from Associate States and Economies of the General Conference met at the BIPM in October 2006. The first day of the meeting focused on the preparations for the 2007 General Conference and contained a number of presentations, which set out the main themes of the CIPM report on *National and International Needs in Metrology* (the "Kaarls report") and which outlined the BIPM programme of work. The meeting concluded with a summary of the state of play of the potential redefinitions of a number of SI units.

1.6 Meeting of the CIPM

The 95th meeting of the CIPM was held in October 2006. The main business items were the preparations for the 2007 General Conference, finalisation of the BIPM programme of work and budget for 2009-2012, the Convocation and the Resolutions to be presented to the General Conference. In addition there were the usual reports from Presidents of Consultative Committees. The CIPM was pleased to note that the 8th edition of the *SI Brochure* was launched on World Metrology Day 2006. For the first time, the Brochure was

complemented by two summaries for widespread distribution. All three documents can be downloaded from the BIPM website.

The CIPM also approved the use of a logo, in line with the recommendations of the Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB) to be used by NMIs and Designated Institutes (DIs) that are signatories to the CIPM MRA. The aim is to make use of this logo so as to aid recognition of certificates which are issued within the CIPM MRA and which are, therefore, accepted by all other signatories.

The CIPM passed recommendations on the secondary representations of the second and on coordination of the development of advanced time and frequency transfer techniques.

1.7 The General Conference on Weights and Measures

The 23rd CGPM in November 2007 will be presented with a draft programme of work for the BIPM for the period 2009-2012. We have adopted a different style from previous draft programmes of work and will present a structured approach to the justification and impact of the programme, together with a clear statement of need for new activities and projects. The programme of work was presented to NMI Directors at their meeting in October 2006, and was then discussed by the CIPM in October 2006. The CIPM endorsed a programme of work that would require an increase in the BIPM dotation of 15 % from 1 January 2009. The key elements in the programme of work will enable the BIPM to continue its current programme of work, to make faster progress with its watt balance and other work in relation to the realization of the proposed redefinition of the kilogram. The programme of work also reflects the increased importance of optical clocks to TAI, and proposes work in support of key comparisons in chemical metrology. The CIPM also discussed the proposal of the Consultative Committee for Ionizing Radiation (CCRI), which strongly endorsed (as it did again in May 2007) a new project at the BIPM to address the needs of the dosimetry community based on high energy photons generated by linear accelerators. However, the CIPM took the view that the CGPM should be asked to support the start-up work for this project during 2009-2012 but that implementation would be deferred until the subsequent period.

The Convocation of the General Conference contains twelve Draft Resolutions which cover global trends in metrology, work in relation to the

proposed changes to definitions of some SI units and a number of policy issues in relation to the operation of the Metre Convention. The Convocation was sent to Member States in January 2007.

1.8 The Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB)

The JCRB met in October 2006 and May 2007. As always, the JCRB focuses on ways to speed up the efficiency of the intra- and inter-Regional Metrology Organization (RMO) reviews of Calibration and Measurement Capabilities (CMCs), and to develop international confidence in the reviews of Quality Systems by the RMOs. The October 2006 JCRB meeting finalized its review of the use of a logo on calibration certificates issued by NMIs within the framework of the CIPM MRA, and recommended the logo for acceptance to the CIPM. It also accepted the positive recommendations in the report of a special panel convened to study the Quality System of the International Atomic Energy Agency, a signatory to the CIPM MRA. In May 2007, the main topics were the evolution of a common definition, with the accreditation community, of the term CMC, together with supporting notes that would enable its widespread acceptance and implementation. The JCRB also agreed on a recommendation to the CIPM on the criteria to be used in the selection of peer-reviewers for Quality Systems at NMIs.

1.9 The Joint Committee for Guides in Metrology (JCGM)

A major achievement of the year was the finalization of the 3rd edition of the VIM – the *International Vocabulary of Metrology, Basic and General Concepts and Associated Terms*. This edition changes the treatment of measurement uncertainty from an error approach (sometimes called “traditional approach” or “true value approach”) to the internationally adopted “uncertainty approach” and therefore necessitated reconsideration of some of the related concepts appearing in the 2nd edition of the VIM (1993). It also took the opportunity of including more terms which were of value to the chemical community. The “VIM 3” has been approved by all eight partner bodies. The BIPM will adopt the agreed text and place it on the BIPM website for access by the metrology community. The Working Group on the Expression of Uncertainty in Measurement, the GUM, also finalized its work on a supplement to the GUM which deals with Monte Carlo

methods. This has also been approved by all partner bodies and will also be adopted by the BIPM and placed on our open website.

The meeting of the JCGM itself in December 2006 reviewed the JCGM "Charter" and identified a number of priority topics for the working groups, notably a study of uncertainty for use in conformity assessment.

1.10 The Joint Committee for Traceability in Laboratory Medicine (JCTLM)

The Executive Committee of the JCTLM met in December 2006 and agreed the timetables for the next round of nominations of higher order reference materials and reference measurement procedures, and for nominations of laboratory reference measurement procedures. The first list of reference measurement services offered by laboratories was published on the JCTLM website in June 2007.

The work of the Committee helps identify priorities for comparisons to be carried out within the broad remit of the Consultative Committee for Amount of Substance (CCQM) and the JCTLM framework. It is increasingly seen as a model which could be used in collaborations with other intergovernmental organizations and international bodies as the BIPM continues to develop closer collaborations with them.

1.11 Liaison with intergovernmental organizations and international bodies

BIPM's liaison work is a major part of our activity. In the last year we have made progress on a number of fronts:

- Discussions are continuing with the World Meteorological Organization (WMO) over their intention to become a signatory to the CIPM MRA. Unlike the International Atomic Energy Agency (IAEA), the WMO does not have its own laboratories and new arrangements need to be agreed so that the WMO can participate fully. WMO has also agreed to collaborate with the BIPM to arrange an international conference and workshop on the role of metrology in the study and observation of climate change. The meeting will probably be held in early 2009.
- BIPM representation on the Codex Alimentarius Commission.
- Further World Health Organization (WHO) collaboration in the work of the CCQM and the JCTLM.

- The signing of an Agreement between the CIPM and the International Commission on Illumination (CIE) which recognises the responsibilities and roles of the two bodies and sets up formal coordination mechanisms. These relate, in particular, to the need to ensure the SI traceability of data from the CIE's work on measurements of light, optical radiation, colour, optical properties of materials, photobiological and photo-chemical quantities.
- Continued collaboration with the International Organization for Standardization (ISO) and representation through BIPM's liaison status on ISO CASCO and ISO REMCO as well as their membership of the Joint Committee on Coordination of Assistance to Developing Countries in Metrology, Accreditation and Standardization (JCDCMAS).
- As a result of the Common Statement and Declaration by the BIPM, the International Organization of Legal Metrology (OIML) and the International Laboratory Accreditation Cooperation (ILAC) on the relevance of various international agreements on metrology to trade, legislation and standardization, collaboration with the ILAC has been strengthened in several areas. In particular, the BIPM/ILAC Working Group had made good progress on a common definition of calibration and measurement capability (CMC) and on means of developing greater confidence in the uncertainty and traceability claims of accredited laboratories using the BIPM's key comparison database. The BIPM was represented at the ILAC General Assembly as well as at the Accreditation Issues Committee which held a meeting to discuss, and recommend, the common CMC definition. Recognizing that much of what the BIPM and ILAC work on the international level needs to be reinforced at the regional level, the second meeting of the Regional Metrology Organizations and the Regional Accreditation Bodies was held in March 2007. It is the only forum in which the two sets of bodies meet regularly and is helping to create stronger regional collaborations.
- Collaboration with the OIML is increasing. We have finalized a common document on the importance of metrology and the arrangements for a joint web portal on metrology which will present a general description of what the two bodies do, with links to each organization's web pages.

1.12 World Metrology Day (WMD)

The BIPM Director's message on 20 May, the anniversary of the signing of the Metre Convention in 1875, proved to be more successful than ever

before. The theme, "Measurements in our environment", attracted a huge degree of attention from NMIs and other international bodies. Some 85 national events to mark WMD were held in 63 Member States and Associates as well as in States which have, as yet, no formal links with the BIPM. In partnership with the PTB and the NMISA for the basic version, and in collaboration with other NMIs, some 32 versions, in 18 languages, of a WMD poster were produced.

1.13 BIPM staff commissions

The BIPM Statute currently provide formally for four staff commissions, although two others advise the Director on a staff loans fund and on management of the medical insurance scheme.

The Commission for Information and Security had a broad remit to advise the Director on a number of matters and is responsible for organizing the annual staff meeting and elections of members of all the commissions. However, with the establishment of a formal committee responsible for health and safety at the BIPM, the role of the commission for Information and Security has been reduced. During the year, the Director also launched a review of the formal commissions so as to improve their effectiveness and efficiency. The review's recommendations include the merger of the two commissions concerned with the Staff Statute and salaries, and the remainder of the work of the Information and Security Commission.

As mentioned in the 2005-2006 Director's Report, the BIPM has initiated a review and up-dating of the Staff Statute. This has drawn heavily on the advice of the Statute Commission. The review is still in progress and is a major exercise which will result in a proposal to the CIPM for approval.

The Salaries Commission has maintained its regular reviews of the BIPM staff salaries in relation to those of the Paris-based "coordinated organizations" and the French public sector, and has been consulted on the procedures for improving the effectiveness and value of the annual appraisal of the staff.

The final formal commission is concerned with social affairs and has maintained an active programme of events aimed at improving the interactions between staff members through cultural visits and week-end excursions.

The two remaining commissions have met when needed.

1.14 Science at the BIPM

Mass: Significant progress has been made in support of the International Avogadro Coordination project (IAC). Our new Sartorius CCL 1007 balance has been commissioned and is in almost constant operation. This balance, which incorporates BIPM technology under a licensing agreement, operates in vacuum, air or other non-reactive gases. Ultimately it will be used to calibrate a 1 kg silicon sphere in vacuum with respect to a 1 kg prototype maintained in ambient air. The transfer is made through a special set of artefacts designed and manufactured at the BIPM. The BIPM has already supplied an additional set of these artefacts to one NMI and will fulfill orders from three additional NMIs in the near future.

The requirements for mass metrology within the IAC are in many important ways similar to those of watt balance experiments. We recognize the need to coordinate such activities within the BIPM, as well as throughout the world. For this reason we suggested that the CCM create two Task Groups (TG) within the CCM Working Group on Mass Standards. One TG will coordinate work on the transfer of the mass unit from air to vacuum conditions, as well as the maintenance of mass standards under vacuum or well-defined atmospheres. The second TG will assist the BIPM in a re-examination of the uncertainty chain leading to the international prototype of the kilogram. We consider both TGs to be essential preparative steps to any of the proposed redefinitions of the kilogram. The CCM implemented our suggestions at its last meeting, in March 2007.

We continue our core activity, which is the calibration of national prototypes for Member States and the calibration of 1 kg standards in stainless steel for NMIs of Member States. Demand for these services was below the average, but not unusual for a one-year period. The calibration service successfully passed an external peer-review, as required by our Quality Management System. As part of the review, the following measurement capabilities were audited: comparison weighing, volume determination, determination of the magnetic properties of mass standards, location of the centre of gravity of mass standards. These services also provide an essential infrastructure for the IAC and watt balance projects. Two examples of support are: volume calibration of the special artefacts mentioned in the first paragraph, which is essential to their use; internal calibrations of submultiples of the kilogram, which was exploited to characterize the linearity of the Sartorius balance.

Finally, we have maintained our contact with the LISA team of the European Space Agency (ESA). This year, the BIPM determined the magnetic

susceptibilities of three test masses that are being characterized for the LISA test package.

Time, Frequency and Gravimetry: The international time scales TAI and UTC are computed regularly and the results published monthly in *Circular T*, which serves as a monthly update of key comparison CCTF-K001.UTC (the re-named CCTF-K2001UTC). The stability of TAI, expressed in terms of an Allan deviation, is estimated to be at or below 0.4×10^{-15} for averaging times of one month. During the period of this report, eleven primary frequency standards contributed to the improvement of the accuracy of TAI; this included seven caesium fountains (IT CSF1, LNE-SYRTE FO1, LNE-SYRTE FO2, LNE-SYRTE FOM, NIST-F1, NMIJ F1 and PTB CSF1). A total correction of -2.4×10^{-15} has been applied throughout the year to $[f(EAL) - f(TAI)]$. Since July 2005, the scale unit of TAI has been estimated to match the SI second to about 1×10^{-15} . The Section has worked closely with the CCTF Working Group on Primary Frequency Standards on improving the accuracy of TAI. Within the activities of this working group, a workshop was held in June with the participation of laboratories involved in the development and operation of primary frequency standards and BIPM staff.

The computation of time links using common-views of GPS satellites has been replaced by the GPS all-in-view method in the regular calculation of the time scales. Clock comparisons based on GPS phase and code observations have been studied for future application in the calculation of TAI. Extensive comparisons of the different techniques and methods for clock comparisons are computed regularly and published on the internet. Calibration programmes of GPS receivers have been organized and run by the Section.

The Section has provided support to the Joint CCL/CCTF Working Group on Frequency Standards (former Joint CCL/CCTF Working Group on Secondary Representations of the Second), in which some members of the staff have responsibilities.

Research work is also dedicated to space-time reference systems. The cooperation with the USNO (United States) for the provision of the Conventions Product Centre of the International Earth Rotation and Reference Systems Service (IERS) continues, and a workshop on the IERS Conventions is being organized for September 2007 at the BIPM.

At the end of 2006, the BIPM piloted for the last time key comparison BIPM.L-K11. Staff of the Section have contributed to the transfer of this key

comparison to NMIs. A new protocol has been elaborated, and the key comparison, under the name CCL-K11, will in the future be under the responsibility of BEV (Austria) as pilot laboratory. The Section has also provided calibration and measurement service of lasers for both internal and external users.

An important number of requests for iodine cells have been satisfied in the year covered by this report. Many of the demands concern specially designed cells. Studies on the realisation of fibre-cells have started.

Improvements of the gravimeter FG5-108 have progressed in cooperation with the VNIIM (Russian Federation). Some theoretical investigations have been conducted to improve corrections of the position of the free-falling mass in the gravimeter.

Cooperation between the Section and the special projects at the BIPM continues. Preliminary studies have been made for accurate gravity measurements for the BIPM watt balance. A member of the Section assists in the winding of the coils for the watt balance. In addition, the Section is involved in the construction of the interferometer for length measurements in the calculable capacitor.

Electricity: This year has been crucial for the Section because three experienced scientists have retired and have been replaced by the staff transferred from the Radiometry and Photometry section in 2003 and one new staff member recruited in May 2006. The training of these new members of the Section has been the priority during the last few years, to ensure the continuity and quality of our services.

During the last year all three calibration services: voltage, resistance and capacitance have been audited by external experts. Special attention was paid to knowledge transfer from the experienced staff to the new staff. All auditors expressed their satisfaction with the level of competence of the new staff. In addition, a first Josephson on-site comparison was successfully carried out by the younger staff. Three on-site comparisons of Josephson voltage standards have been successfully completed, with the INMETRO, the NMIA and the NMi VSL. The agreement between the BIPM and with both NMIA and NMi VSL is of the order of 1 part in 10^{10} , which is an excellent result. In the case of INMETRO, a higher noise level is responsible for a ten times larger uncertainty. A voltage comparison using Zener voltage standards as transfer standards was carried out with the NML (Ireland). A new comparison of resistance standards at the level of 1Ω with the NIST, to link

a SIM comparison to the KCDB, is under preparation. Preparations have also started for a capacitance comparison of 10 pF with the NIST, to validate BIPM's uncertainty budget and to prepare for the determination of the von Klitzing constant at the BIPM.

The renewal of the Josephson equipment is continuing with the development of a compact and transportable probe holder and new electronic filters. We have also tested a compact programmable microwave source which will, in the future, replace the much more complex present system based on a Gunn diode. The new automatic system for the more efficient calibration of Zener diodes has been tested and needs some further improvement.

In the field of impedance measurements, a new double current source for the cryogenic current comparator built last year, was constructed, demonstrating that the Electricity section still masters these important technologies. Some of the crucial components linking the quantized Hall resistance (QHR) with conventional resistors have been verified at the level of a few parts in 10^9 by comparing pairs of QHR samples connected in parallel and series configuration with a single sample.

The measurement sequence from resistance to capacitance, using a quadrature bridge, has been optimized. This is important for the planned measurement of the von Klitzing constant with the calculable capacitor and for our capacitance metrology in general. Further improvement is planned by addressing the frequency dependence of the resistors in the bridge.

We have started a programme to renovate the impedance laboratories. This has allowed us to move the capacitance laboratory close to the QHR laboratory. A cable between both laboratories now gives a direct connection of the QHR apparatus, without moving any standards.

Our work on time series analysis has been brought to an end by addressing the problem of calculating the variance of the mean of a time series of stochastically correlated measurements of a weak stationary process. The variance of the mean of white noise measured through a low pass filter was determined in four different ways, which were shown to be in good agreement. The results can be directly applied to some of the measurements in the Electricity section but the scope of applications is much larger.

Calculable capacitor: The BIPM workshop continues to fabricate components for the two calculable capacitors being developed in collaboration with the NMIA. Two members of the Electricity section have spent three weeks at the NMIA to learn about the project and to optimize the

shape of the guard electrodes. A member of the Time, Frequency and Gravimetry section has visited the NMIA to discuss questions related to the interferometer needed to measure the relative position of the guard electrodes. Agreement has been reached on the general approach. The mode coupling optics will be developed at the BIPM during this year and we have started to set up an interferometric test bench to study the contribution of the interferometer to the total uncertainty of the system. The chain linking the quantum Hall resistance to capacitance standards has been improved. A first electrode bar has been fabricated at the NMIA with a cylindrical geometry within the specifications. It is planned that our instrument shall arrive at the BIPM in 2008.

Watt balance: A cooperative venture has been started with the Technical University of Aachen (Germany), with the objective of fabricating and assembling the magnetic circuit for the watt balance. This is particularly difficult because very small mechanical tolerances of the pole pieces are needed. The balance suspension has been re-designed for greater stiffness and to correct some other mechanical imperfections. An electrostatic damping system was added to stabilize the coil against rotations around the vertical axis, which should reduce the velocity noise during the vertical movement of the coil. The interferometer is being integrated into the system so that, in future, velocity readings can be obtained directly from the interferometer. An independent technique to verify the velocity readings of the interferometer, based on the measurement of the Doppler shift, has been set up. A first version of the moving coil has been built and inserted into the test magnet. We have developed a technique for precisely synchronising the measurements of the induced voltage by the digital voltmeter and that of the velocity by the interferometer, so that noise components common in both signals are suppressed in the voltage-velocity ratio. The elasto-mechanical properties of the ground have been determined for the conception of an anti-vibration base.

Ionizing Radiation: We have presented to the CCRI the new BIPM graphite cavity primary standard for the determination of air kerma in gamma ray beams, based on the differential volume measurements and Monte Carlo calculations. The new value of the BIPM's air kerma rate, which is indeed higher than the previous value, is chiefly a result of the increased value to the correction factor for axial non-uniformity of the beam, which has been determined with an improved precision by using Monte Carlo calculations. The new value was accepted by the CCRI in May subject to a scientific publication describing the results, after which time it will be announced and

introduced from a fixed date. The prototype graphite calorimeter for absorbed dose to water is being constructed ready for the first trials. The concept is based on the pre-determined value of the specific heat capacity of the graphite core which is under measurement at the moment. The primary standard free air chamber for mammography dosimetry has been designed and constructed and is presently being compared with the low-energy free air standard.

Seven new dosimetry comparisons and some further measurements for an earlier comparison have been made. No progress has been made regarding the planned brachytherapy comparison due to lack of resources. Three comparison reports have been published and the others are at different draft stages. Twenty-one national secondary standards have been calibrated and the Quality System for calibrations successfully underwent its second peer-review. Continuing effort was expended to comply with French environmental regulations concerning high activity ^{60}Co sources, including a series of in-house seminars on radiation protection.

We have completed the analysis of the ^{55}Fe comparison that was held in 2006 and the results have the potential to support the measurement of 23 other radionuclides through the grouping system set up by the CCRI(II). Of the nineteen laboratories that participated in this comparison, two had results that differed significantly from the key comparison reference value and this is being investigated. Following the significant delays in receiving the samples experienced by some NMIs, caused by the difficulties in cross-border movement of radioactive material, a seminar was presented to the IAEA on the margins of their General Conference, and they offered their support for any international effort in this respect.

Thirteen laboratories submitted ampoules to seventeen of the BIPM ongoing activity comparisons using the International Reference System (SIR). Studies of ^{237}Np , ^{241}Am and ^{85}Kr measurements have been made to support international comparisons and $^{99}\text{Tc}^{\text{m}}$ was measured successfully in both the SIR and the SIR transfer instrument to provide the link needed to extend such comparisons specifically to NMI on-site measurements for short-lived radionuclides. The new SIR measurement system continues to produce consistent results and should be adopted at the end of 2007. Impurity activity levels were measured using the BIPM Ge(Li) gamma spectrometer for seven radionuclides submitted for comparisons. Due to lack of resources, no progress has been made in calibrating the HPGe spectrometer. The BIPM

Quality System has been extended to include the SIR, which was successfully peer-reviewed at the end of 2006.

The Section has given strong support to both the Consultative Committee for Acoustics, Ultrasound and Vibration and the Consultative Committee for Ionizing Radiation, and their associated meetings held over 23 days in the last 12 months.

Chemistry: In October 2006, the protocol of a new key comparison coordinated by the BIPM (BIPM.QM-K1, Ozone at ambient level) was distributed to potential participants. The first participant of the 2007-2008 cycle was the NIST in January 2007, with six other participants expected in 2007. An external audit of the Quality System established for the activities directly linked with the ozone photometer comparisons was successfully undertaken.

A study of systematic biases and measurement uncertainties in NIST standard reference photometers (SRPs) was published in *Metrologia* in October 2006, and led to the NIST establishing a "NIST SRP upgrade kit" in order to minimize the two major biases revealed by the study. BIPM-SRP32 was upgraded, and an installation procedure developed. The BIPM is now able to install upgrade kits for those participants in BIPM.QM-K1 maintaining a NIST SRP. A generalized least-square regression implemented in the ozone comparison software is described in an article written in collaboration with Dr W. Bremser (BAM) and submitted to *Metrologia* in May 2007.

The programme to develop a primary ozone photometer using a frequency-doubled laser as a light source has continued. The detector chain has been modified to use UV photodiodes, and the laser cooling system has been improved. Additional optical filters have been placed in the laser beam to reject the residual portion of the fundamental wavelength in the frequency-doubled beam. Initial measurements of ozone concentration performed with this first version of a laser-based SRP succeeded in measuring ozone mole fractions in dry air to within a few percent of the values determined by a mercury lamp-based SRP.

All measurements related to the BIPM coordinated study, CCQM-P73 (Comparison of nitrogen monoxide gas standards), were completed. Gravimetrically prepared NO standards in the range (30-70) $\mu\text{mol/mol}$ from 11 NMIs were analyzed using two independent methods as well as Fourier transform infrared (FTIR) spectroscopy for impurity analysis. A reference

value for the comparison was calculated from the most consistent set of gas standards, and it could be shown that in all but one case that impurity measurement problems were the cause of discrepancies of certified values from the reference value. The comparison draft B report was circulated in June 2007.

The BIPM's nitrogen dioxide gas standard dynamic facility was upgraded to include a nitrogen generator and new control and data acquisition software for the FTIR spectrometer. Studies of the consistency of nitrogen dioxide concentrations calculated from permeation rates and those measured by various analysers are currently underway, and comparisons with certified values in gas cylinders based on static gravimetry are planned. Following the request of the CCQM Gas Analysis Working Group, a planned future comparison of NO₂ gas standards will be extended to include the comparison of spectroscopic methods for gas concentration determination.

The organic analysis programme has developed a facility for purity assessment and to organize comparisons of NMI's facilities for primary calibrator characterization, initially for analytes of interest to the laboratory medicine community. Refurbishment of a laboratory to provide an area for controlled gravimetric transfer of materials and the accurate preparation of calibration solutions was completed in 2007. The BIPM is coordinating subsequent rounds of the CCQM-P20 series of organic substance purity analysis comparisons: CCQM-P20.e for theophylline; and CCQM-P20.f for digoxin. For CCQM-P20.e the main focus has been the identification and quantification of theophylline and related compounds from the xanthine group. For CCQM-P20.f, methods for the determination of the steroid glycosides digoxin and digitoxin, and various related cardiac glycosides as well as their corresponding aglycones have been developed.

The fifth meeting of the Executive Committee of the JCTLM was held at the BIPM in December 2006, and the timetable for the approval of Cycle III nominations of higher order reference materials and reference measurement procedures, and of Cycle I nominations of laboratory reference measurement procedures was agreed. The construction of the internet-based searchable database for higher order reference materials and measurement methods/procedures approved by the JCTLM was completed and, the new website of the JCTLM database was launched in December 2006. From December 2006 to June 2007, the number of external connections to the JCTLM database website was, on average, 750 each month. The first list of reference measurement services offered by laboratories was published on the

JCTLM website in June 2007. The JCTLM web application will be extended to include the reference measurement laboratory services as a searchable category to the database, and this will be available by the end of 2007.

1.15 Publications, lectures and travel of the Director

1.15.1 External publications

1. Wallard A.J., News from the BIPM – 2006, *Metrologia*, 2007, **44**, 97-103.
2. Wallard A.J., Amélioration de la traçabilité des mesures au niveau international : un point sur la collaboration entre le BIPM et l'ILAC, *Revue française de métrologie*, 2006, No. 8 (Vol. **2006-4**), 53-58.
3. Wallard A.J., Guest Views, *ISO Focus*, October 2006, 4-7.
4. Wallard A.J., Measurement Principles and Structures, *Springer Handbook of Materials Measurement Methods*, Springer, 2006, 3-16 (ISBN 3-540-20785-6).
5. Wallard A.J., Metrology and Society, *Proc. International School of Physics "Enrico Fermi", Course CLXVI, Metrology and Fundamental Constants*, Societa Italiana di Fisica, 2007, 1-9.
6. Wallard A.J., The evolution of metrology: Past times to the present day, *Proc. International School of Physics "Enrico Fermi", Course CLXVI, Metrology and Fundamental Constants*, Societa Italiana di Fisica, 2007, 11-19.
7. Wallard A.J., The organization of metrology, *Proc. International School of Physics "Enrico Fermi", Course CLXVI, Metrology and Fundamental Constants*, Societa Italiana di Fisica, 2007, 21-33.

1.15.2 Travel (conferences, lectures and presentations, visits)

A.J. Wallard to:

- London (United Kingdom), 3-4 July 2006, for a meeting of the Quantum Metrology Working Group of the DTI;
- Turin (Italy), 7-8 July 2006, for a meeting of the bureau of the CIPM and to the CPEM;
- Varenna (Italy), 18-28 July 2006, to the International School of Physics "Enrico Fermi" on Metrology and Fundamental Constants;

- Nashville (United States), 5-11 August 2006, to the NCSLI Conference and Board of Management;
- Hanover (Germany), 28 September 2006, for a meeting with the PTB;
- Geel (Belgium), 29 September 2006, for a workshop at IRMM;
- Cape Town (South Africa), 17-20 October 2006, to the 41st CIML meeting and for a presentation;
- Lima (Peru), 21-23 October 2006, to a JCDCMAS workshop and a presentation;
- Mexico (Mexico), 25-28 October 2006, to the CENAM and for a talk at the Metrology Symposium; 13-15 November 2006, to the General Assembly of ILAC;
- Brussels (Belgium), 30 November 2006, to a meeting of DG Enterprise;
- Tokyo and Tsukuba (Japan), 10-14 December 2006, for meetings and a presentation at NMIJ and for discussion with MITI;
- New Delhi (India), 15-16 December 2006, to a meeting of APMP;
- Berlin (Germany), 11 January 2007, to the PTB and to a meeting for the launch of the iMERA project of EUROMET;
- Los Angeles (United States), 24-26 January 2007, to the Measurement Science Conference, for a keynote speech;
- Morro Bay (United States), 27-30 January 2007, to the NCSLI Board Meeting;
- Washington DC (United States), 31 January – 1 February 2007, to the NIST and the US State Department;
- Braunschweig (Germany), 11 January 2007, to the PTB;
- Vienna (Austria), 12-13 March 2007, to a meeting of the JCDCMAS;
- Ottawa (Canada), 23-26 April 2007, to a meeting of the NRC-INMS Advisory Board;
- Pretoria (South Africa), 1-5 May 2007, for the 18th JCRB meeting and a related workshop;
- Vienna (Austria), 10 May 2007, for the 5th meeting of the Accreditation Committee of ILAC General Assembly;
- London (United Kingdom), 30 May 2007, to a meeting of EUROMET.

1.16 **Activities of the Director related to external organizations**

The Director is a member of the Scientific Council of the INRIM, Turin; a member of IUPAC's Interdivisional Committee on Terminology, Nomenclature and Symbols; and a member of IUPAP-C.2 Commission on symbols, units, nomenclature, atomic masses and fundamental constants (SUNAMCO). He is a Visiting Professor in the Institute of Mathematics and Physical Sciences of the University of Wales at Aberystwyth; a member of the Board of the National Conference of Standards Laboratories International (NCSLI); a member of the Scientific Academy of Turin; a member of UK's Pathfinder Programme Working Group and the National Measurement System Board of the Department for Universities, Innovation and Skills; a member of the Advisory Board of INMS-NRC, Canada, and Chairman of the JCRB and the JCGM.

2 **MASS (R.S. DAVIS)**

2.1 **Calibrations**

2.1.1 **Certificates (P. Barat and R.S. Davis)**

During the past year, certificates were issued for the following 1 kg prototypes in platinum-iridium: No. 48 (Denmark) and No. 72 (Rep. of Korea). Calibration of the national prototypes of Singapore and Hungary is underway.

Certificates for 1 kg standards in stainless steel were issued to: SIRIM (Malaysia) (two) and DMDM (formerly ZMDM, Serbia) (one). Calibrations of 1 kg stainless steel standards are currently being carried out for LATU (Uruguay) and SPRING (Singapore).

We have also carried out internal BIPM calibrations of mass standards used with our pressure balance (see Section 2.9), and a 100 g auxiliary standard used for mass calibrations.

Calibrations were made for EIM (Greece) of the magnetic susceptibilities of two metal blocks used with a BIPM-type magnetic susceptometer.

2.1.2 Quality Management System (P. Barat, R.S. Davis and C. Goyon-Taillade)

In conformity with the BIPM Quality Management System (QM), the mass calibration service underwent a successful external audit. This, our second peer-review since introducing the QM system, was carried out by Dr Ph. Richard (METAS), Chairman of the CCM Working Group on Mass Standards. A range of measurement capabilities was audited because, depending on the request, a calibration certificate may include results for mass, density (or volume), magnetic properties (susceptibility and permanent magnetization) and height of centre of gravity.

2.2 **Balances to support development programmes** (P. Barat, H. Fang and A. Picard)

As mentioned last year, room 105 was completely renovated in order to accommodate the new Sartorius CCL 1007 mass comparator. Commissioning was carried out for the comparator. The devices and probes used to measure the relevant parameters for air density determination inside the airtight enclosure were implemented and commissioned. Computer programs in LabView have been written or adapted to acquire the data coming from the mass comparator as well as from the instruments used to measure air parameters (thermodynamic air temperature T , relative humidity h , dew point temperature t_r , barometric pressure p and the mole fraction of carbon dioxide x_{CO_2} in air). In addition, the program used to compute weighing results and air densities, previously written for the BIPM FB2 balance, has been adapted for the Sartorius comparator. An oil free vacuum pump system has been connected to the enclosure. After pumping down for about one day, the residual pressure stabilizes at about 0.004 Pa, which is sufficiently low for our purposes.

During the comparator commissioning, we observed that the scale of the balance was not linear throughout its range of 2 g. Engineers from Sartorius came to update the linearity parameters in the Sartorius software. Investigations have also been undertaken at the BIPM to characterize the balance behavior. The errors due to the weighing position on the carousel have been estimated by comparing the mass differences between two masses placed successively at different carousel positions. So far, the range of these errors over all eight positions of the carousel has been within 2.0 μg and 0.3 μg in air and under vacuum, respectively. Additional investigations in air need to be made in order to reduce these errors.

Comparisons of two 1 kg Pt/Ir masses and a 1 kg silicon sphere against a 1 kg Pt/Ir cylinder have been carried out during four months, alternately in air and under vacuum. For the Pt/Ir-Pt/Ir comparisons, we obtained a reproducibility of the mass difference, corrected of drift, of 1.2 μg in air and 0.4 μg under vacuum. The reproducibility was 4.0 μg in air and 1.1 μg under vacuum for the Si-Pt/Ir comparisons. The standard deviation of several series of measurements, performed under the same air or vacuum condition where the balance case remains closed, was 1.0 μg in air and 0.3 μg under vacuum for the Pt/Ir-Pt/Ir comparison. We obtained a standard deviation of 4.7 μg in air and 0.6 μg under vacuum for the comparison of a silicon sphere against platinum. The repeatability of measurements during a series of weighings was 0.8 μg in air and 0.2 μg under vacuum for the two Pt/Ir masses. It was 4.0 μg in air and 0.3 μg under vacuum for the Si-Pt/Ir comparison. The reported values of the reproducibility and the repeatability in air include the uncertainty coming from the air buoyancy correction. A better estimate of the intrinsic performance of the comparator is given by the repeatability and reproducibility evaluated under vacuum, although even in this case, there will still be a contribution from the instability of the mass artefacts themselves.

The Sartorius balance is in almost constant operation, mainly in support of the Avogadro project. Due to insufficient staffing, the FB2 balance is no longer used.

2.3 Water vapour sorption on silicon spheres

(P. Barat, H. Fang and A. Picard)

In the framework of the Avogadro project, a wide work plan has been launched this year to better evaluate the physical and chemical water sorption on silicon sphere surfaces. The Avogadro constant determination requires the knowledge of the mass of the core of the sphere; i.e. without any trace of water, contamination and oxide layer on the surface. The contamination is easily removed by using a well defined washing protocol, whose efficiency has already been demonstrated, proposed by the NMIA. The mass of oxide layer on the surface is evaluated by other laboratories for further correction. Therefore, the purpose of this work is to investigate the water sorption effects, first on a natural oxide layer and afterwards re-investigate the effects on a well controlled thermal oxide layer (9 nm), as planned in the Avogadro project. Two silicon spheres, named S1 and S2, ordered from a Japanese company last year were delivered early this year. The first sphere will always

be maintained in air as a reference, whilst the sphere S2 will be weighed in air as well as under vacuum. In addition, the NMIJ/AIST has kindly lent a silicon sphere named NMIJ-CZ on which we plan to carry out a thermal oxide treatment after the study of sorption effects made on the natural oxide layer. So far, the physical sorption (reversible effect) has been investigated on the S2 and NMIJ-CZ spheres. The difference in mass weighed in air and under vacuum permits us to deduce the change in physical sorption between vacuum and air of 50 % relative humidity. We obtained a change of about 32 ng/cm² for the NMIJ-CZ sphere, which is close to one layer of water. This result confirms what was seen in the previous study carried out at the BIPM two years ago on small silicon sorption artefacts. Weighings made on the S2 sphere gave a coefficient as large as 115 ng/cm², which needs to be clarified. The study will continue by sending the sphere NMIJ-CZ to Germany for the thermal oxide deposit and afterwards a repetition of the previous study.

2.4 International Avogadro Coordination project (A. Picard)

The BIPM continues to be an active participant in the CCM Working Group on the Avogadro Constant and acts as the coordinator for the mass determination of silicon spheres in the framework of the International Avogadro Coordination (IAC) project. The BIPM was the pilot laboratory for the international mass comparison of the sphere AV0#3, which is now completed. The main innovation of this comparison is based on the fact that it was the first international mass comparison under vacuum and at the highest level of accuracy ever achieved. Among the five laboratories involved in this comparison, only one didn't have the facility needed for vacuum weighings. An overall consistency check of the results obtained has been made and one laboratory was identified as discrepant for results obtained both in air and under vacuum. Reference values have been determined with their associated standard deviations of 6 µg and 3 µg in air and under vacuum, respectively. Nevertheless, a mass difference of about 20 µg between measurements performed in air and under vacuum has been observed, but it is within the uncertainties. Finally, the target fixed by the IAC to obtain a relative uncertainty of 4×10^{-9} has been reached in vacuum on this particular mass comparison.

2.5 Humidity generator (H. Fang)

We recall that the BIPM has developed a humidity generator in the range from 5 °C to 15 °C for accurate in-house calibrations of dew point meters or humidity sensors. Excellent repeatability and reproducibility of measurements has been obtained. Nevertheless, more investigations on thermal gradient inside the main saturator are necessary. Unfortunately, this work has been discontinued since early 2005 due to a lack of staff resources. To verify the performance of a new Michell dew-point temperature instrument used for the CCL Sartorius mass comparator, measurements were carried out late last year at dew points of 5 °C, 10 °C and 15 °C. Two relative humidity sensors and our master dew point meter were also investigated. The last was sent to LNE-CETIAT for calibration four months later. Our values agreed to 0.01 °C with those given by LNE-CETIAT for 10 °C and 15 °C. For 5 °C, a difference of 0.1 °C was observed. These results are very encouraging after almost two years without using the generator. It is hoped that work will be taken up again late this year with the goal of establish a service for humidity calibration within the BIPM Management Quality System.

2.6 Pt-Ir 1 kg sorption artefacts (A. Picard)

To support the teams working on both the watt balance and the Avogadro project, the BIPM has been manufacturing four sets of two 1 kg Pt-Ir sorption artefacts. These artefacts are used to make the link between national prototypes which are maintained in air and the test masses employed in the watt balance experiments or the silicon spheres used in the Avogadro project, which are all weighed under vacuum. Each set of sorption artefacts is composed of one classical prototype (cylindrical in form with height and diameter equal to 39 mm) and one artefact in the form of a stack of eight separated discs kept apart at each level by three bent Pt-Ir rods. The difference in surface area between the 1 kg cylinder and the 1 kg stack is about 186 cm². The volume difference is very small. The fabrication of these artefacts, especially the stacks, is tedious and time consuming. So far, two sets have been delivered and two others will be completed before the end of this year. Preliminary measurements carried out on the BIPM set gave a difference of physical water vapour sorption of about 45 ng/cm² between air, at about 50 % relative humidity, and the vacuum within the balance. This coefficient is consistent with the result obtained in the previous study undertaken at the BIPM.

2.7 **Glove box** (A. Picard)

At its meeting in March 2007, the CCM identified a number of preparative steps towards a redefinition of the kilogram in terms of fundamental or atomic constants. In particular, certain features of any *Mise en pratique* are becoming clearer and the CCM recommends that these should be addressed immediately. Among them are the need to transfer mass artefacts kept under vacuum or inert gas to mass comparators, the need to organize international comparisons with artefacts kept under vacuum or inert gas and the desirability that the BIPM coordinates such comparisons. In anticipation of this recommendation, earlier this year we began to study a device which will permit the transfer of a mass under vacuum or inert gas without contact with ambient air, from any transportable container to the Sartorius CCL 1007 comparator. Cooperation with the Sartorius company is underway in order to adapt a Vacuum Transfer System (VTS) to our Sartorius comparator in the best possible way. The VTS will be coupled to the balance and could be evacuated or, alternatively, filled with pure N₂. We also need a commercial, off-the-shelf inert gas glove box (GB) which need not be located at the balance. The GB can be operated at a pressure slightly below atmospheric but not under vacuum. The purity of the inert dry gas maintained by such a unit is such that the maximum impurity content of H₂O and O₂ will be less than 1 μmol/mol. The mass enclosed in the travel container will be manually transferred to a separate automatic loadable container (ALC) inside the GB. The ALC should be designed in order to receive 1 kg Pt-Ir or stainless steel cylinders and 1 kg silicon spheres. It will be connected to the VTS for the transfer to the balance. A special need of the Avogadro project is the coupling of a vacuum oven to the GB in order to bake the sphere, thereby eliminating water that is chemisorbed and physisorbed on the surface. We hope to receive the whole bench transfer system early next year.

2.8 **Hydrostatic weighing apparatus** (R.S. Davis and C. Goyon-Taillade)

We recall that this apparatus is used to determine the density and volume of mass standards, including new 1 kg prototypes manufactured by the BIPM. This year, densities were determined for a pair of Pt-Ir mass standards: one is a cylinder and the other is a stack of eight disks, separated at each level by three rods, 2 mm in diameter. The stack is a challenging object to weigh in a hydrostatic apparatus. The pair of artefacts will be used in the Mass section

to correct for sorption effects between air and vacuum, as described in Section 2.6.

These determinations have been made with doubly distilled water as the standard. The density of water is calculated from the CIPM 2001 formula, with suitable corrections for isotopic abundance, dissolved air and pressure. Work is in progress to replace water by the two 500 g cylinders of single-crystal silicon received in June 2006. They were obtained through the help of our colleagues at the NMIJ/AIST, who also determined their densities. New software has been written for data acquisition and analysis. Preliminary tests with the silicon cylinders in water have been performed, as a preliminary step to using a transfer liquid other than water. The agreement between the water density, calculated from the formula, with the value of the density calculated from the silicon artefacts is remarkably close, and consistent with the uncertainty of artefacts themselves.

The measurement algorithm has been improved in that the balance sensitivity is determined during each weighing series in air. Previously, the sensitivity was determined separately, just prior to weighing the mass standards. We plan to use similar algorithm for weighing in the transfer liquid.

2.9 Pressure (P. Barat, R.S. Davis and C. Goyon-Taillade, M. Rami*)

Calibrations of BIPM manometers with respect to the pressure balance maintained in the Mass section have been carried out every three months.

The final step of the commissioning of our manometer was a bilateral comparison piloted by the LNE (France). Formally, this has been done as a supplementary comparison (EUROMET.M.P-S3). The LNE has produced a draft A report and our editorial comments were returned to the LNE in October 2006.

Several of the manometers of the Mass section are measured *in situ* by means of vacuum-tight tubes running from the pressure balance to other laboratories. We have studied the influence of different parameters on these pressure measurements and discovered that the long length of tubing does not influence the results. However, we did learn that the manometer used in the study is sensitive to convection from the air-conditioning system. We have also studied the effect of different ambient temperatures on results

* Student at the IUT Saint-Denis (France).

obtained from the manometers. Some unexpected results were obtained but we have not completed a full analysis of the data.

2.10 Other work

2.10.1 Collaboration with European Space Agency on LISA programme (R.S. Davis)

Last year we reported special magnetic susceptibility measurements on a 2 kg cubical test mass made of an alloy of gold and platinum. These measurements were requested by the LISA-Pathfinder team and were the subject of a press release issued in October 2006 by the European Space Agency. This year we constructed a modified susceptometer designed specifically for these measurements. Susceptibility measurements have recently been completed on the same test mass and two additional test masses.

2.10.2 G, Torsion balance experiment (R.S. Davis, T.J. Quinn* and C.C. Speake**)

An apparent problem with one of the three modes of this experiment has delayed the final report of results. If the problem cannot be resolved by September 2007, we will nevertheless end the experiment and report the results.

2.11 Publications, lectures, travel: Mass section

2.11.1 External publications

1. Becerra L.O., Berry J., Chang C.S., Chapman G.D., Chung J.W., Davis R.S., Field I., Fuchs P., Jacobsson U., Lee S.M., Loayza V.M., Madec T., Matilla C., Ooiwa A., Scholz F., Sutton C., van Andel I., Magnetic properties comparison of mass standards among seventeen national metrology institutes, *Metrologia*, 2006, **43**(5), 426-434.
2. Davis R.S., Practical approach to minimizing magnetic errors in weighing, *Measure*, 2006, **1**(3), 70-72.

* Director Emeritus of BIPM.

** University of Birmingham (UK).

3. Davis R.S., Mass metrology: Underlying assumptions, present best practice, new frontiers, *Proc. International School of Physics "Enrico Fermi", Course CLXVI, Metrology and Fundamental Constants*, Societa Italiana di Fisica, 2007, 473-498.
4. Davis R., Coarasa J., Errors due to magnetic effects in 1 kg primary mass comparators, *Measurement*, 2007, **40**, 769-773.

2.11.2 BIPM report

5. Davis R.S., Calculation of the effective area of DHI piston-cylinder No. 517, working in the absolute mode at a nominal pressure of 1000 hPa, *Rapport BIPM-2006/10*, 12 pp.

2.11.3 Travel (conferences, lectures and presentations, visits, training)

R.S. Davis to:

- Politecnico di Torino, Turin (Italy), 8 July 2006, to attend a meeting of the CCEM Working Group on Electrical Methods for Monitoring the Stability of the Kilogram;
- CPEM, Turin (Italy), 10-14 July 2006;
- International School of Physics "Enrico Fermi" Varenna (Italy), 18-22 July 2006, to present lectures on mass metrology;
- APGRADE Workshop, Institut Laue-Langevin, Grenoble (France), 26-28 October 2006, to present an invited talk on how a watt balance can be used to link the kilogram to the Planck constant;
- 2006 meeting of Combined Regional Measurement Assurance Programme, 30 October – 2 November 2006, Boulder (United States), invited by the NIST Weights and Measures Division to introduce the subject of possible changes to the SI and to participate in sessions devoted to international metrology;
- DFM (Denmark), 6 November 2006, to participate in a surveillance visit of the mass activities;
- ADMET-06, Pressure and Vacuum Workshop, Meeting of APMP TCM, New Delhi (India), 11-14 December 2006 (presented ADMET-06 keynote address: Metrology before and after the CIPM MRA);
- EUROMET TC-Mass, 28 February – 2 March 2007, Teddington (United Kingdom), to represent the BIPM;

- EUROMET TC-Therm, 26-28 March 2007, Berlin (Germany) to coordinate CCT activities;
- TempMeko, 20-24 May 2007, and meetings of CCT working groups, 25 May 2007, Lake Louise (Canada).

R.S. Davis and A. Picard to INRIM, Turin (Italy), 6-7 July 2006, to attend a meeting of the IAC committee.

A. Picard to:

- IKZ, Berlin (Germany), 17 October 2006 and 26-27 February 2007, to attend meetings of the IAC committee;
- Sartorius, Ilmenau (Germany), 18 October 2006, for technical discussion on the glove box project as well as on the CCL 1007 mass comparator;
- NMIA, Sydney (Australia), 13-21 June 2007, for delivery of enriched ^{28}Si and technical discussions in the context of IAC project and about air-vacuum mass measurements.

2.12 Activities related to the work of Consultative Committees

R.S. Davis is Executive Secretary of the Consultative Committee for Mass and Related Quantities (CCM) and the Consultative Committee for Thermometry (CCT). He was invited to attend the meeting of the Consultative Committee for Units (CCU) held in June 2007. The CCM met at the BIPM on 23 March 2007. This was an extraordinary meeting convened to respond to Recommendation 1 (CI-2005) of the 94th CIPM meeting concerning preparative steps towards a new definition of the kilogram (among other units).

A. Picard spends 20 % of his time working as coordinator for mass measurements in the International Avogadro Coordination project/CCM Working Group on the Avogadro Constant (see Section 2.6).

[Note: A. Picard has been transferred to the watt balance experiment, where he devotes the remaining 80 % of his time.]

2.13 Visitors to the Mass section

- Messrs T. Fehling and T. Froehlich (Sartorius AG, Germany), 6-7 November 2006, to discuss arrangements for technology transfer between the BIPM and Sartorius and for technical support of the CCL 1007 mass comparator.

- Dr Ph. Richard (METAS), 30 November – 1 December 2006, to peer review BIPM mass calibration services.
- Dr C. Mitsas (EIM), 11-12 January 2007, to consult on magnetic measurements of mass standards.
- Open House in the Mass section, 12 February 2007, to introduce the BIPM staff to the Avogadro project.
- Mr C. Sutour and Mrs C. Stumpf (LNE), 16 March 2007, to discuss status of LNE determinations of the argon content of air.
- Dr E. Williams and Dr Z. Jabbour (NIST), 20 March 2007 for technical discussion on the procedure to transfer test masses under vacuum or in inert gas.
- Prof. F. Lepoutre (CNAM), 29 March 2007.
- Prof. M. Himbert (LNE-INM/CNAM), 25 April 2007.
- Mr T. Froehlich (Sartorius AG, Germany), 9-10 May 2007, for technical intervention on the CCL 1007 mass comparator and on the glove box project.
- Messrs L. Soli (Thales-Alenia Space, Italy) and L. Trougnou (ESA-ESTEC), 18-19 June 2007, for characterization of the magnetic susceptibility of test masses used in the LISA project of the European Space Agency.
- Dr S.-M. Lee (SPRING Singapore), 18 June – 27 July 2007 to study means of transferring the unit of mass from the BIPM to SPRING.

2.14 Student to the Mass section

- M. Rami (student at the IUT Saint-Denis, France), 16 April – 22 June 2007, to assist in characterization of pressure apparatus.

3 TIME, FREQUENCY AND GRAVIMETRY (E.F. ARIAS)

3.1 International Atomic Time (TAI) and Coordinated Universal Time (UTC) (E.F. Arias, Z. Jiang, H. Konaté, W. Lewandowski, G. Petit, G. Thibaudeau*, L. Tisserand and P. Wolf**)

The reference time scales, International Atomic Time (TAI) and Coordinated Universal Time (UTC), are computed from data reported regularly to the BIPM by the various timing centres that maintain a local UTC; monthly results are published in *Circular T*. Consequently, with the new structure of the section, the traditional *Annual Report of the BIPM Time Section* has changed its name to *BIPM Annual Report on Time Activities*, but the contents remain the same. The *BIPM Annual Report on Time Activities for 2006*, volume 1, complemented by computer-readable files on the BIPM website (<http://www.bipm.org>), provides the definitive results for 2006.

3.2 Algorithms for time scales (Z. Jiang, W. Lewandowski and G. Petit)

The algorithm used for the calculation of time scales is an iterative process that starts by producing a free atomic scale (*Échelle atomique libre* or EAL) from which TAI and UTC are derived. Research into time scale algorithms is conducted in the Section with the aim of improving the long-term stability of EAL and the accuracy of TAI.

3.2.1 EAL stability

Some 86 % of the clocks used in the calculation of time scales are either commercial caesium clocks of the HP/Agilent 5071A type or active, auto-tuned hydrogen masers. To improve the stability of EAL, a weighting procedure is applied to clocks where the maximum relative weight each month depends on the number of participating clocks. About 14 % of the participating clocks have, on average, been at the maximum weight, during 2006. This procedure generates a time scale which relies upon the best clocks.

* Assistant since 1 April 2007.

** Physicist until 31 December 2006.

Since 2003, it is estimated that the stability of EAL, expressed in terms of an Allan deviation, has been at or below 0.4×10^{-15} for averaging times of one month. Slowly varying long-term drifts limit the stability to around 2×10^{-15} for averaging times of six months.

3.2.2 TAI accuracy

To characterize the accuracy of TAI, estimates are made of the relative departure, and its uncertainty, of the duration of the TAI scale interval from the SI second, as produced on the rotating geoid, by primary frequency standards. Since July 2006, individual measurements of the TAI frequency have been provided by eleven primary frequency standards, including seven caesium fountains (IT CSF1, LNE-SYRTE FO1, LNE-SYRTE FO2, LNE-SYRTE FOM, NIST F1, NMIJ F1 and PTB CSF1). Reports on the operation of the primary frequency standards are regularly published in the *BIPM Annual Report on Time Activities* and on the BIPM website.

Starting in July 2004, a monthly steering correction of, a maximum, 0.7×10^{-15} is applied as deemed necessary. Since July 2006, the global treatment of individual measurements has led to a relative departure of the duration of the TAI scale unit from the SI second on the geoid ranging from $+0.7 \times 10^{-15}$ to $+3.7 \times 10^{-15}$, with a standard uncertainty of about 1×10^{-15} . Since September 2006, we have used for this treatment the standard uncertainties of $[UTC - UTC(k)]$ to estimate the uncertainty in linking the primary standards to TAI. Over the year, six steering corrections have been applied for a total correction of $[f(EAL) - f(TAI)]$ of -2.4×10^{-15} .

3.2.3 Independent atomic time scales

TT(BIPM)

Because TAI is computed in “real-time” and has operational constraints, it does not provide an optimal realization of Terrestrial Time (TT), the time coordinate of the geocentric reference system. The BIPM therefore computes an additional realization TT(BIPM) in post-processing, which is based on a weighted average of the evaluation of the TAI frequency by the primary frequency standards. We have provided an updated computation of TT(BIPM), named TT(BIPM06), valid until December 2006. Here, we have used all recently available data from the new caesium fountains and a revised

estimation of the stability of the free atomic time scale EAL on which TAI is based.

3.3 Primary frequency standards and secondary representations of the second (E.F. Arias, G. Petit and P. Wolf*)

Members of the BIPM Time, Frequency and Gravimetry section are actively participating in the work of the CCTF Working Group on Primary Frequency Standards (PFS), seeking to encourage the creation of better documentation, comparisons, and the use of high accuracy PFS (Cs fountains) for TAI.

Other microwave and optical atomic transitions are being proposed as secondary representations of the second by the CCL/CCTF Joint Working Group on Standard Frequencies (until October 2006, CCL/CCTF Joint Working Group on Secondary Representations of the Second). A list containing frequency values and uncertainties for Rb, Hg⁺, Yb⁺, Sr⁺ and Sr has been proposed by the Joint Working Group and recommended by the Consultative Committee for Time and Frequency (CCTF): Recommendation CCTF 2 (2006) and by the CIPM: Recommendation 1 (CI-2006). An extensive comparison of measurements from all Cs PFS, including eight fountains, spanning seven years has been carried out. BIPM staff continues to participate in the rapidly evolving field of optical frequency standards, addressing, for example, the issue of their comparison at the 10⁻¹⁷ uncertainty level or below.

3.4 Time links (E.F. Arias, Z. Jiang, H. Konaté, W. Lewandowski, G. Petit, L. Tisserand and P. Wolf*)

Clock comparisons can presently be made by three independent techniques: satellite common-view based on C/A code measurements from GPS single frequency receivers; satellite common-view obtained with dual-frequency, multi-channel GPS geodetic type receivers (P3); and two-way satellite time and frequency transfer through geostationary telecommunications satellites (TWSTFT). Significant improvement is being made with the growing number of time links with P3 receivers (twelve official links in June 2006, and several more computed as additional links), and with the increasing number of TWSTFT observations (up to twelve per day for links in Europe and with North America). The classical GPS single-channel single-frequency

* Physicist until 31 December 2006.

receivers that today represent only 25 % of the time transfer equipment are being replaced to allow multi-channel, single or dual frequency observations. As a result, there has been an improvement in the accuracy for time transfer, and the whole system of time links has become more reliable.

Testing continues on other time and frequency comparison methods and techniques. Exhaustive analysis has proved that further improvement should be possible, in particular, for clock comparison over long distances by calculating GPS all-in-view solutions instead of the current GPS common-views. The CCTF Working Group on TAI has established two study groups to analyze the benefits of this change, and which reported to the CCTF at their meeting in September 2006. The new method has been implemented in TAI computation in October 2006, and a complete description has been published.

3.4.1 Global Positioning System (GPS) and Global Navigation Satellite System (GLONASS) code measurements

All GPS links are corrected for satellite positions using IGS (International GNSS Service) post-processed, precise satellite ephemerides, and those performed with single-frequency receivers are corrected for ionospheric delays using IGS maps.

3.4.2 Phase and code measurements from geodetic-type receivers

GPS and GLONASS time and frequency transfer may also be carried out using dual-frequency, carrier-phase measurements in addition to code measurements. This technique, already in common use in the geodetic community, can be adapted to the needs of time and frequency transfer. These studies are conducted in the framework of the IGS Working Group on Clock Products, of which a physicist of the Section is a member.

The method developed to perform the absolute calibration of the Ashtech Z12-T hardware delays allows us to use this receiver for differential calibrations of similar receivers worldwide. Calibration trips began in January 2001. Since 2006, calibration results have also been issued for the new type of receiver Septentrio PolaRx2, and other types of receivers are being investigated in collaboration with laboratories equipped with such receivers. From July 2006 to June 2007, 12 such calibrations have taken place concerning receivers in six laboratories. The travelling Z12-T had to be

repaired at the end of 2006 and a Septentrio receiver has been used as a travelling receiver since that time. At least two receivers remain at the BIPM to serve as a local reference with which the travelling receiver is compared between calibration trips.

Data from geodetic-type receivers worldwide are collected for TAI computation, using procedures and software developed in collaboration with the Observatoire Royal de Belgique (ORB). As of June 2007, 23 laboratories regularly provide such P3 data. Time links computed using these data are systematically compared to those generated by other available techniques, notably for two-way time transfer. Geodetic-type receivers also provide raw phase measurements which may be used, along with the code measurements, to compute time links. This is routinely done by the IGS for some time laboratories which are also part of the IGS network. In addition, new Precise Point Positioning (PPP) software, obtained in collaboration with geodetic institutes, allows the BIPM to compute its own solutions for such time links. Comparisons between PPP, IGS, P3 and two-way links have led to insightful results on the stability of each technique. A procedure to regularly compute PPP time links for TAI computation is being installed.

3.4.3 Two-way time transfer

Three meetings related to TWSTFT activities have been held since July 2006. The BIPM collects two-way data from 16 operational stations and undertakes treatment of some two-way links. About ten TWSTFT links are routinely used in the computation of TAI; some others are in preparation for their introduction into the computation of TAI. The BIPM is also involved in the calibration of two-way time-transfer links by comparison with GPS.

3.4.4 Uncertainties of TAI time links

The values of the type A and type B uncertainties of TAI time links are published in the *Circular T*, together with the information on the time links used in each monthly calculation.

3.4.5 Calibration of TAI time links

The BIPM is conducting a series of calibrations of GPS time equipment in time laboratories which contribute to TAI. From July 2006 to June 2007,

GPS/GLONASS time equipment in three laboratories and GPS P3 equipment in seven laboratories have been calibrated. The BIPM is also taking part in the organization of TWSTFT calibration trips.

3.5 Key comparisons (E.F. Arias, W. Lewandowski and L. Tisserand)

Monthly updates of key comparison in time CCTF-K001.UTC are published after the publication of *Circular T*. Timing centres in laboratories who are participants to the CIPM MRA from Member States and Associates of the CGPM, take part in this key comparison.

3.6 Pulsars (G. Petit)

Collaboration continues with the Observatoire Midi-Pyrénées (OMP), Toulouse, and other radio-astronomy groups observing pulsars and analyzing pulsar data to study the potential capability of millisecond pulsars as a means of sensing the very long-term stability of atomic time. The Time, Frequency and Gravimetry section provides these groups with its post-processed realization of Terrestrial Time.

3.7 Space-time references (E.F. Arias, G. Petit and P. Wolf*)

A web and ftp site for the *IERS Conventions* has been established at the BIPM (<http://tai.bipm.org/iers/>) and a user discussion forum has been created (<http://tai.bipm.org/iers/forum/>) for users to offer comments related to the future updates of the *IERS Conventions*. Updates to the *Conventions* (2003) have been posted on the website (<http://tai.bipm.org/iers/convupdt>). These updates consider several new models for effects that affect the positions of Earth's points at the mm level, which is now significant. These modifications are studied with the help of the Advisory Board for the *IERS Conventions* updates, including representatives of all groups involved in the IERS.

Activities related to the realization of reference frames for astronomy and geodesy are developed in cooperation with the IERS. In these domains, improvements in accuracy will enhance the need for a full relativistic treatment and it is essential to continue participating in international working groups on these matters; e.g. through the new IAU Commission "Relativity

* Physicist until 31 December 2006.

in Fundamental Astronomy". Cooperation continued for the maintenance of the international celestial reference system and work started in the framework of the IAU, IVS and IERS for the construction of a new conventional reference frame.

3.8 Comb development (R. Felder and L. Robertsson)

The year-long cooperation we have had with NIST concerning optical frequency comb characterization has been completed and reported. A compilation of the results from several experiments using different techniques has been published confirming our earlier results of the excellent homogeneity of the comb spectrum.

3.9 BIPM key comparison BIPM.L-K11 (R. Felder and L. Robertsson)

In 2003, the 22nd General Conference endorsed the proposal of the CIPM to close the BIPM Length section during 2006. Consequently, the BIPM can no longer pilot the BIPM.L-K11 key comparison and the last measurements were made in the end of 2006 on lasers from Egypt, France, Italy, the Republic of Korea, and Turkey.

Besides providing direct traceability for these standards, the measurements constitute a high-level traceability network from which the reduced uncertainty in the realization of the metre implementation can extend to smaller NMIs. Furthermore, the accumulated information from these measurements provides better values for the recommended radiations that are to be included in the *Mise en pratique*, yielding an improvement which was not available for the different frequency comparisons made in BIPM.L-K10.

It is also worth noting that after the introduction of comb technology into some smaller NMIs, participation in BIPM.L-K11 has been seen as a way to provide comb validation to a level relevant to support their claimed measurement capability.

To meet the requests of the CCL and the needs of NMIs for such comparisons a questionnaire was prepared and distributed to the Member States. The responses indicated that there continues to be a need for this type of measurement and a distributed structure for the continuation of BIPM.L-K11 has therefore been proposed. In this proposal, the BEV (Austria) will serve as the pilot laboratory together with four node laboratories, MIKES, NMIJ, NPL and NRC, in the different RMOs. Final

details concerning the operation of the new comparison named CCL-K11 will be discussed during the September meeting of the CCL in 2007.

3.10 Calibration and measurement service (R. Felder, J. Labot and L. Robertsson)

In addition to the formal BIPM.L-K11 programme, the Section has provided calibration and measurement service for internal as well as specific external needs. With the closure of the Length section and the BIPM.L-K11 comparison, the service for external users has also stopped. However, a certain need of laser characterisation and frequency determinations for internal use does exist at the BIPM, and our reference lasers and the combs have been used for such internal needs during the year. This includes the lasers for iodine cell quality testing, both at 633 nm and 532 nm, lasers for the calculable capacitor project and the gravimeter instrumentation at the BIPM. Modern gravimeters are equipped with frequency-stabilized laser sources used for the determination of the position of the falling test mass. In contrast to other sites suitable for comparisons of gravimeters, the BIPM is able to provide unique facility of laser characterisation in connection to the International Comparisons of Absolute Gravimeters (ICAG) that are carried out every four years at the BIPM, thereby making this site even more attractive.

3.11 Iodine cells (R. Felder, J. Labot and L. Robertsson)

Few NMIs maintain an ability to manufacture iodine cells for stabilized lasers, as it is a complex activity which requires 'know-how' as well as a laboratory system. The BIPM provides this service based on accumulated experience as a cost recovery activity. We have continued to receive a strong demand for iodine cells from NMIs and laboratories for use in stabilized lasers and in spectroscopy. This year, we have sold a total of 16 iodine cells. It is important to note that this demand concerns, to a great extent, specially designed cells with specific geometrical features.

In response to pumping problems, the vacuum system used for the filling process of iodine cells has been completely dismantled and rebuilt several times. As this vacuum system is now almost 25 years old, it is probably time to think about its replacement.

A number of NMIs have indicated an interest in using a new type of iodine cell, which should lead to enhanced performance of stabilized lasers. Based

on its current facilities, the BIPM has therefore carried out the first steps in the provision of a filling service for such cells. This cell is based on a hollow optical fibre, evacuated and filled with iodine. It is suggested that by using the guided mode of the fibre to define the electromagnetic field distribution, rather than the mirror position, improved reproducibility could be obtained, and by using longer fibres, a better short-term stability could be envisaged. However, it is a considerable technical challenge to realise such a fibre-cell. A 50 cm long fibre has been evacuated, filled and sealed and first spectroscopic signals recorded. The linear absorption of several lines in molecular iodine was observed.

The standard iodine cells we produce are controlled by a frequency comparison with our reference laser BIW 167. The iodine cells are therefore placed in the cavity of an auxiliary laser, BIPM7, for which we needed to replace the gain tube. The mechanical assembly of this laser has been modified and several He-Ne laser tubes have been tested before we get a satisfying running operation.

Specially designed cells with specific geometrical features cannot be controlled by using a (He-Ne)/I₂ laser. In this case, the cells under test are placed in a (Nd:YAG)/I₂ system which is compared by a beat frequency method to our reference device at $\lambda = 532$ nm, previously calibrated using our frequency comb. The whole set-up has been re-started to respond to this demand of specific iodine cells.

3.12 Gravimeter FG5-108 (L. Vitushkin and O. Orlov*)

The compact Nd:YVO₄/KTP/I₂ laser at a wavelength of 532 nm (output laser power of 3.5 mW) was modified at the VNIIM and installed on the interferometer of the absolute gravimeter simultaneously with the conventionally used He-Ne/I₂ laser at a wavelength of 633 nm (output laser power of about 100 μ W). This made it possible by means of the convenient alignment of the interferometer to make the measurement of the motion of free-falling test body simultaneously or successively using both (or one of the) laser radiations. The input laser beam at 532 nm was attenuated to obtain the same amplitude of the interference signal as that at 633 nm.

The successive measurements of free-fall acceleration g with the laser radiations at 532 nm and 633 nm were performed at the site A of the BIPM

* Guest scientist from VNIIM.

using the conventional data acquisition system of the FG5-108 and the software NEWTON 3.12. The difference between the results obtained at two wavelengths was less than 2 μ Gal.

The acquisition of the interference signals at both wavelengths was made using the BIPM's new data acquisition system based on the fast data acquisition card with the sampling rate of 100 M samples/s.

The dropping chamber of the FG5-108 was sent in March 2007 for repair and maintenance to the producer "Micro-g LaCoste, Inc."

3.13 Gravimetry, theoretical investigations

3.13.1 Truncation tests of the results of g measurements (L. Vitushkin and V. Nalivaev*)

The truncation tests, i.e. the study of the dependence of the results of g measurement on the choice of the initial and final interference fringes of the series of recorded fringes used in the data processing, were performed for the data obtained with the gravimeter FG5-108 during the comparison ICAG-2005.

3.13.2 Correction related to the distortion due to diffraction effects (L. Robertsson)

The modern design of an absolute gravimeter is based on laser interferometers for the determination of the time-dependent position of the falling test mass. Ideally, the light field for such an interferometer is considered to be a monochromatic plane wave of infinite lateral extension. However, the fact that the laser sources most often used have a resonant cavity composed of spherical mirrors imposes broader conditions on the Helmholtz equation giving beam-like solutions with different spatial extensions. For each of these, minute corrections in the phase progression compared to the plane wave approximation are present. A study has been made in which expressions for these phase-corrections were derived for the case of a two-beam interferometer. The contribution from these diffraction-induced shifts to the g value determined in absolute gravimetry has been calculated.

* Guest scientist from VNIIMS.

3.13.3 Correction related to the finite speed of light (L. Vitushkin)

The existing methods for the evaluation of the correction to the results of g measurements related to the effects of the light propagation in the interferometer with the free-falling reflector are under analysis for the preparation of the recommendations by the CCM Working Group on Gravimetry on the evaluation of such a correction for the absolute ballistic gravimeters.

3.14 **The 7th International Comparison of Absolute Gravimeters, ICAG-2005** (Z. Jiang and L. Vitushkin)

The results of the absolute and relative measurements have been presented to the pilot laboratory, the BIPM. The discussion group (moderated by A. Germak, INRIM) was organized at the Second Joint Meeting of the CCM Working Group on Gravimetry and IAG Study Group 2.1.1 on Comparison of Absolute Gravimeters (METAS, 7-8 June 2006) to help some groups from the geophysical community to evaluate the uncertainty budget according to the GUM.

The preparation of the Report A on the ICAG-2005 is in progress.

3.15 **Preliminary study on the BIPM watt balance project in view of gravimetry** (Z. Jiang)

The watt balance requires an uncertainty of 10^{-8} in the absolute gravity value. An initial investigation has been carried out for accurate gravity measurements, of the equipment and the influence of local and global environment.

3.16 **Publications, lecture, travel: Time, Frequency and Gravimetry section**

3.16.1 External publications

1. Arias E.F, Time scales and relativity, *Proc. International School of Physics "Enrico Fermi", Course CLXVI, Metrology and Fundamental Constants*, Societa Italiana di Fisica, 2007, 367-392.
2. Jiang Z., Dach R., Petit G., Schildknecht T., Hugentobler U., Comparison and combination of TAI time links with continuous GPS carrier phase results, *Proc. EFTF-IFCS 2006*, 2007, 440-447.

3. Jiang Z., Petit G., Redundancy in the TAI TWSTFT time transfer network, *Proc. EFTF-IFCS 2006*, 2007, 468-475.
4. Ma L.-S., Bi Z., Bartels A., Kim K., Robertsson L., Zucco M., Windeler R.S., Wilpers G., Oates C., Hollberg L., Diddams S.A., Frequency Uncertainty for Optically Referenced Femtosecond Laser Frequency Combs, *IEEE J. Quant. Electr.*, 2007, **43**(2), 139.
5. Matsakis D., Lee M., Dach R., Hugentobler U., Jiang Z., GPS Carrier Phase Analysis Noise on the USNO-PTB Baselines, *Proc. FCS 2006*, 631-636.
6. Matsakis D., Arias E.F., Bauch A., Davis J., Gotoh T., Hosokawa M., Piester D., On optimizing the configuration of time-transfer links used to generate TAI, *Proc. 20th EFTF*, 2006, 448-454.
7. Nawrocki J., Rau Z., Lewandowski W., Małkowski M., Marszalec M., Nerkowski D., Steering UTC(AOS) and UTC(PL) by TA(PL), *Proc. 38th PTTI - Applications and Planning Meeting*, 2006, Reston, VA, 2007, 379-388.
8. Petit G., Defraigne P., Warrington B., Uhrich P., Calibration of dual frequency GPS receivers for TAI, *Proc. 20th EFTF*, 2006, 455-459.
9. Petit G., Jiang Z., Using a redundant time link system in TAI computation, *Proc. 20th EFTF*, 2006, 436-439.
10. Robertsson L., On the diffraction correction in absolute gravimetry, *Metrologia*, 2007, **44**, 35-39.

3.16.2 BIPM publications

11. *BIPM Annual Report on Time Activities for 2006*, 2007, **1**, 100 pp.
12. *Circular T* (monthly), 7 pp.

3.16.3 Travel (conferences, lectures and presentations, visits)

E.F. Arias to:

- Santiago de Compostela (Spain), 24 November 2006, invited lecturer at the Jornada de Metrología;
- San Francisco (United States), 8-9 December 2006, for the IGS Strategic Planning Retreat; 10 December 2006, for the 29th meeting of the IGS Governing Board; 12 December 2006, for the 7th GGOS Steering Committee meeting;

- Vienna (Austria), 21 February and 5 June 2007, for preparatory meetings of the International Committee on GNSS;
- Paris (France), 21 March 2007, for the Journée Martine Feissel at the Séminaire Espace-temps à l'Observatoire de Paris, with an invited presentation;
- Geneva (Switzerland), 28 May – 1 June 2007, for the joint EFTF/FCS meeting and for the meeting of the CCTF Working Group on Primary Frequency Standards.

E.F. Arias and G. Petit to Prague (Czech Republic), 15-24 August 2006, for presentations to the 26th General Assembly of the International Astronomical Union.

E.F. Arias and W. Lewandowski to Geneva (Switzerland), 28 August – 1 September 2006, for the meeting of the Working Party 7A of the International Communications Union (ITU).

Z. Jiang to:

- Istanbul (Turkey), 28 August – 1 September 2006, for the First Symposium of the International Gravity Field Service, presentation;
- Hsinchu (Chinese Taipei), 12-15 March 2007, for the First Asia Workshop on Superconducting Gravimetry, presentation;
- Geneva (Switzerland), 29 May – 1 June 2007, for the joint EFTF/FCS meeting, presentation.

W. Lewandowski to:

- Warsaw (Poland), several trips of a few days each to the Space Research Centre and Central Office of Measures;
- Brussels (Belgium), several trips of a few days each to the Galileo Joint Undertaking;
- Turin (Italy), 12-14 July 2006, for the CPEM 2006, for a poster presentation;
- Fort Worth (Texas, United States), 23 September – 1 October 2006, for the 46th meeting of the Civil GPS Service Interface Committee (chairmanship of the Timing Sub-committee), and for the ION GNSS;
- Noordwijk (The Netherlands), 2-3 November 2006, for a Galileo Time Advisory Group at the ESA ESTEC facilities;
- Washington DC (United States), 4-8 December 2006, for the PTTI meeting and CGGTTS and TWSTFT Working Groups meetings;

- New Delhi (India), 9-16 December 2006, for the APMP ATF'2006 meeting with an invited presentation;
- Florence (Italy), 19-22 May 2007, for the Fluctuations and Noise SPIE Meeting with an invited presentation;
- Geneva (Switzerland), 27 May – 1 June 2007, for the joint EFTF/FCS meeting with a poster presentation.

G. Petit to:

- Nançay (France), 6 July 2006, for participation in pulsar observations;
- Turin (Italy), 10-13 July 2006, for the CPEM 2006, with a presentation;
- San Francisco (United States), 10-15 December 2006, for a meeting of the IERS Directing Board, and for the AGU Fall meeting;
- Vienna (Austria), 15-18 April 2007, for the General Assembly of the European Geophysical Union, with a presentation, and for a meeting of the IERS Directing Board;
- Paris (France), 3 May 2007, for a workshop “Pulsars théories et observations”, with a lecture; 15 May 2007, for a review group for the CNES;
- Geneva (Switzerland), 28 May – 1 June 2007, for the joint EFTF/FCS meeting, presentations, meeting of the CCTF Working Group on Primary Frequency Standards.

R. Felder to ENSAM, Paris (France), 11-13 June 2006, for a training course on Wolfram Mathematica.

R. Felder and L. Robertsson to:

- Turin (Italy), 10-14 July 2006, for the CPEM 2006;
- NPL, Teddington (United Kingdom), 3-4 October 2006, for the International Workshop on Optical Frequency Combs for Space.

J. Labot to Noizay (France), 6-9 November 2006, for a training course of glass blowing.

L. Robertsson to:

- Gothenburg (Sweden), 20 October 2006, for the Symposium on cluster science and spectroscopy;
- NRC, Ottawa (Canada), 21-26 October 2006, as technical expert for the assessment of the optical frequency group;
- NMIA, Sydney (Australia), 14-16 May 2007, for discussions on the calculable capacitor project;

- Tsukuba (Japan), 18 May 2007, for the joint NMIJ-BIPM Workshop on optical frequency comb, with a presentation on “Laser frequency combs as working tools for the dissemination of the metre”;
- Singapore, 21 May 2007, for a visit to the National Metrology Centre SPRING Singapore;
- Bad Honnef (Germany), 4-7 June 2007, for the symposium “Atomic clocks and fundamental constants”, session chairman.

L. Vitushkin to:

- Istanbul (Turkey), 28 August – 1 September 2006, for the First Symposium of the International Gravity Field Service, presentation and the round table on the standardization of the presentation of the results of the absolute gravity measurements;
- Querétaro (Mexico), 22-27 October 2006, for a presentation at the Symposium on metrology and for the discussion on the construction of the site for absolute gravity measurements at CENAM;
- San Jose (United States), 10 November 2006, for a presentation on the proposed experiment on the measurement of the gravitational constant at Stanford University;
- College Park (United States), 14 November 2006, for a presentation on the proposed experiment on the measurement of the gravitational constant at Maryland University;
- Moscow (Russian Federation), 30 January 2007, for three presentations at the Moscow Seminar on gravimetry at the O. Yu. Schmidt Institute for the Physics of the Earth;
- Hsinchu (Chinese Taipei), 12-15 March 2007, for a presentation at the First Asia Workshop on superconducting gravimetry;
- St Petersburg (Russian Federation), 23-25 April 2007, for the meetings on the design of the absolute ballistic gravimeter and for the meeting of the international scientific committee of the Symposium “Terrestrial gravimetry. Static and mobile measurements – TG-SMM-2007”.

3.17 Activities related to external organizations

E.F. Arias is a member of the IAU, participating in three of its working groups: on nutation, on the international celestial reference system, and on the redefinition of UTC. She is an associate member of the IERS, a member of the International Celestial Reference System Product Centre, and of the

Conventions Product Centre of the IERS. She is a member of the International VLBI Service (IVS), and of its Analysis Working Group on the International Celestial Reference Frame. She is the BIPM representative at the Governing Board of the IGS. She is the BIPM representative to the International Committee for GNSS. She is a member of the Argentine Council of Research (CONICET) and an associated astronomer at the SYRTE, Paris Observatory. She is the corresponding member of the Bureau des Longitudes. She is the BIPM representative to the Working Party 7A of the Study Group 7 of the ITU-R, and a member of its Special Rapporteur Group on the future of UTC.

W. Lewandowski is the BIPM representative to the Civil GPS Service Interface Committee and Chairman of its Timing Sub-committee. He is a member of the Scientific Council of Space Research Centre of the Polish Academy of Sciences. He also chairs a Working Group on Scientific Metrology at Polish Ministry of Economy. Together with E.F. Arias, he is the BIPM representative to the Working Party 7A of the Study Group 7 of the ITU-R.

G. Petit is co-director of the Conventions Centre of the IERS and representative (until end 2006) to the Directing Board of the IERS. He is vice-president of the IAU Commission 52 "Relativity in fundamental astronomy", member of the IAU Working Group on Numerical Standards in Fundamental Astronomy, of the IGS Working Group on Clock Products and of the Fundamental Physics Group of the CNES.

L. Vitushkin is the chairman of the Study Group 2.1.1 on Comparison of Absolute Gravimeters of the IAG Commission 2 "Gravity field". He is member of the International Scientific Committee of the IAG Symposium "Terrestrial gravimetry. Static and mobile measurements – TG-SMM-2007" that will take place on 20-23 August 2007 in St Petersburg (Russian Federation).

3.18 Activities related to the work of Consultative Committees

E.F. Arias is Executive Secretary of the CCTF. She shares with R. Felder the Secretariat of the CCL/CCTF Joint Working Group on Frequency Standards. She is a member of the CCTF Working Groups on Two-Way Satellite Time and Frequency Transfer, on Primary Frequency Standards and of the Study Group on time links optimization of the CCTF WG on TAI.

Z. Jiang is a member of the CCTF Working Group on TWSTFT.

W. Lewandowski is Secretary of the CCTF Working Group on TWSTFT and Secretary of the CCTF Working Group on Global Navigation Satellite Systems Time-transfer Standards.

L. Vitushkin is the chairman of the CCM Working Group on Gravimetry.

G. Petit is a member of the CCTF working groups on TAI, on algorithms, on primary frequency standards, and on the CGGTTS.

R. Felder is the Executive Secretary of the CCL and Joint Secretary to the Joint CCL/CCTF Working Group on Frequency Standards. The report of the 12th meeting of the CCL (2005) has been completed and posted on the BIPM website with the corresponding working group reports. The updating of the *Mise en pratique* list of the CCL, on the BIPM website, has been made.

A meeting of the CCL/CCTF Joint Working Group on Frequency Standards was held at BIPM on 11-12 September 2006. A list of recommended frequencies as secondary representations of the second was established and recommended by the CCTF and the CIPM.

The 13th meeting of the CCL will be held at BIPM, 13-14 September 2007. It will be preceded by its subsequent working groups (WGDM and CCL/CCTF Joint Working Group on Frequency Standards).

In the framework of the transfer of key comparison CCL-K11, L. Robertsson has redesigned the technical protocol.

3.19 Visitors to the Time, Frequency and Gravimetry section

- Dr J. Faller (JILA/NIST), 5 July and 19 December 2006.
- Mrs A. Foks (SRC), 31 August – 22 September 2006.
- Prof. L.-S. Ma, 12-20 September 2006.
- Dr P. Balling (CMI) and Dr M. Merrimaa (MIKES), and Mr G. Mileti (ON), 12 September 2006.
- Dr Yu. S. Domnin (VNIIFTRI) and Dr F.-L. Hong (NMIJ/AIST), 13 September 2006.
- Mr R. Holzwarth (MENLO Systems), 26 September 2006.
- Mr Y. Kobayashi (AIST/NMIJ), 2 October 2006.
- Ing. M. Orain, M.-C. Mérianne and F. Grisch (ONERA), 6 October 2006.
- Dr P. Tuckey and Mr D. Valat (LNE-SYRTE), 12 October 2006.

- A team of Discovery Channel Television, 14 November 2006.
- Dr H.S. Suh (KRISS) and Dr H. Hatem (NIS), 20 November – 1 December 2006.
- Dr F. Bertinetto and Dr P. Cordiale (INRIM), 27 November – 1 December 2006.
- Dr J.-P. Wallerand (LNE-INM/CNAM), 27-30 November 2006.
- Dr R. Hamid and Dr E. Sahin (UME), 4-8 December 2006.
- Mr M. Fleury (Micro-Contrôle, France), 21 December 2006.
- Dr A. Michaud (NRC), 13 March 2007.
- Ing. X. Messing (BOC Edwards, France), 30 March 2007.
- Dr C. Clarck (NIST), 15 May 2007.
- Mrs M. Miho (Nippon News Network), 6 June 2007.
- Drs Zhengming Wang, Haibo Yuan (NTSC), 4-9 June 2007.
- Dr H. Belaidi (INMETRO), 19 June 2007.

3.20 Guest workers

- Dr O. Orlov (VNIIM), 27 November – 20 December 2006, for the experiments on the absolute gravity measurements with the laser at 532 nm.
- Dr V. Nalivaev (VNIIMS), July 2006, to work on truncation tests of the results of g measurements.

4 **ELECTRICITY (T.J. WITT*)**

4.1 **Electrical potential: Josephson effect** (R. Chayramy, D. Reymann** and S. Solve)

4.1.1 Josephson array measurements

The improvement of the Josephson equipment is still in progress. The new probe holder designed for the calibration of Zener diodes has been successfully tested and is now operational. A second one, designed for the compact transportable standard has been assembled. The oversized circular waveguide is divided into two parts which are assembled for the comparison and disassembled for transportation. A new Cryoperm[®] magnetic shield and its fastening apparatus have been designed. The electronic filters have been mounted and have shown the expected frequency response. The reproducibility of the rf power distribution along the waveguide has been studied. For this purpose, a dedicated power measurement chain has been set up. It will also serve to characterize the batch of microwave sources that we use to bias Josephson arrays.

The latest version of a commercial compact programmable microwave-source has been successfully operated under the conditions of a comparison of two Josephson array voltage standards (JAVS).

We received two new programmable Josephson arrays: a 10 V SINIS array was donated by PTB and a 1.2 V SNS array was donated by NIST. Preliminary tests have confirmed that they both operate well under the BIPM experimental conditions. In the future, the 10 V chip will be used as primary standard for Zener calibrations and the 1.2 V chip should be implemented as the electromotive force standard of the BIPM watt balance.

The activities in the field of voltage measurement were audited in September 2006, with special attention paid to knowledge transfer from D. Reymann (retired on 30 September 2006) to S. Solve. Both the implementation of the quality procedures and the knowledge transfer were validated by the external auditor.

* Retirement on 30 June 2007.

** Until his retirement on 30 September 2006.

4.1.2 Zener diode measurements

In the first series of measurements, the new automatic system developed to measure the 1.018 V output of Zener voltage standards (see Director's Report 2005-2006) has been carried out using two different types of null detectors: an analog null detector and a digital nanovoltmeter. Even if the results obtained are coherent, some improvements are still necessary. As the new system doesn't share any components with the old one, a period of measurement with both systems in parallel is planned in the future to detect any systematic difference and to ensure the traceability of our Zener measurements.

4.2 Electrical resistance and impedance

4.2.1 DC resistance and quantum Hall effect

(F. Delahaye*, N. Fletcher, R. Goebel and A. Jaouen)

Three long-standing members of the Section retired in 2006 and early 2007. They have been replaced successfully and, as planned, with three staff of the Photometry and Radiometry section which closed in 2004 and who have been working alongside the three retiring staff for the last years.

The routine work of maintenance of the QHR primary reference and the calibration of the first-level working standards was conducted mainly by the new staff members, as part of their training under the supervision of F. Delahaye.

Pairs of QHR samples have been assembled, using the micro-bonding facility, both in parallel and series configurations. Their comparison with a single reference element allowed the whole resistance scaling to be checked with an accuracy of a few parts in 10^9 , including the one-hertz bridge and the ratio of our Hamon transfer resistor.

The activities in the field of resistance measurement were audited in October 2006, with special attention paid to knowledge transfer to the new staff members. Both the implementation of the quality procedures and the knowledge transfer were validated by the external auditor.

The cryogenic current comparator (CCC) constructed and validated last year is in routine use. A new version of the double current source associated with

* Until his retirement on 31 December 2006.

the CCC was constructed and is currently being tested in the framework of the progressive renewal of the instrumentation.

A NIST-BIPM bilateral comparison of one-ohm resistance was agreed during the last CCEM (following the BIPM.EM-K13.a protocol) to allow linking of a SIM comparison to BIPM.EM-K13.a. The preparation and the measurements of the BIPM travelling standards have started, and the comparison should be completed by the end of 2007.

The laboratory housing the QHR facility was completely refurbished. The measurements carried out just after the reinstallation of the equipment demonstrated that the refurbishment had no measurable influence on the results.

4.2.2 Maintenance of a reference of capacitance (R. Chayramy, F. Delahaye*, R. Goebel and N. Fletcher)

The training of the new section members on the various coaxial bridges in use for calibrations and for linking capacitance to the QHR reference continued until the end of 2006. In September 2006, a successful external audit validated the knowledge transfer to the new staff, as well as the implementation of the Quality System and procedures.

After continued investigations of a new version of the ac/dc transfer resistors used in the quadrature bridge, a change in the measurement sequence was implemented, giving a useful improvement in type A uncertainty. The scatter on repeat quadrature transfers (from resistance to capacitance) is now better than 1 part in 10^8 . The largest remaining component in the overall uncertainty for the measurement chain is the knowledge of the frequency dependence (between 1 Hz and 1541 Hz) of the resistors. This will be addressed in the coming months with a campaign of measurements with reference to the existing BIPM coaxial standard resistors (which have calculable frequency dependence). This work on the quadrature bridge has included the first application of Allan variance analysis to the noise properties of the BIPM coaxial bridges.

In June 2007, the bridges and standards for capacitance work were moved to the recently refurbished laboratory where the calculable capacitor (see special projects) will be housed. The BIPM primary reference group of four

* Until his retirement on 31 December 2006.

10 pF standards was transferred to a new temperature controlled oil bath in this laboratory (the old bath having reached the end of its serviceable life). Measurements (including the link to the QHR) before and after the move showed that there was no significant disruption to the values of the standards. Calibrations of capacitors for NMIs are due to restart in July 2007. The new laboratory benefits from improved air-conditioning, and is also closer to the QHR laboratory. A cable has been installed which allows a direct connection to the QHR apparatus, meaning that no standards need now be moved to make the link from QHR to 10 pF. When the calculable capacitor is installed, it will be possible to make the proposed measurement of R_K entirely in one room.

Measurements of a set of four 10 pF travelling standards have been begun in preparation for a bilateral comparison with NIST (on-going key comparison BIPM.EM-K14.a). The relative combined uncertainty for this comparison is expected to be better than 1 part in 10^7 . A good result at this level of uncertainty will provide a rigorous validation of the BIPM's uncertainty budgets for capacitance traceability. The comparison should also be a useful exercise for both laboratories in preparation for measurements of R_K .

4.3 Time-series analysis of measurement results (T.J. Witt*)

This year we have addressed the problem of calculating the variance of the mean, $\text{var}(\bar{X})$, of a time series of stochastically correlated measurements of a weakly stationary process. In such cases, the variance of the mean of n measurements is often calculated incorrectly as $\text{var}(X)/n$. This important quantity can be correctly expressed in terms of the autocorrelation function (ACF) at lag k , $\rho(k)$. This approach was used to evaluate $\text{var}(\bar{X})$ for white voltage noise measured at regular time intervals τ_0 through a low pass filter of bandwidth B by four methods: (1) by developing the expression $\rho(k) = \exp(-4B\tau_0k)$ evaluated by estimating B from the sample spectrum; (2) by noting that $\rho(k) = \phi^k$, $\phi = \exp(-4B\tau_0) < 1$, is the ACF of a first order autoregressive process, AR(1) for which $\text{var}(\bar{X})$ is readily evaluated in terms of ϕ ; (3) by estimating $\text{var}(\bar{X})$ from the sample ACF, $\hat{\rho}(k)$, using the cut-off lag for an AR(1) process; (4) by applying the general method recently proposed by Zhang (*Metrologia*, 2006, **43**, S276-S281), to estimate $\text{var}(\bar{X})$ from $\hat{\rho}(k)$, assuming that the data may be described by a moving average process with a cut-off lag deduced from the (k) themselves. The values of

* Retirement on 30 June 2007.

$\text{var}(\bar{X})$ from the four methods are in good agreement. This provides firm support of Zhang's method, which is important because of this method's wide scope of application. The results of this work can be applied directly to some of the ongoing measurements in the Electricity section but the scope of application is extremely broad and extends well beyond metrology. This work has recently been published in *Metrologia* (see list of publications in the section).

4.4 Thermometry (R. Chayramy, S. Solve and M. Stock)

The internal calibration service for thermometers in the room temperature range is operated by S. Solve who also works in dc voltage metrology. The retirement of D. Reymann led to the decision to concentrate on the latter field and to interrupt the thermometry calibration service for a period of one year. In autumn 2007, we will review the need for this in-house activity. In the meantime, BIPM's thermometers are calibrated at the LNE.

4.5 BIPM ongoing key comparisons in electricity

(R. Chayramy, F. Delahaye*, N. Fletcher, R. Goebel, A. Jaouen, D. Reymann**, S. Solve and T.J. Witt***)

In the ongoing BIPM key comparison programme, BIPM.EM-K10.b (10 V Josephson standards, on-site), we have participated in one new 10 V JAVS comparison, with the NMi VSL (The Netherlands) in October 2006. The comparison was successful, which is of particular significance since it is the first Josephson comparison carried out since the retirement of D. Reymann; it demonstrates the successful transfer of knowledge of this important comparison programme to the younger staff. For completeness, we also list the results of INMETRO and NMIA which were not available for inclusion in last year's Director's Report:

$$\begin{aligned} (U_{\text{INMETRO}} - U_{\text{BIPM}})/U_{\text{BIPM}} &= +19 \times 10^{-10}, & u_c/U_{\text{BIPM}} &= 16 \times 10^{-10} \\ (U_{\text{NMIA}} - U_{\text{BIPM}})/U_{\text{BIPM}} &= +0.9 \times 10^{-10}, & u_c/U_{\text{BIPM}} &= 1.7 \times 10^{-10} \\ (U_{\text{NMi VSL}} - U_{\text{BIPM}})/U_{\text{BIPM}} &= -1.5 \times 10^{-10}, & u_c/U_{\text{BIPM}} &= 1.8 \times 10^{-10}. \end{aligned}$$

* Until his retirement on 31 December 2006.

** Until his retirement on 30 September 2006.

*** Retirement on 30 June 2007.

The noise in the BIPM Josephson array voltage is negligible compared to the intrinsic noise of a Zener standard so that these comparisons make it possible to identify sources of error otherwise buried in the noise.

The CCEM has approved our proposal of a modified protocol for the BIPM bilateral comparisons of Josephson voltage standards, BIPM.EM-K10.a and BIPM.EM-K10.b. In the modified procedure, not only the final results, but also the preliminary results will be published, if the work during the comparison campaign led to a significant improvement of the participant's standard. The final results will be considered as a follow-up comparison, and only these will be displayed in the comparison graphs in the KCDB.

Ongoing BIPM voltage comparisons using electronic voltage standards as transfer standards (BIPM.EM-K11.a and .b) were made at 10 V with the NML (Ireland) in April 2007. The results are not yet available.

The results of the comparison with the NCM (Bulgaria) carried out in 2006 (see Director's Report 2005-2006), are:

$$\text{At } 1.018 \text{ V: } (U_{\text{NCM}} - U_{\text{BIPM}}) = -1.39 \text{ } \mu\text{V}, \quad u_c = 1.0 \text{ } \mu\text{V}$$

$$\text{At } 10 \text{ V: } (U_{\text{NCM}} - U_{\text{BIPM}}) = -0.99 \text{ } \mu\text{V}, \quad u_c = 4.0 \text{ } \mu\text{V}$$

where u_c is the combined overall standard uncertainty.

Ongoing BIPM resistance comparisons at 1 Ω (BIPM.EM-K13.a) and at 10 k Ω (BIPM.EM-K13.b) were made last year with the INM (Romania) and the NML (Ireland) but the results were not available for inclusion in last year's Director's Report. Those results are:

$$(R_{\text{INM}} - R_{\text{BIPM}})/1 \text{ } \Omega = +7.0 \times 10^{-8}, \quad u_c/1 \text{ } \Omega = 13 \times 10^{-8}$$

$$(R_{\text{INM}} - R_{\text{BIPM}})/10 \text{ k}\Omega = -9 \times 10^{-8}, \quad u_c/10 \text{ k}\Omega = 9 \times 10^{-8}$$

$$(R_{\text{NML}} - R_{\text{BIPM}})/1 \text{ } \Omega = 0 \times 10^{-8}, \quad u_c/1 \text{ } \Omega = 19 \times 10^{-8}$$

$$(R_{\text{NML}} - R_{\text{BIPM}})/10 \text{ k}\Omega = +28 \times 10^{-8}, \quad u_c/10 \text{ k}\Omega = 46 \times 10^{-8}$$

where u_c is the combined standard uncertainty.

4.6 **Calibrations** (R. Chayramy, F. Delahaye*, N. Fletcher, R. Goebel, A. Jaouen, D. Reymann**, S. Solve and T.J. Witt***)

This year, the Electricity section calibrated the following standards: Zener diode standards at 1.018 V and 10 V for Egypt, Greece and Serbia; 1 Ω resistors for Austria, Egypt, Serbia and Thailand; 10 k Ω resistors for Austria, Denmark, Malaysia and Serbia; 1 pF capacitors for Brazil, Spain, Thailand and Turkey; 10 pF capacitors for Austria, Brazil, Finland, Greece, Mexico, Romania, Spain, Thailand and Turkey; and 100 pF capacitors for Austria, the Czech Republic, Finland, Greece, Mexico, Romania, Spain, Thailand and Turkey.

4.7 **Publications, lectures, travel: Electricity section**

Publications and travel of the section's staff related to the watt balance and calculable capacitor projects are listed under section 7.3.1.

4.7.1 External publications

1. Stock M., Witt T.J., CPEM 2006 Round table discussion 'Proposed changes to the SI', *Metrologia*, 2006, **43**, 583-587.
2. Reymann D., Solve S., Limits to the Accuracy of 10-V Josephson Standards Revealed by BIPM On-Site Comparisons, *IEEE Trans. Instrum. Meas.*, 2007, **56**, 555-558.
3. Fletcher N.E., Giblin S.P., Williams J.M., Lines K.J., New Capability for Generating and Measuring Small DC Currents at NPL, *IEEE Trans. Instrum. Meas.*, 2007, **56**, 326-330.
4. Solve S., Reymann D., Chayramy R., A New Fully Automated Measurement Chain for Electronic Voltage Standards at 1.018 V, *IEEE Trans. Instrum. Meas.*, 2007, **56**, 588-591.
5. Witt T.J., Using the autocorrelation function to characterize time series of voltage measurements, *Metrologia*, 2007, **44**, 201-209.

* Until his retirement on 31 December 2006.

** Until his retirement on 30 September 2006.

*** Retirement on 30 June 2007.

6. Urano C., Reymann D., Solve S. *et al.*, Comparison of two 10 V Josephson Arrays of the NMIJ-AIST, *CPEM 2006 Digest*, 2006, 392-393.
7. Klushin A.M., Solve S. *et al.*, A new millimeterwave synthesizer for Josephson Voltage Standards, *CPEM 2006 Digest*, 2006, 368-369.
8. Stock M., Solve S., International comparison of water triple point cells leading to a more precise definition of the kelvin, *Proc. Symposium of Metrology 2006*, Querétaro, Mexico, 2006, 6 pp.
9. Litorja L., Stock M., et al., Final report on the CCPR-S2 supplementary comparison of area measurements of apertures for radiometry, *Metrologia*, 2007, **44**, *Techn. Suppl.*, 02002.

4.7.2 BIPM reports

10. Georgieva U., Reymann D., Witt T.J., Bilateral comparison of 1.018 V and 10 V standards between the NCM (Bulgaria) and the BIPM, April to June 2006 (part of the ongoing BIPM key comparisons BIPM.EM-K11.a and .b), *Rapport BIPM-2006/05*, 7 pp.
11. Reymann D., Solve S., Afonso E., Ferreira V., Landim R.P., Comparison of the Josephson voltage standards of the INMETRO and the BIPM (part of the ongoing BIPM key comparison BIPM.EM-K10.b), *Rapport BIPM-2006/06*, 14 pp.
12. Reymann D., Solve S., Budovsky I., Rigby R., Comparison of the Josephson voltage standards of the NMIA and the BIPM (part of the ongoing BIPM key comparison BIPM.EM-K10.b), *Rapport BIPM-2006/09*, 12 pp.
13. Popovici G., Cirneanu L., Simionescu M., Jaouen A., Delahaye F., Fletcher N., Witt T.J., Bilateral comparison of 1 Ω standards (ongoing BIPM key comparison BIPM.EM-K13.a) between the INM (Romania) and the BIPM, May 2006, *Rapport BIPM-2006/11*, 6 pp.
14. Popovici G., Cirneanu L., Simionescu M., Jaouen A., Delahaye F., Fletcher N., Witt T.J., Bilateral comparison of 10 k Ω standards (ongoing BIPM key comparison BIPM.EM-K13.b) between the INM (Romania) and the BIPM, April 2006, *Rapport BIPM-2006/12*, 7 pp.
15. Power O., Jaouen A., Delahaye F., Fletcher N., Witt T.J., Bilateral comparison of 1 Ω standards (ongoing BIPM key comparison

BIPM.EM-K13.a) between the NML (Ireland) and the BIPM, April 2006, *Rapport BIPM-2006/13*, 6 pp.

16. Power O., Jaouen A., Delahaye F., Fletcher N., Witt T.J., Bilateral comparison of 10 k Ω standards (ongoing BIPM key comparison BIPM.EM-K13.b) between the NML (Ireland) and the BIPM, April 2006, *Rapport BIPM-2006/14*, 6 pp.

17. Solve S., Chayramy R., van den Brom H.E., Houtzager E., Comparison of the Josephson voltage standards of NMi VSL and the BIPM (part of the ongoing BIPM key comparison BIPM.EM-K10.b), *Rapport BIPM-2007/01*, 12 pp.

4.7.3 Travel (conferences, lectures and presentations, visits)

T.J. Witt, M. Stock, F. Delahaye, D. Reymann, N. Fletcher, R. Goebel and S. Solve to the CPEM 2006, Turin (Italy), 10-14 July 2006:

- D. Reymann presented a lecture entitled "Limits to the accuracy of 10 V Josephson standards revealed by the BIPM on-site comparisons", *CPEM 2006 Digest*, 12-13;
- N. Fletcher presented a lecture entitled "New capability for generating and measuring small dc currents at NPL", *CPEM 2006 Digest*, 152-153;
- S. Solve and D. Reymann presented a poster entitled "A new automated measurement chain for electronic voltage standards at 1.018 V", *CPEM 2006 Digest*, 370-371;
- T.J. Witt presented a lecture entitled "Using the autocorrelation function to characterize time series of voltage measurements"; *CPEM 2006 Digest*, 454-455;
- F. Delahaye and R. Goebel participated in the presentation of a poster entitled: "Preliminary investigation of the use of quantum Hall array resistance standards as travelling standard", *CPEM 2006 Digest*, 514-515.

F. Delahaye, N. Fletcher, R. Goebel, D. Reymann, S. Solve, M. Stock, and T.J. Witt attended the following CPEM 2006 satellite meetings in Turin (Italy):

- CCEM WG on monitoring the kilogram (M. Stock);
- CCEM WGRMO (T.J. Witt);
- CCEM WGLF (R. Goebel, S. Solve, M. Stock, T.J. Witt);

- CCEM GT-RF (S. Solve, M. Stock, T.J. Witt);
- CCEM WGACQHR (R. Goebel, T.J. Witt);
- CCEM WGSP (M. Stock, T.J. Witt);
- EUROMET EM sub-field: dc and quantum metrology (N. Fletcher, T.J. Witt);
- Specialist meeting on SET (N. Fletcher);
- CPEM Executive Committee (M. Stock, T.J. Witt).

T.J. Witt visited the INRIM electricity laboratories in Turin, on 14 July 2006.

T.J. Witt attended the EUROMET TCEM meeting at EIM, Thessaloniki (Greece), 18-20 October 2006; he presented a lecture entitled: "Towards new definitions of some SI units in terms of fundamental constants".

M. Stock to:

- CENAM, Querétaro (Mexico), to participate at CCPR working group meetings (WGKC, WGCMC, WGSP), 22-24 October 2006; to present a plenary lecture at the Metrology Symposium, 25 October 2006, on "Watt balances and the future of the kilogram" and to present a lecture on "International comparison of water triple point cells leading to a more precise definition of the kelvin";
- Bucharest (Romania), to participate at the EUROMET experts meeting for Radiometry and Photometry, PHORA, on 19-20 April 2006;
- PTB, Berlin (Germany), 18 October 2006, to attend the first meeting of the CCT SI Task Group and to give an overview presentation on the new SI;
- WMO, Geneva (Switzerland), 11 December 2006, to represent the BIPM at the meeting of the Commission on Instruments and Methods of Observation (CIMO).

N. Fletcher, R. Goebel and S. Solve attended meetings of the EUROMET TCEM subfields "DC and Quantum Metrology" and "Low Frequency", MIKES, Espoo (Finland), 25-29 June 2007.

S. Solve and R. Chayramy to Delft (The Netherlands), 18-25 October 2006, for a comparison of Josephson standards with NMI VSL.

S. Solve to:

- NIST, Boulder (United States), 1-8 October 2006, to select and learn to operate a 1.2 V SNS JAVS;
- LNE, Trappes (France), 2 February 2007, for technical discussions.

4.8 Activities related to external organizations

T.J. Witt is a member of the Executive Committee of the CPEM.

N. Fletcher is a member of the Program Committee of the CPEM.

4.9 Activities related to the work of Consultative Committees

T.J. Witt is Executive Secretary of the CCEM. He attended the CCEM working group meetings at CPEM 2006 in Turin, Italy (see 4.7.3). A meeting of the Working Group on Proposed Changes to the SI (WGSI) was held on 16-17 January 2007 at the BIPM. The CCEM meeting took place on 14-15 March 2007, preceded by three days of working group meetings (GT-RF, WGACQHE, WGLF, WGRMO, WGSP).

M. Stock is Executive Secretary of the CCPR and an *ex-officio* member of all CCPR working groups. The CCPR meeting was held on 21-22 June 2007, preceded by three days of working group meetings (WGKC, WGCMC, WGSP, WGUUV). M. Stock was Executive Secretary of the CCT until September 2006 and participated in the elaboration of the report of the CCT SI Task Group on implications of the kelvin redefinition. He is also a member of the CCEM Working Group on Strategic Planning and of the Working Group on Proposed Modifications of the SI. He became Executive Secretary of the CCEM in July 2007.

4.10 Visitors to the Electricity section

- Drs J. Butorac and D. Ilic (University of Zagreb, Faculty of Electrical Engineering and Computing, Croatia) and Mr R. di Silva (LNE), 14 September 2006; visits to the impedance, voltage and watt balance laboratories.
- Drs D. Woldman (scientific advisor to Dr W. Anderson) and A. Gilla (NIST), 4 October 2006; discussions of work in the Electricity section.
- Mr F. Overney (METAS), 7-8 September 2006, external quality audit on the capacitance measurements.
- Dr S. Djordjevic (LNE), 19-20 September 2006, external quality audit on the dc voltage calibrations.
- Dr D. Inglis (NRC), 16-17 October 2006, external quality audit on the resistance measurements.

- Dr R. Behr (PTB), 14-17 November 2006, delivery, operation and technical discussions on a 10 V SINIS array.
- Dr S. Djordjevic and Mr O. Seron (LNE), 14-17 November 2006, visit and discussions on voltage standards calibration setups.
- Dr C. Buchal (Jülicher SQUID GmbH) and Dr O. Monnoye (LNE), 23 February 2007, visit of the dc voltage laboratory and technical discussions.
- Dr A. Katkov (VNIIM), 15 March 2007, visit and discussions on the organization of a comparison of voltage standards.
- Dr K. Kyu-Tae, Dr K. Tae-Weon and Dr S. Yang Sup (KRISS), 16 March 2007, for a visit to the dc voltage laboratory.
- Dr K. Koji and Dr N. Yasuhiro (NMIJ), 16 March 2007, for a visit to the dc voltage laboratory.
- Dr W. van Bommel (Philips Lighting), President of the CIE, 2 April 2007, visit to the watt balance and electricity laboratories.
- Messrs J. Ferris, J. Gust and C. Hockert (NCSLI), 3 April 2007, visit to the watt balance and electricity laboratories.
- Mrs T. Cincar-Vujovic and Mr Z. Sofranac (DMDM), 17 April 2007, visit, discussions and collecting a voltage standard after calibration.

5 IONIZING RADIATION (P.J. ALLISY-ROBERTS)

5.1 X- and γ -rays

(P.J. Allisy-Roberts, D.T. Burns, C. Kessler, S. Picard and P. Roger)

5.1.1 Dosimetry standards and equipment

A new determination of the air kerma rate in the ^{60}Co reference field has been made using the variable-volume ionization chamber designed and manufactured at the BIPM, and a differential method in which changes in ionization current are measured for known changes in the chamber volume. The experiment required a large number of dimensional measurements, made using the co-ordinate measuring machine of the BIPM, as well as ionometric measurements for each chamber size, corrected for the effects of ion

recombination, polarity, orientation and stem scatter. Also required were high-precision Monte Carlo calculations of k_{wall} and k_{an} for each chamber size. When analysed differentially, the data for the variable-volume chamber give an air kerma rate higher than the existing standard by 2.7 parts in 10^3 . Of this, 1.5 parts in 10^3 are due to the different methods used, differential or direct. The remaining 1.2 parts in 10^3 arise from a difference between the direct volume determination for the new chamber and that for the existing standard. These results were presented to the CCRI and a decision was taken on the best estimate. This change will be implemented, along with the changes to the standard proposed in 2005, following the publication of the latest results in the open literature. At the same time, the higher activity (CIS-Bio) ^{60}Co source will be adopted as the reference field.

The results of Monte Carlo calculations of correction factors for the ^{60}Co absorbed dose to water standard were presented to the CCRI. Although these indicate an overall change of 4 parts in 10^3 , it was agreed to await the results of the BIPM calorimetric absorbed dose standard before a decision is made on the implementation of these changes. The results will be published in *Physics in Medicine and Biology*.

An absorbed dose graphite calorimeter, of a new design, is currently being constructed at the BIPM. The conception is such that the specific heat capacity of graphite at ambient temperature is used to obtain the absorbed dose directly from the measured temperature rise. For an improved understanding of the various uncertainties involved, a series of differential measurements of the specific heat capacity of graphite have been carried out during the past year, particularly to identify the causes of certain systematic effects. These measurements, combined with earlier direct measurements, have contributed to a robust uncertainty budget. The specific heat capacity of a particular graphite sample has been determined with a precision of 9 parts in 10^4 .

The specific heat capacity of synthetic sapphire, a reference material for specific heat capacity, has been determined recently with a combined relative uncertainty of 9 parts in 10^4 at ambient temperature. The result is in agreement with previous determinations made by other groups. The present study gives support to the reliability of the data and the stated uncertainty obtained for graphite, not only concerning the experimental method but also to the empirical analysis technique that is applied to the measured temperature-time dependent data.

An ensemble of samples has been machined from the same ultra-pure graphite block as the calorimeter core. These are currently being measured to determine the reproducibility of the measurements and to establish the value of the specific heat capacity of the core.

Most parts of the graphite calorimeter have now been machined and are being prepared for assembly.

Work on the BIPM mammographic facility has continued in preparation for mammography dosimetry comparisons. A new primary standard has been constructed, designed to minimize the uncertainty of the required correction factors. Initial measurements have led to an optimization of the air temperature measurement. A difference of around 4 parts in 10^3 between the new and existing free-air chambers has promoted a study of the effect of the air gaps surrounding the collector plate. Measurements to investigate the electric field uniformity are planned. A molybdenum target x-ray tube will be installed later in 2007. Previous work on the establishment of tungsten-anode mammographic qualities and on the response of ion chambers in these beams has been published as two BIPM reports.

Part of this work was the Monte Carlo calculation of correction factors for the BIPM x-ray standards, including the effects of photon transmission, scatter and fluorescence from the tungsten aperture. The calculations for low-energy x-rays indicate the presence of fluorescence from the aperture and a combined correction factor of up to 2 parts in 10^3 . A correction of similar magnitude has been evaluated for the medium-energy x-ray standard, although in this case the dominant effect is from energetic electrons coming from the aperture reaching the collecting region. More importantly, the medium-energy calculations have led to the identification of a scatter component from the aperture support. The measured (and calculated) effect is over 6 parts in 10^3 at 250 kV and explains the trend with radiation quality seen in the results of a number of BIPM comparisons over the last thirty years.

A number of aspects of the dosimetry programme were presented as papers and posters at the Workshop on Absorbed Dose and Air Kerma Primary Standards, held at the LNE (France) in May 2007 and jointly organized by the LNE-LNHB (France) and the BIPM.

Primary measurements and reference chamber calibrations have continued in all of the reference x- and γ -ray beams, including the mammographic radiation qualities. Calibrations and comparisons are underpinned by a

significant effort in equipment calibration and maintenance, as required by the BIPM Quality System.

5.1.2 Dosimetry comparisons

Air kerma comparisons in low-energy x-rays were made with the LSDG (Belgium) in July 2006 and with the NRC (Canada) in March 2007, and in medium-energy x-rays with the LSDG (Belgium) in July 2006, the NMIJ (Japan) in September 2006, and in June 2007 with the LNHB (France) and the NPL (United Kingdom). Additionally, a third set of measurements was made in September 2006 for the low-energy x-ray comparison with the NMIJ (Japan). An absorbed dose to water comparison in ^{60}Co γ -rays with the ENEA (Italy) was carried out in April 2007. Draft reports for five of these eight comparisons have been issued, along with a draft report of a previous x-ray comparison with the NIM (China). Reports have been published of previous air kerma comparisons with the OMH (Hungary) in ^{60}Co γ -rays and with the NIST (United States) in medium-energy x-rays. The CCRI comparison of dosimetry for industrial radiation processing at high absorbed dose (kGy) levels, piloted by the BIPM, was published in *Radiation Physics and Chemistry*.

A draft B summary report of all air kerma comparisons in ^{60}Co has been approved, in principle, by the CCRI(I). A number of related comparison reports for the BARC (India), GUM (Poland), ITN (Portugal), NIM (China), and the NPL (United Kingdom), are still under discussion. Reports of previous x-ray comparisons with the ARPANSA (Australia), BEV (Austria) and the NMi (The Netherlands) are in preparation.

The four transfer chambers for the high-energy absorbed-dose CCRI key comparison continue to be measured periodically in the BIPM ^{60}Co beam. One of these chambers will be used, together with a well-type ionization chamber, for the upcoming CCRI comparison of brachytherapy dosimetry for ^{192}Ir sources to be piloted by the BIPM.

5.1.3 Calibration of national standards for dosimetry

A review of calibration procedures and an external audit of the calibration services were completed in November 2006. No non-compliances were recorded.

Six series of calibrations of national standards were made in medium-energy x-rays for the IAEA, LNHB (France), and the NIS (Egypt). Two series were made in low-energy x-rays for the IAEA and the NIS (Egypt).

Eleven calibrations of national standards were carried out in the BIPM γ -ray beams in terms of air kerma and absorbed dose to water, as requested by the ČMI (Czech Republic), KRISS (Rep. of Korea), NIS (Egypt), and the IAEA. Two calibrations in terms of ambient dose equivalent were made for the CRRD (Argentina).

The IAEA/WHO dosimetry assurance programme continued to be supported with reference irradiations in the ^{60}Co beam.

5.2 Radionuclides

(P.J. Allisy-Roberts, S. Courte, C. Michotte, M. Nonis and G. Ratel)

5.2.1 Comparison of activity measurements of a ^{55}Fe solution

The last results sent by the 18 laboratories that took part in the measurements of a solution of ^{55}Fe prepared and distributed by the NPL were received by the BIPM at the end of November 2006. The draft A report was then prepared and distributed to the participants for comments and correction. The results were also discussed during the CCRI(II) meeting in May 2007. Although some comments are still awaited, a draft B report is in preparation. Some pertinent features of the comparison are outlined here.

The solution of FeCl_3 in 1 mol/L HCl with 10 $\mu\text{g/g}$ of inactive FeCl_3 as a carrier was dispatched to 19 laboratories, 17 of which sent 25 independent results. Following the CCRI(II) approved CIPM MRA procedures, only 16 participants using primary methods are eligible to be used for the evaluation of a key comparison reference value. No γ -ray emitting impurity was detected in the distributed solution by any of the 11 laboratories that carried out impurity tests. Twelve different methods were used and these can be divided into four main groups: methods using proportional counters (pressurized or not) in conjunction with NaI(Tl) detectors or alone, liquid-scintillation methods (CIEMAT/NIST, TDCR, or $4\pi(\text{LS})\beta$ - γ coincidence efficiency tracing), 4π calorimetry, and methods based on counting x-rays under defined solid angles with different kinds of detectors. The characteristics of the detectors and devices used by the laboratories in their activity determination are completely described in the draft A report. Where possible, an analysis of the results, method by method, was carried out to highlight any potential method-related source of uncertainty. Apart from two

values, which may be outliers, the results show a remarkable homogeneity with those obtained by liquid-scintillation techniques being in good agreement. The use of ^{54}Mn as a tracer instead of ^3H may increase the precision of the measurements but does not really alter the final value of the activity determination. The values obtained with proportional counters using an efficiency tracing show a larger spread. The other methods listed, such as x-ray counting or calorimetry, are in good agreement with the mean value of the comparison. However, some unresolved problems remain, particularly at the BIPM, and further investigations are necessary to clarify the origin of the discrepancy. After the investigations, an additional comparison involving the BIPM, the ENEA, and one or two linking laboratories, as proposed at the CCRI(II) meeting, will be organized. Unfortunately, the overall outcome of the present comparison shows no improvement compared to that of a similar exercise organized in 1996 in the frame of the ICRM. Another, more encouraging conclusion is that an objective although slightly optimistic assessment of the uncertainties was identified through using the Birge criterion.

5.2.2 International Reference System (SIR) for gamma-ray emitting radionuclides

During 2006, the BIPM received 30 ampoules from 13 laboratories; i.e. one ampoule containing ^{65}Zn from the BARC, one containing ^{22}Na from the CIEMAT, two ampoules from the ČMI-IIR (one containing ^{56}Co and one ^{131}I), two ampoules from the IFIN-HH (one containing ^{60}Co and one ^{134}Cs), one ampoule containing $^{166}\text{Ho}^m$ from the IRA-METAS, four from the IRMM all containing ^{237}Np (for a link to a EUROMET comparison and to obtain a KCRV value for this radionuclide), nine ampoules from the LNE-LNHB (one ampoule containing ^{51}Cr , two ^{54}Mn , one ^{75}Se , four ^{85}Kr and one ^{111}In), one ampoule containing ^{51}Cr from the LNMRI-IRD, two ampoules from the NMIJ (one containing ^{57}Co and one ^{133}Ba), three ampoules from the NPL (one containing ^{54}Mn and two ^{201}Tl), one ampoule containing ^{54}Mn from the OMH (now called the MKEH), two from the PTB (one containing ^{22}Na and one ^{186}Re) and one ampoule containing ^{241}Am from the VNIIM (for a link to a COOMET comparison).

All the submissions, except three ^{237}Np ampoules having different masses and the four ^{85}Kr ampoules submitted for the gas pressure study, had been made to generate equivalence values in the BIPM ongoing key comparisons. Including the newly registered measurements for 2006, the cumulative

number of ampoules measured since the beginning of the SIR, in 1976, is now 923, corresponding to a total of 673 independent results for 63 different radionuclides.

The low activity in the ampoule of ^{241}Am produced an ionization current of only about 310 fA in the SIR chambers so it was decided to measure the ampoule several times under different experimental conditions, both with the original SIR measurement chain and the newly developed electronic chain; the final result has been taken as the weighted mean of the individual measurements. A correction factor, deduced from the work of A. Rytz (Ratel G., Michotte C., BIPM comparison BIPM.RI(II)-K1.Am-241 of the activity measurements of the radionuclide ^{241}Am , *Metrologia*, 2003, **40**, *Tech. Suppl.*, 06001), to take into account the high density of the solution of ^{241}Am was applied and the final result is in agreement with the other entries for this radionuclide. This ^{241}Am submission from the VNIIM was made to link the results of a recent COOMET comparison.

With the formal submission of the standardized activity results for ^{237}Np , which constitutes a new SIR key comparison, the final report has now been published and this also contains the links for an earlier EUROMET comparison.

The NPL identified a preparation problem with the first ampoule of ^{201}Tl they submitted and this was withdrawn, their subsequent submission is in good agreement with other participants.

In accordance with a request from the CIPM, the procedures for the SIR have been fully documented and an external peer-review audit was held in November 2006. Some modifications required to clarify the procedures were recommended and almost all have been implemented, with just two laboratory instructions requiring further detail.

The year 2006 has also seen the first full twelve months of running the new data acquisition chain for the SIR in parallel with the present system. The results show agreement to about 10^{-4} which is well within the measurement uncertainties. The systems will continue in parallel until the end of 2007 at which time the new system will be used to measure the SIR ampoules, as long as the present validation and testing continues to indicate the required stability. The new system has been fully documented ready for this implementation.

The development of the extension of the SIR to short-lived radionuclides using a well-type NaI(Tl) transfer instrument is progressing. The detector and

source holders and a special lead shield were designed and manufactured in the BIPM workshop. The whole system has been tested extensively and measurements carried out to enable the uncertainty evaluation for the planned comparison measurements. A $^{99}\text{Tc}^{\text{m}}$ solution produced and standardized at the LNE-LNHB was measured in the SIR and in the transfer instrument and the results are promising. Once the analysis is complete, this first $^{99}\text{Tc}^{\text{m}}$ measurement in the transfer instrument will enable the linking factor to the SIR to be calculated ready for the first comparison on-site at an NMI.

5.2.3 Gamma spectrometry

No significant impurities were detected in any of the ^{131}I , $^{166}\text{Ho}^{\text{m}}$ and ^{65}Zn solutions submitted to the SIR. The expected ^{57}Co and ^{58}Co impurities were measured in a ^{56}Co solution. Some ^{99}Mo was detected in the $^{99}\text{Tc}^{\text{m}}$ solution that was measured in both the SIR and the SIR transfer instrument. A request from the BIPM was made to the CCRI for an NMI to provide some support to calibrate the hyper-pure germanium spectrometer.

5.3 Publications, lectures, travel: Ionizing Radiation section

5.3.1 External publications

1. Allisy-Roberts P.J., Ambrosi P., Bartlett D.T., Coursey B.M., DeWerd L.A., Fantuzzi E., McDonald J.C., Measurement Quality Assurance for Ionizing Radiation Dosimetry, ICRU Report 76, *Journal of the ICRU*, 2006, **6**(2), 50 pp.
2. Burns D.T., Allisy-Roberts P.J., Desrosiers M.F., Nagy V. Yu, Sharpe P.H.G., Laitano R.F., Mehta K., Schneider M.K.H., Zhang Y.L., CCRI supplementary comparison of standards for absorbed dose to water in ^{60}Co gamma radiation at radiation processing dose levels, *Rad. Phys. Chem.*, 2006, **75**(9), 1087-1092.
3. Burns D.T., O'Brien M., Comparison of the NIST and BIPM standards for air kerma in medium-energy x-rays, *J. Res. Natl. Inst. Stand. Technol.*, 2006, **111**, 385-391.
4. Ma L.-S., Picard S., Zucco M., Chartier J.-M., Robertsson L., Balling P., Kren P., Qian J., Liu Z., Shi C., Alonso M.V., Xu G., Tan S.L., Nyholm K., Henningsen J., Hald J., Rowley W.R.C., Barwood G.P., Windeler R., Absolute frequency measurement of the R(12) 26-0 and

R(106) 28-0 transitions in $^{127}\text{I}_2$ at $\lambda = 543$ nm, *IEEE Trans. Instrum. Meas.*, 2006, **55**, 876-880.

5. Ratel G., Median and weighted median as estimators for the key comparison reference value (KCRV), *Metrologia*, 2006, **43**(4), S244-S248.
6. Ratel G., Michotte C., Bobin C., Moune M., Coursol N., Update of the ongoing comparison BIPM.RI(II)-K1.Ga-67 to include the activity measurements of the LNE-LNHB, France, *Metrologia*, 2006, **43**, *Tech. Suppl.*, 06008.

5.3.2 BIPM reports

7. Kessler C., Roger P., Burns D.T., Allisy P.J., Machula G., Csete I., Rabus H., Comparison of the standards for air kerma of the BIPM and the OMH for ^{60}Co gamma radiation, *Rapport BIPM-2006/07*, 14 pp.
8. Kessler C., Establishment of simulated mammography radiation qualities at the BIPM, *Rapport BIPM-2006/08*, 8 pp.
9. Kessler C., Burns D.T., Büermann L., de Prez L.A., A study of the response of ionization chambers to mammography beams, *Rapport BIPM-2007/02*, 8 pp.

5.3.3 Travel (conferences, lectures and presentations, visits)

P.J. Allisy-Roberts to:

- Trappes (France), 4 July 2006, to represent the BIPM at the opening of the new LNE electricity laboratory;
- London (United Kingdom), 18 July 2006, 16 January, 17 April and 28 June 2007 for the editorial board of the *Journal of Radiological Protection*; 5 June 2007 to attend a seminar at the Institute of Physics on project management;
- Vienna (Austria), 18 September 2006, to attend the IAEA General Conference and make a presentation to the intergovernmental organizations on the transport of metrological samples;
- Leeds (United Kingdom), 17-18 October 2006, for the DTI Measurement Advisory Committee (MAC);
- LNE (France), 13 November 2006 and 16 March 2007, to attend the *Comité Scientifique* for ionizing radiation;

- PTB, Berlin (Germany) 6-7 December 2006, to participate in a Workshop on research cooperation in Europe, as a DTI invitee;
- NPL (United Kingdom), 19-20 February 2007, to chair the MAC working group on acoustics and ionizing radiation.

P.J. Allisy-Roberts and C. Kessler to Paris (France), 9-11 May 2007, to attend the joint LNE-BIPM Workshop on Absorbed Dose and Air Kerma Primary Standards.

D.T. Burns to:

- Athens (Greece), 26-27 October 2006, as the BIPM representative at the EUROMET Ionizing Radiation Contact Persons meeting;
- Columbus (Ohio, United States), 9-15 November 2006, to attend the meetings of the Main Commission of the ICRU and the Fundamental Quantities and Units Committee;
- Barcelona (Spain), 22-23 March 2007, to attend a meeting of the ICRU Report Committee on Key Data for Measurement Standards in the Dosimetry of Ionizing Radiation;
- Paris (France), 9-11 May 2007, to attend the joint LNE-BIPM Workshop on Absorbed Dose and Air Kerma Primary Standards and present two papers;
- IAEA, Vienna (Austria), 25-29 June 2007, as a consultant to the IAEA on the revision of the IAEA Technical Report TRS-374.

D.T. Burns and C. Kessler to Seoul (Rep. of Korea), 28 August – 1 September 2006, to participate in the World Congress in Medical Physics and Biomedical Engineering; C. Kessler presented a poster on correction factors for the BIPM free air chamber.

C. Kessler and C. Michotte to Teddington (United Kingdom), 26-27 March 2007, to attend an International Workshop on Monte Carlo Codes at the NPL.

C. Michotte to Paris (France), 27 November 2006, to participate in an ICRM working group meeting comparing Monte Carlo codes used in γ -ray spectrometry.

C. Michotte and G. Ratel to Saclay (France), 19-20 March 2007, to participate in a VERMI workshop on coincidence measurements at the LNE-LNHB.

S. Picard to:

- Coimbra (Portugal), 17-22 September 2006, to participate in the 10th International Symposium on Radiation Physics, and to present “Towards an absorbed dose calorimeter at the BIPM: Determination of the Specific Heat Capacity of Graphite”;
- Paris (France), 7 November 2006, to participate in the one-day conference on applications of the finite element software Comsol, including an interactive mini-course;
- LNE (France), 9-11 May 2007, to attend the joint LNE-BIPM Workshop on Absorbed Dose and Air Kerma Dosimetry and to present a paper and a poster on the BIPM graphite calorimetry research.

G. Ratel to:

- Paris (France), 8-11 January 2007, to attend two ICRM WGs, one on Liquid-Scintillation, the second on Life Sciences;
- Fontenay-aux-Roses (France), 5-6 February 2007, to attend the Treatment initiatives after radiological accidents training course;
- Ispra (Italy), 5-6 March 2007, to attend the Scientific Committee of the ICRM 2007 conference to be held in Cape Town in September 2007 and the Executive board of the ICRM;
- Rungis (France), 15-19 March 2007, to attend les “Cinquièmes rencontres des personnes compétentes en radioprotection” to maintain his radiation protection certification.

5.4 Activities related to external organizations

P.J. Allisy-Roberts is the Chairman of a joint Working Group for the UK national measurement system programme for ionizing radiation and acoustics and the Chairman of the UK Ionising Radiation Health and Safety Forum. She is the BIPM representative on the IAEA SSDL Scientific Committee, a member of the *Comité Scientifique Rayonnements Ionisants* (LNE, France), on the editorial board of the *Journal of Radiological Protection* and the Comité editorial of the *Revue Française de Métrologie*, and a referee for *Physics in Medicine and Biology*, *Medical Physics* and the *British Journal of Radiology*.

D.T. Burns is the BIPM representative at the ICRU, a member of the ICRU Committee on Fundamental Quantities and Units and a member of an ICRU Report Committee. He is the BIPM contact person at the EUROMET for

ionizing radiation and radioactivity and a consultant to the IAEA. He is a referee for *Physics in Medicine and Biology* and for *Medical Physics*.

G. Ratel is the BIPM representative at the ICRM of which he is joint Vice-President. He is also a referee for *Metrologia*, *Applied Radiation and Isotopes* and *Nuclear Instruments and Methods*.

5.5 Activities related to the work of Consultative Committees

P.J. Allisy-Roberts is Executive Secretary of the CCRI and its three sections, all of which met during the month of May 2007 and included two invited seminars as well as two working group meetings. She is also Executive Secretary of the CCAUV, which met in September 2006 followed by the CCAUV RMO WG. She participated in the CCRI RMO WG, which met in November 2006 and made arrangements for the Coincidence Workshop in March 2007 and the Extended SIR WG in April. This last year has also seen the publication of a new *Monographie 6* and a further volume of *Monographie 5* in support of the CCRI(II).

She and D.T. Burns are members of the CCRI(I) Working Group on Metrological Equivalence (key comparisons) and of the CCRI(I) Working Group on Brachytherapy Standards. They both played a significant role in the Scientific Committee for the joint LNE-LNHB/CCRI Dosimetry Workshop held in conjunction with the CCRI(I) in May 2007.

C. Michotte is the coordinator of the CCRI(II) Working Group on the SIR Transfer Instrument. C. Michotte is the contact person at the BIPM and *rapporteur* for the JCGM/WG1 that met in October 2006 and April 2007.

G. Ratel is a member of the CCRI(II) working groups on the extension of the SIR to beta emitters (which met in Sèvres on 12-13 April 2007), on key comparisons (which met in Sèvres on 17 November 2006 and 21 May 2007, attended with P.J. Allisy-Roberts and C. Michotte), on measurement uncertainties, and of the realization of the becquerel (which met in Sèvres on 22 May 2007 and for which he is the *rapporteur*).

G. Ratel and C. Michotte have contributed significantly to the special issue of *Metrologia* for radionuclide metrology as authors and, together with P.J. Allisy-Roberts and D.T. Burns, as referees.

5.6 Visitors to the Ionizing Radiation section

- Dr P. Cassette (LNE-LNHB) and Mr I. Constantin (IFIN), 10 July 2006.
- Mrs I. Le Garrères, Messrs. Branger and D. Lacour (LNE-LNHB), 11 July 2006.
- Dr M.-N. Amiot, Mrs I. Moreau, Messrs. M. Morin and F. Rigoulay (LNE-LNHB), 14 September 2006.
- Drs K. R. Shortt and A. Fajgelj (IAEA), 5 October 2006.
- Dr P. Costa (LNMRI-IRD), 20 November 2006.
- Mr A. Pearce (NPL), 20 November 2006.
- Dr A. Yunoki (NMIJ/AIST), 21 November 2006.
- Mrs E. Le Ray and C. Cholet (ASN, Paris), 24 November 2006.
- Dr B. Chauvenet (LNE-LNHB), 11 January 2007.
- Dr M.-G. Iroulart (LNE-LNHB), 27 March 2007.
- Dr Zhang Hui (NIM), 31 May 2007.
- Prof. D.B. Hibbert (Univ. New South Wales), 14 June 2007.
- Mr C. Bobin (LNE-LNHB), 20 June 2007.

5.7 Guest workers

- Dr N. Reynaert (LSDG), 3-7 July 2006.
- Prof. M.G. Cox (NPL), 24-26 July 2006.
- Drs N. Saito and T. Kurosawa (NMIJ), 17–22 September 2006.
- Dr L. Karam (NIST), for the audit of the SIR Quality System, 15-16 November 2006.
- Dr I. Csete (MKEH), for the audit of the Dosimetry Quality System, 22-24 November 2006.
- Drs N. Rabie and N. Khaled (NIS), 24 January – 7 February 2007.
- Dr J. Mc Caffrey (NRC), 5-8 March 2007.
- Miss M.-K. O'Brien (United States), 2-27 April 2007.
- Dr A. Guerra (ENEA), 16-20 April 2007.
- Mr L. Czap (IAEA), 21–25 May 2007.

6 CHEMISTRY (R.I. WIELGOSZ)

6.1 Gas metrology programme

(M.B. Esler*, E. Flores, P. Moussay, J. Viallon and R.I. Wielgosz)

6.1.1 Ozone photometer comparison programme

(P. Moussay and J. Viallon)

In October 2006, the protocol of a new key comparison coordinated by the BIPM (BIPM.QM-K1 – Ozone at ambient level) was distributed to potential participants, posted on the BIPM website and, finally, presented during the Gas Analysis Working Group meeting held at the KRISS. The comparison will be run as an on-going key comparison, with a call for participants every two years. The first participant of the 2007-2008 cycle was the NIST in January 2007. Six other participants are expected in 2007.

A generalized least-square regression, already implemented in the software OzonE, and developed by Dr W. Bremser (BAM), has been included in the processing of ozone photometer comparison results. The advantages of using a generalized least-square regression approach have been described in an article written in collaboration with W. Bremser and submitted to *Metrologia* in May 2007.

An external audit of the Quality System established for the activities directly linked with the ozone photometer comparisons was successfully undertaken in December 2006.

Upgrade of the NIST Standard Reference Photometers (SRPs)

Following the study of systematic biases and measurement uncertainties in NIST SRPs, which was published in *Metrologia* in October 2006, the NIST established a “NIST SRP upgrade kit” in order to minimize the two major biases revealed by the study. The kit includes a modified source block and new gas cells. The thermal insulation of the source block has been improved in the modified version, in contrast to the BIPM’s system which is based on a thermoelectric cooling system, to prevent heating of the gas by the UV lamp maintained at 60 °C. The new gas cells are quartz tubes closed at both ends by optically sealed quartz windows which are still parallel but tilted. A

* Until 20 October 2006.

similar system, tested at the BIPM during the study, had proven to be successful in avoiding multiple reflections of the light beam.

One "SRP upgrade kit" was installed on BIPM-SRP32 in January 2007 by J. Norris (NIST) and P. Moussay, and an installation procedure developed. The BIPM is now able to install upgrade kits for those participants in the key comparison BIPM.QM-K1 maintaining a NIST SRP as a national standard.

Development of a laser-based SRP

The programme to develop a candidate primary ozone photometer based on a frequency-doubled laser as a light source has continued. The light intensity acquisition chain has been modified to use UV photodiodes instead of the original phototubes in one of the SRPs maintained by the BIPM. Tests have shown that the noise is maintained at the same low level. In parallel, instabilities in the argon laser power were identified as coming from variations of the cooling water temperature. The laser cooling system has been improved to remove this instability source completely. Additional optical filters have been placed in the laser beam to reject the residual portion of the fundamental wavelength (514 nm) in the frequency-doubled (257 nm) beam. The beam diameter has been increased and its power reduced before allowing it to enter the modified SRP. The optical bench of the SRP itself was replaced in February 2007 to use the upgraded SRP32 instrument, which contains the new gas cells in quartz with tilted windows. Initial measurements of ozone concentration performed with this first version of a laser-based SRP succeeded in measuring ozone mole fractions in dry air within 5 % of the values determined by a mercury lamp-based SRP. The next step will focus on reducing the noise level of the laser system using a balanced detection system.

6.1.2 Primary NO₂ gas standard facility (M.B. Esler*, E. Flores and P. Moussay)

The facility was upgraded to include a nitrogen generator (including nitrogen purifier) and new control and data acquisition software for the Fourier transform infrared (FTIR) spectrometer, capable of transferring real-time results. The upgrade will allow sub-nmol/mol mole fractions of water to be obtained in the carrier gas and avoid possible reactions in the permeation

* Until 20 October 2006.

tube chamber. The nitrogen generator facility is expected to produce dry nitrogen with purity of 99.999 999 % (with less than 1 nmol/mol of H₂O and some other molecules such as oxygen).

The FTIR plexiglass enclosure was redesigned to keep the internal water concentration lower than 2 µmol/mol. The Aldrich Collection of FTIR Spectra Edition II library, that contains spectra of 18 454 pure compounds, was acquired to analyze impurities from the permeation system. Studies of the consistency of nitrogen dioxide concentrations calculated from permeation rates and those measured by various analysers are currently underway. Comparisons of NO₂ mole fractions determined from the permeation system and certified values in gas cylinders based on static gravimetry are planned. Following the request of the CCQM Gas Analysis Working Group, a planned future comparison of NO₂ gas standards will be extended to include the comparison of spectroscopic methods for gas concentration determination.

6.1.3 NO gas standard comparison facility (M.B. Esler*, P. Moussay and R.I. Wielgosz)

All measurements related to the BIPM coordinated study, CCQM-P73, were performed over the period August 2006 – October 2007. Gravimetrically prepared NO standards in the range (30-70) µmol/mol from 11 NMIs were analyzed using two independent methods (chemiluminescence and UV absorption) as well as FTIR spectroscopy for impurity analysis. A new set of validation studies was carried out in January 2007 to confirm analysis uncertainties. A reference value for the comparison was calculated from the most consistent set of gas standards, and it could be shown that in all but one case that impurity measurement problems were the cause of discrepancies of certified values from the reference value. The comparison report's draft A was presented to the CCQM-GAWG in April 2007, and the draft B report circulated to the working group in June 2007. The facility has also been upgraded using new software that allows direct communication between the UV analyzer and the computer thus removing the need of the digital voltmeter, and with no degradation in system performance.

* Until 20 October 2006.

6.2 Organic analysis programme

(A. Daireaux, R. Josephs, S. Westwood and R.I. Wielgosz)

The organic analysis programme within the Chemistry section has developed a facility to undertake purity assessments using robust procedures for the identification and summation of impurities. A dedicated facility for the larger scale handling, processing and storage of materials has also been established. A laboratory refurbishment to provide an area for controlled gravimetric transfer of materials and the accurate preparation of calibration solutions was completed in 2007. The laboratory capabilities at BIPM are supported by external collaborations for specialized services such as elemental microanalysis, particle sizing and nuclear magnetic resonance spectroscopy.

6.2.1 Method development

Method development and validation studies required for use in the production and characterisation of the CCQM-P20.e pilot study materials have been completed and were broadened to include the needs of the planned CCQM-P20.f pilot study. For CCQM-P20.e the main focus has been the identification and quantification of theophylline and related structure compounds from the xanthine group. For CCQM-P20.f, methods for the determination of the steroid glycosides digoxin and digitoxin, and various related structure cardiac glycosides as well as their corresponding aglycones have been developed. Procedures developed for this purpose in the last year include:

- LC-MS/MS methods providing both qualitative identification data and permitting the quantification of xanthines and cardiac glycosides as well as for assessing the homogeneity of inherent impurities in the digoxin material.
- LC-UV methods for identification and quantification by external calibration and for assessing the homogeneity of the main component and related structure impurities for the xanthine components of CCQM-P20.e. The same approach is being developed for the analysis of digoxin in the CCQM-P20.f candidate material.
- DSC techniques for estimation of the mole fraction content of high purity samples of theophylline.
- Karl Fischer titration using heated oven transfer for determination of low-level moisture content in solid samples.

- Protocols for the preparation, stability testing and homogeneity assessment of theophylline materials containing gravimetrically-defined levels of related structure impurities and of digoxin materials.

Supporting studies have also been undertaken on analysis of these materials by GC-MS (for volatile organic impurities) and thermogravimetric analysis (for total volatile impurities).

6.2.2 Coordination of CCQM-P20 and development of CCQM-K55

In the autumn of 2006, the homogeneity and stability assessments of the two theophylline candidate materials for CCQM-P20.e, the first comparison coordinated by BIPM, were completed successfully. One unit of each of the study materials, one consisting of high purity theophylline (CCQM-P20.e.1) and the other containing gravimetrically defined mass fractions of related structure impurities (CCQM-P20.e.2), each containing a minimum of 1 g of material, were shipped to each of the twelve participating laboratories under controlled conditions. BIPM was one of the participating laboratories. The participants were required to assign the mass fraction and corresponding uncertainties of theophylline in each material and to provide mass fraction estimates of all major impurities. Initial results and the first draft report of the pilot study were circulated to the participants and were presented at the CCQM Organic Analysis Working Group meeting in April 2007. Reported estimates for the mass fractions of theophylline in both materials showed a good level of agreement both with each other and, in the case of the CCQM-P20.e.2 material, with a gravimetric reference value.

A second pilot study, CCQM-P20.f, will also be coordinated by BIPM. The cardioactive pharmaceutical digoxin is the main component of this study material. Analytical method development required to assess the degree of homogeneity and stability of the material began in 2007. Homogeneity testing was completed successfully in June 2007. The measurements of the isochronous stability of the digoxin material are scheduled for the third quarter of 2007. Distribution of vials, each containing 500 mg of digoxin, to laboratories participating in the comparison is scheduled for late 2007, with the initial discussion of results scheduled for April 2008.

A proposal has been for BIPM to proceed with the coordination of CCQM-K55, the first key comparison on organic purity assessment. The proposed measurand for the study is β -estradiol and the preparation and

characterization of candidate materials is being undertaken in collaboration with NMIJ.

6.3 **Activities related to the JCTLM** (S. Maniguet and R.I. Wielgosz)

R.I. Wielgosz is Executive Secretary of the Joint Committee for Traceability in Laboratory Medicine (JCTLM), and a member of its review team on Quality Systems and Implementation, and S. Maniguet is coordinating the development of the JCTLM database.

The fifth meeting of the Executive Committee of the JCTLM was held at the BIPM in December 2006, and the timetable for the approval of Cycle III nominations of higher order reference materials and reference measurement procedures, and of Cycle I nominations of laboratory reference measurement procedures was agreed.

The construction of the internet-based searchable database for higher order reference materials and measurement methods/procedures approved by the JCTLM was completed and, the new website of the JCTLM database was launched in December 2006. This website is available at <http://www.bipm.org/jctlm/>. It provides the user with an analyte keyword search engine to display lists of higher order reference materials and measurement methods/procedures and a second search facility to access .pdf files of available higher order reference materials and reference measurement methods/procedures for specific analyte or matrix categories.

From December 2006 to June 2007, the total number of external connections to the JCTLM database website is on average of 750 each month. It is not easy to identify the external visitors of the website since the majority of the connections are being made through web providers, but a number of important organizations in the field of laboratory medicine and *in vitro* diagnostics, universities or hospitals have been identified and have regularly visited the website.

The first list of reference measurement services offered by laboratories was published on the JCTLM website in June 2007. The JCTLM web application will be extended to include the reference measurement laboratory services as a searchable category to the database, and this will be available by the end of 2007.

6.4 Activities related to the work of Consultative Committees

R.I. Wielgosz is the Executive Secretary of the CCQM.

J. Viallon is a member of the CCQM gas analysis and surface analysis working groups.

E. Flores is a member of the CCQM Working Group on Gas Analysis.

S. Westwood is a member of the CCQM Working Group on Organic Analysis and is a technical observer on the CCQM Key Comparison Working Group.

R. Josephs is a member of the CCQM bioanalysis and organic analysis working groups.

6.5 CCQM comparisons coordinated by the BIPM

The BIPM is the coordinating laboratory for following CCQM comparisons:

- CCQM-P28 – Ozone, ambient level (completed);
- BIPM.QM-K1 – Ozone, ambient level (on-going);
- CCQM-P73 – Nitrogen monoxide in nitrogen, preparative capabilities;
- CCQM-P20.e – Theophylline, purity analysis series;
- CCQM-P20.f – Digoxin, purity analysis series;
- CCQM-K55 – Purity analysis.

6.6 Activities related to external organizations

R.I. Wielgosz is a BIPM representative to the World Meteorological Organization (WMO) CIMO Expert group on capacity building, the Codex Alimentarius Commission, and ISO TC 212, Clinical laboratory testing and *in vitro* diagnostic test systems, Working Group 2 on Reference Systems, and is a member of the editorial board of *Accreditation and Quality Assurance*.

S. Westwood is the BIPM and CCQM representative at ISO REMCO, and the BIPM representative to the CIPM *ad hoc* Material Metrology Working Group.

R. Josephs is a member of the electronic working group on measurement uncertainty of the Codex Committee on Methods of Analysis and Sampling (CCMAS).

6.7 Publications, lectures, travel: Chemistry section

6.7.1 External publications

1. Linsinger T.P.J., Josephs R.D., Limitations of the application of the Horwitz equation, *Trends Anal. Chem.*, 2006, **25**(11), 1125-1130.
2. Buttinger G., Josephs R.D., Emteborg H., Harbeck S., Krska R., The certification of the mass fraction of deoxynivalenol in acetonitrile (IRMM-315) and of nivalenol in acetonitrile (IRMM-316), IRMM-Information, EUR-Report, Luxembourg (2006), EUR 22178 EN [ISBN 92-79-01699-7].
3. Welzig E., Josephs R.D., Schothorst R.C., van Egmond H.P., Pettersson H., Chan D., Krska R., Type B-Trichothecene calibrants: Comparison of HPLC and GC-results within an intercomparison study, *Mycotoxin Res.*, 2006, **214**, 224-230.
4. Krska R., Welzig E., Josephs R.D., Schothorst R.C., van Egmond H.P., Pettersson H., Chan D., MacDonald S., Feasibility study for the production of certified calibrants for the determination of deoxynivalenol and other B-trichothecenes: Intercomparison study, *AOAC Int.*, 2006, **89**(6), 1573-1580.
5. Viallon J., Moussay P., Norris J.E., Guenther F.R., Wielgosz R.I., A study of systematic biases and measurement uncertainties in ozone mole fraction measurements with the NIST Standard Reference Photometer, *Metrologia*, 2006, **43**, 441-450.

6.7.2 Travel (conferences, lectures and presentations, visits)

R.I. Wielgosz to:

- Garmisch-Partenkirchen (Germany), to WMO-VOC CCL, 3-4 July 2006, to attend the CCQM GAWG and WMO GAW workshop on VOC monitoring and standards;
- Chicago (United States), to the AACC meeting, 24-25 July 2006, to attend JCTLM WG1 and WG2 meetings;
- Wiesbaden (Germany), 15 September 2006, to present CCQM activities to the ENFSI;
- Minneapolis (United States), 18-20 September 2006, to present CCQM activities at the AOAC annual meeting;
- LGC, Teddington (United Kingdom), 15-17 November 2006, for JCTLM Working Groups Meeting;

- Brussels (Belgium), 30 November 2006, to discuss the use of the JCTLM database with EC DG Enterprise;
- RSC, London (United Kingdom), to attend meeting on Trends in Air Quality and present BIPM activities on ground-level ozone standards, 19-20 December 2006;
- Lisbon (Portugal), 7-9 February 2007, to MetChem EUROMET to present JCTLM and BIPM metrology in chemistry activities;
- AFNOR, Saint-Denis (France), 21-23 February 2007, to participate in ISO TC 212 WG2;
- Budapest (Hungary), 2-8 March 2007, CCMAS and IAM, to represent BIPM at the interagency and Codex meetings;
- Bangkok (Thailand), 14-18 May 2007, to give presentations on JCTLM and the BIPM chemistry programme at the APLAC workshop on ISO 15189 and at the NMIT;
- Harvard Business School, Cambridge (United States), 3-8 June 2007, to attend training course.

R.I. Wielgosz and J. Viallon to:

- KRISS, Daejeon (Rep. of Korea), 30 October – 3 November 2006, to participate in the CCQM GAWG meeting, attend the CRM Symposium and visit KRISS laboratories for chemistry;
- Rotterdam (The Netherlands), 14-16 February 2007, to attend the 4th International Gas Analysis Symposium.

R.I. Wielgosz and E. Flores to EC-JRC, Ispra (Italy), 14-15 March 2007, to attend the EUROMET 888, Workshop on dynamic measurements of NO_x, CO, and SO₂ at low ambient level and their comparability.

R.I. Wielgosz and S. Westwood to Linsköping (Sweden), 22-23 March 2007, to assist in the presentation of a workshop on metrological tools for forensic analysis as part of an ENFSI quality and competence liaison group meeting.

J. Viallon to:

- CPEM 2006, Turin (Italy), 10-14 July 2006, to present a lecture on “Systematic biases and measurement uncertainties in ozone mole fraction measurements with the BIPM maintained SRP” (*CPEM 2006 Digest*, 686-687) and to attend a workshop on spectroscopy as a potential primary method for gas analysis;

- PTB, Braunschweig (Germany), 30 November – 1 December 2006, to give the presentation prepared for the CPEM 2006 to the chemistry department and visit their laboratories;
- NOAA-ERSL (Earth Research System Laboratory), Boulder (Colorado, United States), 2-3 May 2007, to attend the NOAA ESRL 2007 Global Monitoring Annual Conference and present a poster on “Requirements for new measurements of the absorption cross-section of ozone for accurate determination of ozone concentration”.

S. Westwood to:

- LGC, Teddington (United Kingdom), 11-12 December 2006, for the follow-up UKAS assessment of LGC for accreditation for reference material production to ISO Guide 34:2000;
- LNE, Paris (France), 21-22 May 2006, to represent BIPM at the third meeting of the *ad hoc* CIPM Materials Metrology Working Group;
- Riga (Latvia), 31 May - 1 June 2007, to present a lecture on establishing an international metrological infrastructure for analytical measurements at the ENFSI annual meeting;
- Tsukuba (Japan), 5-8 June 2007, to represent BIPM and CIPM at the annual ISO Reference Materials Committee (ISO REMCO) meeting.

R. Josephs to:

- Prague (Czech Republic), 27 August – 1 September 2006, Academy of Sciences of the Czech Republic, to participate in the 17th International Mass Spectrometry Conference;
- Institute for Agrobiotechnology, Tulln (Austria), 4-8 December 2006, for LC-MS/MS training course;
- LGC, Teddington (United Kingdom), 16 February 2007, to attend the practical glycoprotein analysis meeting.

S. Maniguet to LGC, Teddington (United Kingdom), 15 to 17 November 2006, for JCTLM working groups meeting.

6.8 Visitors to the Chemistry section

- Drs R.L. Williams, R.G. Manning and T. Morris (US Pharmacopeia), 27 July 2006.
- Dr R. Wessel (NMi VSL), 28 September 2006.
- Dr S. Ronzoni (ABI), 2-4 October 2006.

- Dr J.E. Norris (NIST), 15-26 January 2007.
- Prof. B. Hibbert (Univ. New South Wales), 14 June 2007.

6.9 Guest worker

- Dr Y. Shimizu (NMIJ), 21 August – 15 September 2006.

7 SPECIAL PROJECTS (M. STOCK)

7.1 Calculable capacitor (F. Delahaye*, R. Felder, N. Fletcher, R. Goebel, L. Robertsson, J. Sanjaime, M. Stock, L.F. Vitushkin)

The objective of this project, carried out jointly with the NMIA (Australia) is to build two calculable capacitors capable of realizing a capacitance of 0.4 pF with an uncertainty of the order of 1 part in 10^8 . This will allow us to measure the value of the von Klitzing constant, R_K , for the next CODATA fundamental constants adjustment and will significantly shorten the traceability chain for our capacitance calibrations. Staff members of the Electricity section, the Time, Frequency and Gravimetry section and the workshop are contributing to this work.

One of the biggest challenges in this project is the fabrication of the electrode bars, which need to be cylindrical to within 100 nm over a length of nearly 50 cm. During the last year, a polishing and lapping technique was developed at the NMIA, which has allowed us to fabricate the first electrode bar within these specifications. It is planned that the remaining bars will be made during 2007.

The BIPM workshop has made the vacuum enclosures, the main cell support structure and many other elements for both systems.

Two members of the Electricity section (N. Fletcher and R. Goebel) spent three weeks at the NMIA to familiarize themselves with the existing calculable capacitor, the new project and, in particular, the optimization of

* Until his retirement on 31 December 2006.

the shape of a model of the guard electrodes, to make it insensitive to the imperfect geometry of the main electrodes.

A member of the Time, Frequency and Gravimetry section (L. Robertsson) visited the NMIA to discuss questions related to the interferometer that will be used to determine the relative electrode positions. Agreement was reached on the appropriateness of the selected general parameters. The mode matching optics to couple the laser to the interferometer cavity still needs to be determined. We have made initial calculations for this which will now be refined and discussed with suppliers to find appropriate components. Different solutions for aligning the system have been discussed and will be investigated. We have started to set up an interferometric test bench at the BIPM to study the alignment procedures and to make an assessment of systematic errors related to the excitation of higher order modes in the cavity. The uncertainty related to the interferometer will be one of the limiting factors of the instrument.

As described in the section 4.2.2, the chain linking the quantum Hall resistance to capacitance standards has been improved.

7.2 **Watt balance** (H. Fang, L. Kovalevsky*, J. Labot, M. Nonis, A. Picard, D. Reymann**, M. Stock, T.J. Witt***)

This project is being carried out by staff members from the Electricity section, the Mass section, the Time, Frequency and Gravimetry section and the Ionizing Radiation section.

Work is continuing on the development of the magnetic circuit. The main magnetic and geometric characteristics have been determined, but the fabrication is difficult because the required uniformity of the magnetic field in the air gap requires mechanical tolerances of the large pole pieces in the micrometer range. We have started a cooperative venture with the machine tools department of the Technical University (RWTH) of Aachen (Germany), to develop a fabrication strategy and to build the system. In addition to the fabrication, the high magnetic forces during assembly need to be addressed. During the first project phase, the machining properties of the FeNi alloy have been investigated and a polishing process has been selected for the final surface finish. A high precision lathe will be needed and a company

* Student at the École Normale Cachan (France).

** Until his retirement on 30 September 2006.

*** Retirement on 30 June 2007.

possessing such a machine has been contacted. First concepts for the assembly have been proposed and need to be refined. It is planned that the magnetic circuit should be delivered in the next year.

In June 2006 we achieved for the first time control of the coil velocity during the vertical movement, but the velocity noise was relatively high and we observed a large horizontal run-out of the coil. This led us to the following improvements. The balance suspension has been re-designed for greater stiffness and to correct some other mechanical imperfections. The design of the flexure clamps was modified to reduce stress and to allow for a smoother movement. An electrostatic system to control the coil rotation around the vertical axis has been added; it is composed of three gold-plated glass plates connected to the coil suspension, sandwiched between three pairs of high-voltage electrodes. The rotation during the vertical movement is now $50 \mu\text{rad}$; that is, 30 times less than before. Further work is needed to reduce the unwanted horizontal run-out. An engineering student has worked for several months on a system to control the unwanted horizontal inclinations of the coil. A detailed mechanical design and the results of an investigation of the dynamical properties are available. This device will be tested separately before integration into the suspension.

Work is continuing on the integration of the interferometer into the system, so that velocity readings can be obtained directly from the interferometer. A metallic mirror whose surface has the same shape and size as a portion of the surface of the moving coil was implemented. It will be replaced later by a dielectric mirror with larger reflectivity. A new compact support for the beam splitter and reference mirror was designed. It is directly mounted on the permanent magnet, relative to which the coil velocity needs to be measured, and it incorporates various elements for an independent verification of the interferometer readings.

An independent method for frequency measurement for the determination of velocity was set-up. The electrical signal directly obtained from the beat frequency of the two orthogonal polarized components of the laser source serves as reference signal. The Doppler frequency shift due to the displacement of the moving coil is extracted from the measurement signal with respect to the reference signal by means of a frequency mixer. This method will be compared to the commercial system and used in parallel for velocity servo-control and determination.

An aluminium cabin has been constructed in order to minimise the undesirable air flow and the ambient light in the experiment, which lead to mechanical and electrical noise.

A first version of the moving coil has been made and inserted into the magnet. Synchronisation of the measurements of induced voltage, given by a digital voltmeter, and of the velocity readings coming from the Zygo interferometer is under development. Each voltage value is integrated over 60 ms (3 PLC) whilst the acquisition of the velocity is carried out at 1 kHz. Fabrication of a non-inductive coil with the same electrical resistance as the moving coil is under way. We intend to mount this in series with the moving coil in order to separate the induced voltage from the voltage drop due to the current flow.

A current source has been built which delivers ± 1 mA with a short term stability of about 2 parts in 10^7 . The current can be adjusted within ± 20 % of the full range with a resolution of 0.1 μ A.

A long solenoid coil, which will become the magnetic reference for horizontal alignment of the coil and the magnet, has been obtained from the NIST.

In preparation for the construction of a concrete antivibration base for the watt balance we have invited an expert on vibration isolation for discussion. To underpin the further development, the elastomechanical properties of the ground have been determined and vibration spectra from 0 Hz – 100 Hz have been measured in the future laboratory. We also have analyzed our present velocity measurements for the dominant noise frequencies.

In February 2007, we organized the annual technical workshop on watt balances, WBTM'07, at the BIPM, with 19 external participants from all other watt balance groups.

7.3 Publications, lectures, travel: Special projects

7.3.1 External publications

1. Fang H., Picard A., Reymann D., Stock M., Witt T.J., The BIPM Watt Balance, *IEEE Trans. Instrum. Meas.*, 2007, **56**, 538-542.
2. Stock M., Watt balances and the future of the kilogram, *Proc. Symposium of Metrology 2006*, Quéretaro, Mexico, 2006, 6 pp.

7.3.2 Travel (conferences, lectures and presentations, visits)

H. Fang, A. Picard and M. Stock to Turin (Italy), 8 July 2006, to attend the CCEM Working Group on Electrical Methods to Monitor the Kilogram and to give a presentation on the status of the BIPM watt balance.

M. Stock, A. Picard, H. Fang and T.J. Witt to the CPEM 2006, Turin (Italy), 10-14 July 2006: A. Picard, M. Stock and H. Fang presented a poster entitled "The BIPM watt balance", *CPEM 2006 Digest*, 128-129.

R. Goebel and N. Fletcher to the NMIA (Australia), 11-29 September 2006, for work related to the joint NMIA/BIPM calculable capacitor project.

M. Stock to the Metrology Symposium in Querétaro (Mexico), 25-26 October 2006, to present a plenary lecture on "Watt balances and the future of the kilogram" and a lecture on "International comparison of water triple point cells leading to a more precise definition of the kelvin".

Watt balance technical meeting 2007, BIPM, 15-16 February 2007; M. Stock gave a presentation on the "Progress of the BIPM watt balance" and A. Picard on "Transfer of vacuum masses".

H. Fang, A. Picard, M. Stock and T.J. Witt to the LNE, Trappes (France), 16 February 2007, to visit the watt balance and calculable capacitor facilities.

M. Stock and A. Picard to the Technical University of Aachen (RWTH, Germany), 5 April 2007, for a meeting on the results of the first phase of the cooperation on the fabrication of the watt balance magnet.

A. Picard, M. Nonis and H. Fang to Paris (France), 23 April 2007, for training on I-Labview real time and data acquisition software; 22 May 2007, for training day on NI-DIAdem software.

L. Robertsson to NMIA (Australia), 14-15 May 2007, to discuss questions related to the interferometry for the calculable capacitor.

7.4 Visitors: Special projects

- Messrs G. Small and J. Fiander (NMIA), to discuss the status of the joint NMIA-BIPM project on the calculable capacitor, 5-6 July 2006.
- Drs J. Butorac and D. Ilic (University of Zagreb, Faculty of Electrical Engineering and Computing, Croatia) and Mr R. di Silva (LNE), 14 September 2006; visits to the impedance, voltage and watt balance laboratories.

- An open day was organized on 12 February 2007 to present the watt balance, calculable capacitor and Avogadro projects to the BIPM staff.
- Prof. Moscati (CIPM), 8 March 2007, visit to the watt balance.
- Dr Ch. Sutton (MSL), 21 March 2007, visit to the watt balance.
- Drs W. van Bommel and P. Lighting (President to the CIE), 2 April 2007, visit of the watt balance and electricity laboratories.
- Messrs J. Ferris and J. Gust and Mrs C. Hockert (NCSLI), 3 April 2007, visit to the watt balance and electricity laboratories.
- Dr C. Clark (NIST), 15 May 2007, visit to the watt balance.
- Dr B. Inglis (NMIA and CIPM), 7 June 2007, visit to the watt balance.
- Dr B. Siebert (PTB) and Dr J. Stenger (Head of PTB's Presidential staff office), 14 June 2007, visit of the watt balance and the calculable capacitor.
- Dr J. Flowers (NPL) and Dr D. Newell (NIST), 14 June 2007, visit of the watt balance.

7.5 Student: Special projects

- Mr L. Kovalevsky (École Normale Cachan, France) has worked on the watt balance project from 1 December 2006 to 7 June 2007. The subject of his work was "Design of a suspension mechanism for the BIPM watt balance".

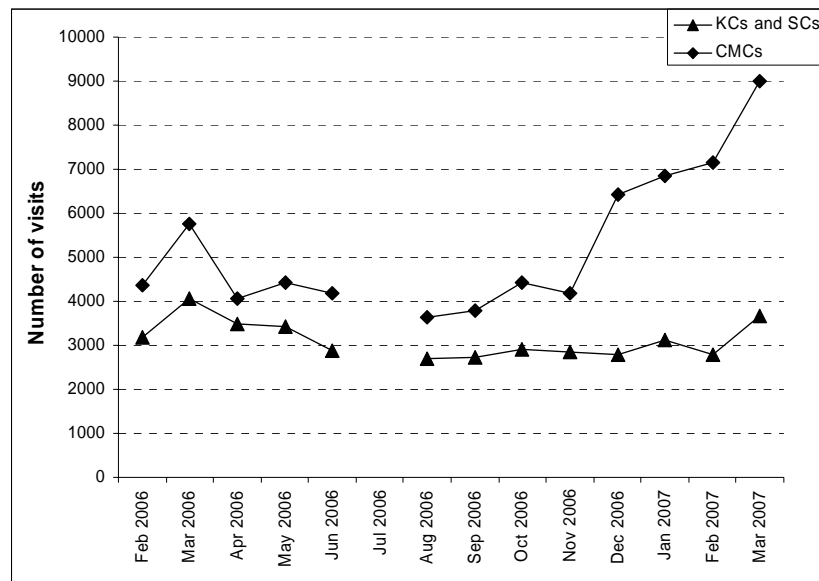
8 THE BIPM KEY COMPARISON DATABASE, KCDB (C. THOMAS)

8.1 Visits to the KCDB website (S. Maniquet and C. Thomas)

Between February 2006 and March 2007, the total number of monthly external connections to the KCDB website increased from 10 300 to 18 200. Details on the number of visits are given for the two main parts of the website (key and supplementary comparisons, and CMCs) in the figure page 270.

As previously noted, the database which holds information on key and supplementary comparisons was basically made “by the NMIs for the NMIs”, and it seems that we have now attracted this audience as the number of visits remains naturally stable.

The number of visitors seeking information on CMCs has increased continuously since the creation of the KCDB. It reached an average level of one visit every five minutes in March 2007.



Number of visits to the KCDB website
(no data available for July 2006)

8.2 Redesign of the KCDB website (C. Thomas)

The graph shown above seems to indicate that the process put in place by the launch of the CIPM MRA has become of interest to users other than our traditional audience, namely metrologists in the NMIs. We know that the communities of regulators and accreditors have an interest in the KCDB website, and the rise in the number of visits to the CMC data is evidence that this interest is growing. In addition, it seems that more recently it has attracted the attention of several commercial and industrial companies who wish to take advantage of the mutual recognition of calibration and measurement certificates issued by NMIs for establishing their traceability.

We suspect, however, that the majority of our new users are not acquainted with the CIPM MRA wording and experience difficulties in this regard. For instance, the expression “key comparison database” and the acronym “KCDB” are generic terms, used to cover a complete and complex web application. The terms “Appendix A”, “Appendix B” and “Appendix C”, although well suited to a document, such as the text of the CIPM MRA itself, are not so easily understood on a website.

Some users have also commented that searching for information on CMCs using the software in place was sometimes difficult: one had first to select a metrology area, and then items presented under the format chosen for the classification of services drawn up for that metrology area. These items may be instruments, such as in dimensional metrology, or quantities, such as in electricity. This can be confusing and led 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.

Consequently, we decided to improve the ease of use of the website, and took a number of actions which led to a new design for the KCDB website, including the access to a new text-based search engine. This new search engine became publicly available on the Internet on 6 March 2007.

The KCDB website is now presented as follows:

- The list of participants (“Appendix A of the CIPM MRA”) is made available in the form of searchable html pages kept on the main BIPM website.
- The KCDB home page gives access to two independent websites: the “Key and supplementary comparisons” website (“Appendix B of the CIPM MRA”), and the “Calibration and Measurement Capabilities – CMCs” website (“Appendix C of the CIPM MRA”). The word “Appendix” is mentioned in a discreet manner, and only on the home page.
- The KCDB home page also gives access to a number of useful links, including statistics, a “Find my NMI”, a glossary, and the *KCDB Newsletters* page.

8.3 A new search engine on the KCDB website

(C. Thomas, in collaboration with L. Le Mée and J. Miles)

As reported previously, the BIPM 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 such software in December 2005. Our new search engine was implemented on the main BIPM website* and on the KCDB, and publicly launched on 6 March 2007.

It takes the form of free-text boxes available from the comparisons and the CMCs websites, in which the user types words. The previous directed search facilities are also maintained for sake of continuity, especially the possibility of downloading .pdf files of reports on comparisons or full lists of CMCs declared by a given country and covering a given metrology area.

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, which allow an easy means of refining the search query. Some illustrative examples are given in the *KCDB Newsletter* No. 7, available at http://kcdb.bipm.org/NL/07/NL_07_Jun07_Content.html.

The main characteristics of the new search engine can be summarized as follows:

- *Relevance of results.* The software parameters are chosen so that the answers are as appropriate as possible (minimizing search time).
- *Refining the 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.
- *Making statistics.* A variety of statistics based on numbers of CMCs or on comparisons corresponding to specified properties are now facilitated and obtained directly.
- *Approximation, exact wording search.* An approximation of two letters on the entry is allowed. It follows that the plural is automatically taken into account. Exact wording search is possible by using quotes.
- *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. The vocabulary will be further expanded in the light of experience.

* See also the section "Publications" of this report for the implementation of the new search engine on the main BIPM website to create the "BIPM metrology portal".

- *Searching a given item.* It can be, for instance, a given certified reference material.

8.4 Content of the KCDB (S. Maniguet and C. Thomas)

8.4.1 Key and supplementary comparisons

On 1 June 2007, the KCDB covered 586 key comparisons (78 from the BIPM, 302 from the CCs, and 206 from RMOs) and 155 supplementary comparisons, which correspond to 44 new comparisons registered over the last six months.

Among the 586 key comparisons that are registered:

- 89 correspond to exercises prior to the implementation of the CIPM MRA, and will never have results published in the KCDB (they were “Approved for provisional equivalence”), and
- 257 have their final reports approved and posted in the KCDB, providing a total of about 800 graphs of equivalence displayed in the KCDB.

The results of 57 RMO key comparisons (22 conducted by APMP, 3 by COOMET, 30 by EUROMET, and 2 by SIM) are published in the KCDB. Linkage has also been carried out for eight bilateral key comparisons subsequent to full-scale CC key comparisons; their results are added on the appropriate graphs of equivalence.

A number of key comparison results are regularly updated. These mainly concern the ongoing BIPM key comparisons in electricity (for instance Josephson standards at 10 V) and on radionuclide activity conducted within the framework of the SIR. These updates correspond to new bilateral comparisons that are regularly carried out between the BIPM and various NMIs. In addition, new data concerning the computation of Coordinated Universal Time, UTC (key comparison CCTF-K001.UTC*), are published every month.

Statistics on the participation in key and supplementary comparisons are regularly updated in the statistics page of the KCDB website at http://kcdb.bipm.org/kcdb_statistics.asp.

* The CCTF key comparison CCTF-K001.UTC was identified as “CCTF-K2001.UTC” until March 2007. The change of identifier is a decision of the CCTF at its 17th meeting held in September 2006.

8.4.2 Calibration and Measurements Capabilities – CMCs

On 28 May 2007, a total of 19 518 CMCs were published in the KCDB:

- 12 255 in general physics;
- 3 463 in ionizing radiation; and
- 3 800 in chemistry.

The detailed distribution of the number of CMCs published by metrology area and by country is available from the KCDB statistics web page.

The detailed situation regarding deletion and re-instatement of CMCs linked to approved Quality Systems (QS) may be found in the KCDB statistics page. Since November 2006, no CMCs were removed from the KCDB, but some were re-instated, among which a number of CMCs in chemistry declared by Canada, and all CMCs from Ukraine and Russia that had been deleted just after the 17th JCRB meeting.

In summary, a total of about one thousand CMCs were deleted from the KCDB between July 2005 and November 2006 because they were not covered by an appropriate QS. This procedure is now ended, and already 600 of them have been re-instated. From now on, all new entries will necessarily satisfy the QS conditions, leading to full confidence in the international recognition of calibration and measurement certificates corresponding to CMC entries.

8.5 **Publicity and *KCDB Newsletters*** (S. Maniguet and C. Thomas)

We try to publicize the KCDB as often as we can through, for example, the distribution of copies of the KCDB leaflet, and the presentation of the KCDB website at workshops and congresses. The KCDB website and new search engine will be demonstrated on Wednesday 1 August 2007 at the NCSLI Conference (Saint Paul, Minnesota, United States), kindly hosted by the NRC on their stand.

In addition, issues 6 and 7 of the *KCDB Newsletter* were launched on 14 December 2006 and 8 June 2007, respectively.

8.6 Travel (conferences, lectures and presentations, visits): KCDB

C. Thomas to:

- Turin (Italy), 7-8 July 2006, for meetings of the CCEM working groups on proposed modifications of the SI (CCEM WGSI) and on coordination of the regional metrology organizations (CCEM RMOWG), and of the CCM *ad hoc* Working Group on Changes to the SI (CCM AHWGSI);
- Berlin (Germany), 25-26 September 2006, for meetings of the IEC TC 1 and 25; and 5-6 June 2007 for the PTB-BIPM Workshop on the Impact of Information Technology in Metrology;
- the Institut de France, Paris (France), 3 October 2006, and 7 February 2007, for meetings of the Working Group of the Académie des sciences “Unités de base et constantes fondamentales”;
- Paris (France), 25 October 2006, for a seminar at the LNE;
- Reading (United Kingdom), 11-12 April 2007, for a joint IEC/ISO Working Group on the definition of the ampere;
- Muldersdrift (South Africa), 2-4 May 2007, for the 18th JCRB meeting and the Workshop on the CIPM MRA.

L. Le Mée, J. Miles and C. Thomas presented the new BIPM search engine at their BIPM colleagues on 28 March 2007, in the framework of the series of BIPM internal seminars.

8.7 Activities related to external organizations

C. Thomas is a member of the “*Cabinet scientifique des Secrétaires perpétuels de l'Académie des sciences de Paris*”. In this context, she acted as the Scientific Secretary of the Working Group of the Académie des sciences “*Unités de base et constantes fondamentales*” until its 20th and last meeting on 7 February 2007. The Working Group was then transformed into an official permanent committee of the Académie des sciences named “*Science et métrologie*” on 24 April 2007. C. Thomas is a member of this Committee and acts as its Scientific Secretary. She is also a member of the Working Group of the LNE on “*Mathématiques et statistiques pour la métrologie*”.

8.8 Activities related to the work of Consultative Committees

C. Thomas is the Executive Secretary of the CCU. She is a member of the CCEM working groups on proposed modifications of the SI (CCEM WG SI)

and on coordination of the regional metrology organizations (CCEM RMO WG), a member of the CCM *ad hoc* Working Group on Changes to the SI (CCM AHWG SI), which became in March 2007 the CCM Working Group on the SI Kilogram (CCM WGSi kg), and a non-voting member of the CCT Working Group on Key Comparisons (WG 7).

C. Thomas attended the following meetings:

- CCL-CCTF Frequency Standards Working Group, 11-12 September 2006;
- 17th CCTF, 14-15 September 2006;
- CCAUV RMO Working Group, 27 September 2006;
- 17th JCRB, 6 October 2006;
- Director's Meeting, 9-10 October 2006;
- 95th CIPM (in part), 11-13 October 2006;
- Seminar presented to a Croatian delegation, 15 November 2006;
- CCRI RMO Working Group, 20-21 November 2006;
- CCEM Working Group on SI, 16-17 January 2007;
- RMOs/RABs Workshop, 9 March 2007;
- 25th CCEM and related meetings, 12-16 March 2007;
- 10th CCM, 23 March 2007;
- 13th CCQM, 19-20 April 2007;
- 18th JCRB, 3-4 May 2007;
- CCRI Section I and II, 14-25 May 2007;
- 18th CCU, 11-13 June 2007;
- 19th CCPR and related meetings, 18-22 June 2007.

C. Thomas is also responsible for the organization of external seminars at the BIPM, and is the Scientific Secretary of the BIPM Metrology Summer School 2008.

S. Maniguet attended the 13th CCQM meeting, 19-20 April 2007.

8.9 Visitors to the KCDB

- Dr A. Steele (NRC) and Dr M. Sargent (LGC), 7 October 2006.
- Prof. M. Himbert (LNE-INM), 7 December 2006.

9 THE JOINT COMMITTEE OF THE REGIONAL METROLOGY ORGANIZATIONS AND THE BIPM, JCRB (P. ESPINA)

The Joint Committee of the Regional Metrology Organizations (RMOs) and the BIPM (the JCRB) met in October 2006 at the BIPM and was hosted by SADC MET in May 2007 at Muldersdrift (South Africa).

9.1 BMC versus CMC

For a number of years, the co-existence of the terms *Best Measurement Capability* (BMC) and *Calibration Measurement Capability* (CMC) created confusion in both the accreditation and metrology communities. Although various attempts were made to reconcile the difference between the terms, confusion prevailed with the potential for undermining the value of the CIPM MRA.

Aiming at resolving this difference of terminology, a small commission composed of members from the Regional Metrology Organizations (RMOs) and the Regional Accreditation Bodies (RABs) met under the chairmanship of the BIPM during the 2006 NCSLI, in Nashville (United States). The commission recommended a new short definition accompanied by a collection of explanatory notes. The results of this meeting were widely circulated among signatories of the CIPM MRA and the ILAC MRA, and the consensus from both communities was that the new definition should be assigned to the term CMC. (Originally there were calls for the use of the term measurement capability (MC), but this proposal lacked general support.)

Currently, the new definition is fixed and final touches to the explanatory notes are being made by both communities. The next and, hopefully, final meeting of the commission will be at the next NCSLI meeting in August 2007, in Saint Paul (United States).

The commission is expected to have a recommendation in time for the 97th meeting of the CIPM in November 2007.

9.2 Criteria for the selection of peer-reviewers for NMIs

The CIPM MRA requires that any participating NMI or DI operates a Quality Management System (QS) that complies with JCRB guidelines

(see http://www.bipm.org/utis/common/documents/jcrb/quality_systems.pdf, JCRB-10/8(1c)) and has been reviewed and accepted by the local RMO. Similarly, its CMCs have to be submitted for review to the local RMO (intra-RMO review), which forwards them to the JCRB for inter-RMO review (see http://www.bipm.org/utis/common/documents/jcrb/AppC_criteria.pdf, JCRB-14/06(2a)).

The process for the review of QS and/or CMCs may require on-site visits by peers selected by the local RMO. While the requirements for these reviews are listed in the above referenced JCRB documents, a new document (Recommendations for on-site visits by peers and selection criteria for on-site visit peer reviewers) gives recommendations for on-site visits by peers and the selection criteria of visiting reviewers. The document also provides recommendations for those inter-RMO CMC review processes that require on-site visits by peers.

The document was presented to the CIPM in October of 2006 for approval but it was sent back to the JCRB with a request to make certain of its aspects less prescriptive. The document was redrafted by the JCRB and recommended to the CIPM for approval on its November 2007 meeting.

9.3 Monitoring CMC changes after the results of comparisons become available

Among the work to be conducted in the next year is the development of RMO processes to monitor changes to published CMCs from their NMIs after the results of comparisons become available. Currently, the lack of such processes is creating confusion among some of the working groups in the RMOs and CIPM Consultative Committees, and the JCRB felt that a common policy on this issue might benefit all. Under the proposed approach, the new RMO processes will be presented to the JCRB where they will benefit from comments offered by other RMOs. It is expected that after consensus is reached at the JCRB, the new processes will be implemented in the RMOs thus helping reduce the confusion on this topic.

9.4 JCDCMAS

Members for the Joint Committee on Coordination of Assistance to Developing Countries in Metrology, Accreditation and Standardization (JCDCMAS) held a workshop on the effects of the bilateral and regional free

trade agreements on the metrology, accreditation and standardization systems, in Lima (Peru) on 23-25 October 2006. The meeting was attended by individuals working on metrology, accreditation, and standardization in the Andes region.

The JCDCMAS held its annual meeting at UNIDO, Vienna (Austria) on 13 March 2007. On that occasion, each member organization presented their activities aimed at the developing world during the last 12 months. A proposal was made to have a combined calendar of activities on the web portal of the JCDCMAS (see <http://www.jcdcmas.org>). The calendar will be based on the current calendar maintained by ILAC. At the same meeting, discussions were held on the activities realized by the group in the last 12 months and it was decided that criteria for specifying what constitutes a JCDCMAS event is needed. Such criteria, which are not yet available, will specify how members are expected to contribute to future activities.

The secretariat of the JCDCMAS remains in the hands of UNIDO (Executive Secretary: O. Loesener Díaz) for a second year. UNIDO is scheduled to retain the secretariat until March 2008.

9.5 Publications, lectures, travel: JCRB

9.5.1 New CIPM MRA documents (please note that we are favouring the publication of new CIPM MRA policy as CIPM documents)

Available at: www.bipm.org/en/committees/jc/jcrb/documents.html

1. Suggested content of RMO Report to the JCRB, JCRB-18/03.7.
2. Report of the 15th JCRB Meeting (28 September 2005), JCRB-15/15.
3. Report of the 17th JCRB Meeting (6 October 2006), JCRB-17/17.

Available at: <http://www.bipm.org/cc/AllowedDocuments.jsp?cc=CIPM>

1. Guidelines for the reviews of CMCs and the monitoring and reporting of the operation of Quality Systems by international intergovernmental organizations, CIPM/06-03.
2. Guidelines for use of the CIPM MRA logo, CIPM/06-04.

9.5.2 Revised CIPM MRA documents

Available at: www.bipm.org/en/committees/jc/jcrb/documents.html

1. JCRB directory, JCRB-18/05.

9.5.3 Travel (conferences, lectures and presentations, visits)

P. Espina to:

- Turin (Italy), 7-9 July 2006, for meeting of the CCEM WG RMO;
- Rio de Janeiro (Brazil), 11-18 September 2006, SIM Quality System Task Force meeting and SIM General Assembly;
- Querétaro (Mexico), 23 October – 1 November 2006, for meetings of the: CCPR WGC MC, SIM Metrology Working Group for Flow, and CCL WGDM;
- Braunschweig (Germany), 1 December 2006, for meetings with staff of PTB Technical Cooperation;
- New Delhi (India), 9-17 December 2006, to participate in: the APMP pressure and vacuum workshop, APMP TCQS meeting, APMP TCM meeting, and the APMP General Assembly;
- Berlin (Germany), 10-11 January 2007, to participate in the EURAMET inauguration ceremony;
- Tunis (Tunisia), 21-23 February 2007, to participate in the UNIDO-AU expert group meeting on “Standards Compliance and Conformity Assessment for the Development of Sustainable Trade as a major potential source of poverty reduction in Africa”;
- Vienna (Austria), 11-13 March 2007, to participate in a BIPM-OIML-ILAC-UNIDO meeting and the annual JCDCMAS meeting; 11 May 2007, to participate in the UNIDO LABNET launching ceremony;
- Gaithersburg (United States), 15-23 March 2007, to attend meetings with NIST staff (B. Collins, K. Gebbie, B. Jeffrey, B. Koch, W. May, M. Moldover, C. Saundry, H. Semerjian, and J. Whetstone);
- Moscow (Russian Federation), 25-27 March 2007, to participate in COOMET QSF TC meeting;
- Minsk (Belarus), 23-26 April 2007, to participate in the 17th COOMET Committee Meeting (i.e., COOMET General Assembly);
- Muldersdrift (South Africa), 30 April – 6 May 2007, to participate in a CIPM Workshop on Enhancing Participation in the CIPM MRA and the 18th Meeting of the JCRB;
- London (United Kingdom), 29-31 May 2007, to participate in the last EUROMET General Assembly and the first EURAMET General Assembly;

- Madrid (Spain), 27 June 2007, to participate in CEM Strategic Panel Meeting.

9.6 Activities related to the work of Consultative Committees

P. Espina participated in the following meetings:

- CCAUV RMO Working Group, 27 September 2006;
- IAEA Quality System review meeting, 5 October 2006;
- 17th JCRB meeting, 6 October 2006;
- 2006 Meeting of Directors of NMIs, 9-10 October 2006;
- 95th CIPM meeting, 13 October 2006;
- CCRI RMO Working Group, 20-21 November 2006;
- BIPM-OIML-ILAC annual meeting, 7 March 2007;
- BIPM-ILAC annual meeting, 8 March 2007;
- RMO-RAB annual meeting, 9 March 2007;
- CCQM KCWG annual meeting, 13-14 April 2007;
- BIPM-OIML-UNIDO meeting, 17 April 2007;
- CCPR WG-CMC meeting, 19 June 2007.

9.7 Visitors to the JCRB

- Mrs L. Seehausen (PTB), on secondment to the BIPM, 7-25 August 2006.
- Bolivian delegation: A. Bort Amelunge, J.C. Castillo, and G. Muñoz (IBMETRO), 7 September 2006.
- Croatian delegation: E. Nemeroff, Z. Sovic, M. Livazovic, L. Celar, D. Jelic, T. Zupic, M. Vrebcevic, M. Polla, K. Gaca, S. Zima, and M. Borsic, 15 November 2006.
- Dr O. Loesener Diaz (UNIDO, JCDCMAS) and Mr P. Reposeur (French consultant), 17 April 2007.
- Mr K. Berry (consultant, United Kingdom), 7 June 2007.
- Mrs K. Royss (PTB) and Dr W. Schmid (EURAMET, PTB), 22 June 2007.

10 QUALITY SYSTEM AND LIAISONS WITH ISO AND ILAC, VIM (R. KÖHLER)

10.1 The BIPM's Quality System (R. Köhler)

The BIPM Quality System required to comply with ISO/IEC 17025 continues its routine operation. In 2006, the second triennial round of external peer reviews was performed. All audits were satisfactory, no major non-conformities were detected and again, the exchange of information in formal and informal discussions during the audits was judged valuable for both the auditors and those being audited. Resulting from the first years of the operation of the BIPM's Quality System, a new edition of the Quality Manual has been undertaken to include ISO 9000 requirements, plus some of the ISO/IEC 17025 requirements for laboratories.

10.2 Liaison with ISO and ILAC (R. Köhler)

The BIPM is continuing to participate in the work of ISO for standards important for its work and as a stakeholder. The most recent activity was monitoring and participation in the ISO CASCO Working Group 28 on the development of an international standard that contains general requirements for the competence of proficiency testing providers. This standard is intended to replace the existing ISO/IEC Guide 43:1997, Proficiency testing by interlaboratory comparisons – Part 1: Development and operation of proficiency testing schemes and Part 2: Selection and use of proficiency testing schemes by laboratory accreditation bodies.

The ILAC and BIPM continue their annual bilateral meetings and also participate in the annual trilateral BIPM-ILAC-OIML meeting.

10.3 JCGM WG 2: VIM (R. Köhler)

Following the retirement of F. Delahaye, R. Köhler took on the secretariat of the Working Group 2, which has been producing a new edition of the VIM. The working group met twice in early 2007 and finalized the document which is now with ISO for final editing and printing.

10.4 Travel (conferences, lectures and presentations, visits)

R. Köhler to:

- Geneva (Switzerland), 3-4 May 2007, for ISO CASCO Working Group 28;
- PTB, Berlin (Germany), 4-8 June 2007, for the 3rd Workshop on the Impact of Information Technology in Metrology;
- Lille (France), 19-20 June 2007, for the International Metrology Congress to give a presentation on the VIM.

11 PUBLICATIONS AND INFORMATION TECHNOLOGY (J. WILLIAMS)

11.1 Reports of the CIPM and Consultative Committees (D. Le Coz, J.R. Miles, C. Thomas and J. Williams)

Since July 2006 the following have been published:

- *International Committee for Weights and Measures*, 94th meeting (2005), 2006, **73**, 242 pp.
- *Director's Report on the Activity and Management of the BIPM (2006)*, 2006, **7**, 301 pp.
- *Convocation of the 23rd General Conference on Weights and Measures*.
- *Programme of Work and Budget of the BIPM for the four years 2009-2012*; prepared for the 23rd General Conference on Weights and Measures.
- *Evolving Needs for Metrology in Trade, Industry and Society and the Role of the BIPM*; prepared for the 23rd General Conference on Weights and Measures.

Note: all scientific publications are listed in the appropriate sections of the report.

Following a decision made by the International Committee for Weights and Measures at its 92nd meeting in October 2003, reports of meetings of Consultative Committees are published only on the BIPM website. Full bilingual printed versions in French and English no longer appear.

11.2 *Metrologia* (J.R. Miles, D. Saillard and J. Williams)

Since the beginning of 2003, *Metrologia* has been produced in partnership with Institute of Physics Publishing (IOPP) Ltd., the publishing arm of the Institute of Physics.

The technical details of the production of *Metrologia* between the BIPM and IOPP are continuing to work well. The journal appears on time and we benefit from the extensive marketing network of IOPP to assist in maintaining the subscriptions levels of the journal at a time when subscription levels are falling for the majority of technical scientific journals. Special issues of the *Metrologia* are still organized by an invited specialist editor in cooperation with the editor at the BIPM. Over the period of this report, there was one special issue of *Metrologia* published in the period of this report: Statistical and Probabilistic Methods for Metrology, volume 43(4).

In addition to appearing in the printed journal, all submissions that have been accepted are made freely available for one month on the *Metrologia* section of the website for IOPP (www.iop.org/EJ/journal/Met).

The impact factor of *Metrologia* continues to increase. The impact factor (IF) is defined as being: number of citations in the current year to papers published in previous two years / number of papers published in previous two years.

Year	2000	2001	2002	2003	2004	2005	2006
IF	0.820	0.945	0.842	0.983	1.314	1.479	1.657

It is important for us to achieve and maintain an impact factor above 1.0 as this is typically the cut-off value that librarians and subscriptions managers look at when they are seeking which journals with low impact factor to cut from their budgets.

The *Technical Supplement to Metrologia* is doing well with 54 abstracts published in 2006 and 30 already published in 2007, with many more in the pipeline.

The following table gives details of the rapidity of the editorial process for manuscripts submitted to *Metrologia*; demonstrating that the editorial and publication processes involving BIPM and IOPP are working well.

	2004	2005	2006
Receipt of manuscript to Web publication	57.1 days	35.9 days	40 days
Receipt of manuscript to print publication	106 days	96.9 days	95 days

11.3 Information Technology (L. Le Mée, J.R. Miles and G. Petitgand*)

Over the period of this report, the Information Technology (IT) Group continued to investigate and identify means of improving the reliability, security and performance of the BIPM's computer network and internet service, and to put in place the appropriate new software and hardware to meet the desired objectives. For example, improvements in the reliability of the most essential elements of the BIPM's computer network have been based upon a geographical separation of the servers and a means of automatically sharing the load between servers, so that if one ceases to function, its tasks are automatically switched to other servers (load balancing).

Responding to demand from staff of the BIPM, the IT group examined the most efficient means of working at distance from the BIPM using portable computers. The IT group identified the most appropriate technology and then proceeded to install this technology to assist the work of staff members. The solutions identified involved installation and networking of VPN (Virtual Private Network) card, communication cards of third generation (UMTS) and hand held BlackBerry units.

Towards the end of the reporting period, the IT group made a significant change in the software and hardware that provides the 'firewall' protection for the BIPM's network. In addition, the IT group has recently proceeded to increase the capacity of the backup system for data storage using magnetic cartouches.

The IT group was closely involved in the choice and installation of the new search engine, which is available on the BIPM's website and on the KCDB website. The IT group was involved in finding solutions to the indexing of websites and of presenting the results recovered by the new search engine. The IT group has also been involved in other aspects of development of the

* Until 15 June 2007.

BIPM's website; including, information about the use of the logo for the CIPM MRA and for certificates.

Over the period of this report the IT group was involved in the purchase, installation and administration of almost 180 office and laboratory computers, and the installation and integration into the office network of multifunction photocopiers. In addition, the IT group was responsible for networking the suit of new meeting rooms created by the refurbishment of the old workshop.

11.4 The BIPM website (L. Le Mée and J.R. Miles)

As the BIPM's primary means of communication, our website contains a wealth of information. Restricted-access areas have been set up for almost eighty different user groups (Consultative Committees, Working Groups and others) to provide access to their working documents, and these "behind the scenes" documents alone represent over 2.5 Gbytes of disk space.

Amongst the other new services added this year, the list of signatories of the CIPM MRA has been made available as searchable html pages. These are easier to consult than the previous flat .pdf file, and include additional functionality such as links to the external sites and other areas of the BIPM website, and give details of which domains of metrology are covered by the designated institutes whenever this information is available (see <http://www.bipm.org/en/cipm-mra/>). In accordance with the CIPM's guidelines for use of the CIPM MRA logo, adopted in 2006, the guidelines and the list of laboratories authorized to include the logo in their calibration certificates, are now available in the CIPM MRA section of the website.

Close links are maintained between the BIPM website and the BIPM key comparison database (KCDB). From the country-specific areas on the website (see http://www.bipm.org/en/convention/member_states/), dedicated links are provided to the calibration and measurement capabilities declared by the participating laboratories, and statistics are available on their participation in key and supplementary comparisons. The data in the KCDB can also be accessed directly using the new BIPM metrology portal (see below).

Amongst many other updates, the "scientific work" section has been restructured to mirror the changes in the scientific sections of the BIPM (<http://www.bipm.org/en/scientific/>), and Appendix 2 of the SI Brochure, which is now produced in electronic form only, on the BIPM website, has

been brought up-to-date with a new *Mise en pratique* for the kelvin, and updated texts on the practical realization of the definitions of the units of time and electrical quantities, as well as how to realize the mole.

11.5 The BIPM metrology portal (L. Le Mée, J.R. Miles and C. Thomas)

A significant project over the last year has been the implementation of our new search engine on the BIPM website and the KCDB.

The new search engine was launched publicly on 6 March 2007. It has the advantages of full-text and multi-language searching, and dynamically generated tables of contents based on each search results page to allow an easy means of refining the search query. As one of the niche services offered by the BIPM, the new BIPM metrology portal (<http://search.bipm.org/>) provides a convenient starting point to search for relevant information on the BIPM website, the KCDB, and the websites of all NMIs participating in the CIPM MRA.

As reported previously, a small working group comprising Mr Le Mée (IT group), Dr Miles (webmaster) and Dr Thomas (coordinator of the KCDB) carried out a comparison of several commercially available search engines with a view to the needs of the BIPM. In accordance with their findings, the BIPM purchased the software “exalead:one enterprise” in December 2005.

Installation of the search engine was undertaken during 2006. The software comprises seven principal programmes running continuously, and thirty-two exploring programmes to crawl the BIPM and NMI websites. We currently have twenty-five distinct data sources, covering web pages, file directories, and databases. In a close collaboration between the BIPM and EXALEAD, tailoring the product to the specific needs of the BIPM involved a substantial amount of work and over 8000 lines of coding.

11.6 Travel (conferences and visits): Publications and Information Technology section

J. Williams to NPL (Teddington), 23-24 January 2007, to work with the specialist editor on a future special issue of *Metrologia* (Radionuclide Metrology).

J. Miles to Berlin (Germany), 5-7 June 2007, for the PTB-BIPM Workshop on the Impact of Information Technology in Metrology.

12 MEETINGS AND LECTURES AT THE BIPM

12.1 Meetings

The following meetings were held at the BIPM:

- The CCTF met on 14-15 September 2006; it was preceded by meetings of its working groups from 11-13 September (including the CCL/CCTF Joint Working Group on 12-13 September).
- The CCAUV met on 25-26 September 2006; it was followed by meetings of its RMO Working Group on 27 September.
- A Quality System Review Meeting for International Organizations was held on 5 October 2006.
- The JCRB held its 17th meeting on 6 October 2006.
- The Directors' meeting was held on 9-10 October 2006.
- The Joint Committee for Guides in Metrology (JCGM) met on 3 November 2006. Working Group 1 (GUM) of the JCGM met on 25-27 October 2006 and on 24-27 April 2007, and Working Group 2 (VIM) on 29 January – 2 February 2007.
- The CCRI(II) Key Comparison Working Group met on 17 November 2006, and the CCRI RMO Working Group on 20-21 November 2006.
- A meeting of the JCTLM Executive was held on 1 December 2006.
- The CCEM Working Group on Proposed Modifications to the SI was held on 16-17 January 2007.
- A watt balance technical meeting (WBTM'07) was held from 14-16 February 2007.
- A joint meeting of the CIPM/ILAC/OIML Working Group was held on 7 March 2007. It was followed by a BIML/ILAC workshop on 8 March, and a BIPM/ILAC meeting on 9 March.
- The CCEM met on 15-16 March 2007; it was preceded by meetings of its working groups from 12-14 March.
- The CCM met on 23 March 2007; it was preceded by a meeting of the CCM working group chairpersons on 22 March.
- The CCQM met on 19-20 April 2007; it was preceded by meetings of its working groups from 13-18 April.

- The CCRI met on 31 May 2007; it was preceded by meetings of its three sections from 14-31 May.
- The CCU met on 11-13 June 2007.
- A meeting of a CODATA Task Group on Fundamental Constants was held on 14 June 2007.
- The CCPR met on 21-22 June 2007; it was preceded by meetings of its working groups from 18-20 June.

12.2 External Seminars

The following lectures were given at the BIPM, as part of the regular schedule of External Seminars:

- B. Chauvenet and J. Chavaudra (LNE-LNHB): Les accélérateurs linéaires en radiothérapie : Intérêt clinique et problèmes métrologiques associés, 20 September 2006.
- M. Moldover (NIST): Progress toward a primary pressure standard based on the dielectric permittivity of helium, 17 October 2006.
- P. Giacomo: VIM 3: Pourquoi ? Comment ?, 29 November 2006.
- M. Desenfant and N. Fischer (LNE, Trappes): Le supplément 1 du GUM, 19 December 2006.
- S. Guellati-Khelifa (Laboratoire Kastler Brossel, Paris): A new determination of the fine structure constant based on Bloch oscillations of ^{87}Rb atoms in a vertical optical lattice, 24 January 2007.
- E.R. Williams (NIST): Experimental progress toward an SI based on fundamental constants, 28 February 2007.
- L. Palafox (PTB): AC voltage standards based on programmable Josephson arrays at PTB, 18 June 2007.

12.3 Internal Seminars

- G. Petitgand: Étude sur la mise en place d'une stratégie de gestion électronique de documents au sein du BIPM, 22 January 2007.
- C. Goyon and P. Barat: Le nouveau système d'étalonnage des manomètres du BIPM, 30 January 2007.
- J. Miles, L. Le Mée and C. Thomas: Implantation du moteur de recherche EXALEAD sur les sites web du BIPM et de la KCDB, 28 March 2007.

- “An Inconvenient Truth”, by D. Guggenheim (A documentary film about climate change, specially global warming).

13 CERTIFICATES AND NOTES OF STUDY

In the period from 1 July 2006 to 30 June 2007, 81 Certificates and 2 Notes of Study were delivered.

For a list of Certificates and Notes see pages 136-140.

14 FINANCE, ADMINISTRATION AND GENERAL SERVICES (B. PERENT)

The BIPM's Finance, Administration and General Services section is responsible for the smooth running of a wide range of support services such as financial, equipment purchase, legal and other services. During the last year, the administrative members of the section moved to a common location which will facilitate more efficient working. The section has also played a major role in the projects to update the BIPM's Staff Statute and the more effective operation of the Staff Commissions, in the preparation of the 23rd CGPM, in particular for the Convocation, including drafting Resolutions, the “*Programme of work and budget of the BIPM for the four years 2009-2012*” and the Kaarl's report.

14.1 Accounts

Details of the accounts for 2006 may be found in the “*Rapport annuel aux Gouvernements des Hautes parties contractantes sur la situation administrative et financière du Bureau International des Poids et Mesures*”. An abstract of Tables taken from this report may be found on pages 141-147.

The headings for the tables may be translated as follows:

Compte I : Fonds ordinaires	Account I: Ordinary funds
Compte II : Caisse de retraite	Account II: Pension fund
Compte III : Fonds spécial pour l'amélioration du matériel scientifique	Account III: Special fund for the improvement of scientific equipment
Compte IV : Caisse de prêts sociaux	Account IV: Social loans fund
Compte V : Réserve pour les bâtiments	Account V: Building reserve
Compte VI : <i>Metrologia</i>	Account VI: <i>Metrologia</i>
Compte VII : Fonds de réserve pour l'assurance maladie	Account VII: Reserve fund for medical insurance

Two additional tables detail the payments made against budget in 2006 and the balance sheet at 31 December 2006. This is done under the headings:

Détail des dépenses budgétaires Bilan au 31 décembre 2006	Statement of budgetary expenditure Balance at 31 December 2006
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It should be noted that in all tables, since 2001, the unit of currency is the euro, according to Resolution 13 of the 21st General Conference.

14.2 Staff

14.2.1 Appointments

- Mr Edgar Flores Jardines, born 7 July 1977 in Mexico City (Mexico), Mexican nationality, previously Doctoral student at Institut für Meteorologie und Klimaforschung, Atmosphärische Umweltforschung (IMK-IFU) and at Universidad Nacional Autónoma (Mexico), was engaged as *chimiste* in the Chemistry section from 3 January 2007.
- Mr Bruno Vincent, born 4 November 1961 in Deuil-la-Barre (France), French nationality, previously mechanic in a French private company, was engaged as *mécanicien* in the Workshop section from 1 March 2007.
- Mr Guillaume Thibaudeau, born 17 March 1967 in Toulon (France), French nationality, previously consultant in a French private company, was engaged as *assistant* in the Time, Frequency and Gravimetry section from 1 April 2007.

14.2.2 Promotions and change of grade

- Mrs Céline Fellag-Ariouet, *secrétaire*, was promoted *secrétaire principale* from 1 January 2007.

- Mr Alain Jaouen, *technicien* in the Electricity section, was promoted *technicien principal* from 1 January 2007.
- Dr Claudine Thomas*, *physicien principal*, Coordinator of the BIPM key comparison database, was promoted *physicien chercheur principal* from 1 January 2007.
- Dr Robert I. Wielgosz*, *chimiste principal*, head of the Chemistry section, was promoted *chimiste chercheur principal* from 1 January 2007.

* These promotions resulted from a vote of the CIPM during its 95th meeting in October 2006.

14.2.3 Departures

- Dr Dominique Reymann, *physicien principal* in the Electricity section, retired on 30 September 2006 after 33 years of service.
- Mr Jean-Bernard Caucheteux, *mécanicien principal* in the Workshop section, retired on 31 December 2006 after 19 years of service.
- Mr François Delahaye, *physicien chercheur principal* in the Electricity section, retired on 31 December 2006 after 20 years of service.
- Dr Thomas Joseph Witt, *physicien chercheur principal*, head of the Electricity section, retired on 30 June 2007 after 35 years of service.

On their retirement, the Director thanked each of these members of staff for the effective and devoted service during their years at the BIPM.

- Dr Michael B. Esler, *chimiste* since 4 February 2002 in the Chemistry section, left the BIPM on 20 October 2006.
- Dr Peter Wolf, *physicien* since 1 January 1998 in the Time, Frequency and Gravimetry section, left the BIPM on 31 December 2006.
- Mr Gérald Petitgand, *technicien* since 15 February 2000 in the Publications section, left the BIPM on 15 June 2007.

14.3 Buildings

14.3.1 Grand Pavillon

- Refurbishment of three offices on the first floor.
- Refurbishment of three offices on the ground floor.
- Redecoration of the Grande Salle.

- Update of the electricity fittings.
- Maintenance of the roof.

14.3.2 Petit Pavillon

- Renovation of the old workshop to provide additional meeting rooms.
- Refurbishment of a room for archives.

14.3.3 Observatoire

- Redecoration of rooms 3, 11 and 12.
- Refurbishment of room 105.
- Partial replacement of air-conditioning equipment in rooms 6, 14 and 105.
- Maintenance of the roof.

14.3.4 Ionizing Radiation building

- Partial replacement of air-conditioning equipment in rooms S6 and S7.
- Replacement of air-conditioning equipment in rooms R15 and S2.
- Refurbishment of rooms S2 and R11.

14.3.5 Nouveau Pavillon

- Renovation of the lime tree Allee.
- Investigations to identify the origins of a leak at level -2.

14.3.6 Pavillon du Mail

- Partial replacement of air-conditioning equipment.

14.3.7 Outbuildings and park

- Repair of part of the boundary fence.

14.4 Travel: Finance, administration and general services section

B. Perent to:

- Turin (Italy), 7-9 July 2006, for a meeting of the bureau of the CIPM;
- Leuven (Belgium), 15 June 2007, to attend a seminar on ageing and health care benefits.

B. Perent and R. Cèbe to:

- Noordwijk (The Netherlands), 10-11 May 2007, to attend a workshop on pensions in international organizations;
- Turin (Italy), 15-16 May 2007, to attend a meeting on privileges and immunities in international organizations.

R. Cèbe to Washington DC (United States), 27 March 2007, to attend a colloquium on international administrative tribunals and the rule of law.

15 SECRETARIAT (F. JOLY)

There continues to be a heavy workload on the Secretariat with the many meetings held at the BIPM. These meetings are essentially those of Consultative Committees and Working Groups (some of them are particularly complex with parallel sessions in different parts of the BIPM, and even at locations not on the site of the BIPM; for example, the CCQM). The large amount of work required to run the meetings of the BIPM was exacerbated this year with the work required to prepare and run the General Conference, held in November 2007. In addition, the meetings of Directors of National Metrology Institutes, which took place during the General Conference, required special attention given the number of delegates from the General Conference who joined the Directors to visit the various science sections of the BIPM.

Amongst its other responsibilities, the BIPM's Secretariat maintains records of the BIPM's wide range of international contacts. This database has been revised and now can be integrated with the other BIPM databases. The Secretariat, with the assistance of the Administration section also ensures the smooth running of an increasing number of meetings at the BIPM.

The Secretariat is continuing to develop its knowledge of IT tools, so that our most important documents for Consultative Committees or for communications with Member States, Associates of the CGPM and NMI Directors can be accessed from the BIPM's website.

16 WORKSHOP AND SITE MAINTENANCE **(J. SANJAIME)**

The BIPM workshop provides an essential and much-valued contribution to our work programme. Many of the activities of the workshop are mentioned in the reports of the individual sections, but the core mission of the workshop is to support the technical programme with the construction of specialized apparatus and, where necessary, when NMIs and others bring items to the BIPM for calibration. In this latter case, ancillary equipment is often needed at short notice in response to any problems that may arise or to make repairs if equipment is damaged in transit, so that the calibration may proceed smoothly. The availability of a rapid response is critical to the efficiency of the BIPM's services to NMI staff who may only be able to visit the BIPM for fixed, short periods of time.

The workshop carries out high-precision mechanical work for the scientific sections of the BIPM. In addition, the workshop is the only source of platinum-iridium prototype kilograms, which are made exclusively for the Metre Convention and which make use of the specialized equipment and unique experience of the workshop staff.

During the year, the workshop has successfully contributed to:

- the manufacture of a large number of elements of the calculable capacitor in a project with the NMIA (Australia) and the NRC (Canada), which have been sent to Australia;
- the BIPM's watt balance project also benefited this year from the completion of a number of components;
- a number of mass prototypes in platinum-iridium alloy and in stainless steel were manufactured;

- a new mass comparator is well on the way to being completed at the BIPM; and
- the manufacture of complex detectors in graphite for the Ionizing Radiation section.

In addition, the members of the workshop have assisted in a variety of tasks relating to the maintenance of the site.

LIST OF ACRONYMS USED IN THE PRESENT VOLUME

1 Acronyms for laboratories, committees and conferences*

A*STAR	(former SPRING) Agency for Science, Technology and Research, Singapore (Singapore)
AACC	American Association for Clinical Chemistry, Washington DC (United States)
ADMET	International Conference on Advances in Metrology
AFNOR	Association Française de Normalisation, La Plaine Saint-Denis (France)
AGU	American Geophysical Union, Washington DC (United States)
AIST*	National Institute of Advanced Industrial Science and Technology, see NMIJ/AIST
AOAC	Association of Analytical Communities
AOS	Astrogeodynamical Observatory, Borowiec (Poland)
APLAC	Asia Pacific Laboratory Accreditation Cooperation
APMP	Asia/Pacific Metrology Programme
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency, Sydney and Melbourne (Australia)
ASN	Autorité de Sûreté Nucléaire, Paris (France)
ATF	Asia Pacific Time and Frequency Workshop
BAM	Bundesanstalt für Materialforschung und -prüfung, Berlin (Germany)
BARC	Bhabha Atomic Research Centre, Trombay (India)
BEV	Bundesamt für Eich- und Vermessungswesen, Vienna (Austria)
BIPM	International Bureau of Weights and Measures/ Bureau International des Poids et Mesures
CC	Consultative Committee of the CIPM
CCAUV	Consultative Committee for Acoustics, Ultrasound and Vibration/Comité Consultatif de l'Acoustique, des Ultrasons et des Vibrations
CCEM	Consultative Committee for Electricity and Magnetism/ Comité Consultatif d'Électricité et Magnétisme

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

CCL	Consultative Committee for Length/ Comité Consultatif des Longueurs
CCM	Consultative Committee for Mass and Related Quantities/ Comité Consultatif pour la Masse et les Grandeurs Apparentées
CCMAS	Codex Committee on Methods of Analysis and Sampling
CCPR	Consultative Committee for Photometry and Radiometry/ Comité Consultatif de Photométrie et Radiométrie
CCQM	Consultative Committee for Amount of Substance: Metrology in Chemistry/Comité Consultatif pour la Quantité de Matière : Métrologie en Chimie
CCRI	Consultative Committee for Ionizing Radiation/ Comité Consultatif des Rayonnements Ionisants
CCT	Consultative Committee for Thermometry/ Comité Consultatif de Thermométrie
CCTF	Consultative Committee for Time and Frequency/ Comité Consultatif du Temps et des Fréquences
CCU	Consultative Committee for Units/ Comité Consultatif des Unités
CEM	Centro Español de Metrología, Madrid (Spain)
CENAM	Centro Nacional de Metrología, Mexico (Mexico)
CETIAT*	Centre Technique des Industries Aéronautiques et Thermiques, Villeurbanne (France), see LNE
CGGTTS	CCTF Group on GPS Time-Transfer Standards
CGPM	General Conference on Weights and Measures/ Conférence Générale des Poids et Mesures
CIE	International Illumination Commission/Commission Internationale de l'Éclairage
CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, Madrid (Spain)
CIML	International Committee of Legal Metrology/ Comité International de Métrologie Légale
CIMO*	Commission for Instruments and Methods of Observation, see WMO
CIPM	International Committee for Weights and Measures/ Comité International des Poids et Mesures
CMI	Český Metrologický Institut/Czech Metrological Institute, Prague (Czech Rep.)
CMI-IIR	Český Metrologický Institut/Czech Metrological Institute, Inspectorate for Ionizing Radiation, Prague and Brno (Czech Republic)

CNAM*	Conservatoire National des Arts et Métiers, Paris (France), see LNE
CNES	Centre National d'Études Spatiales, Toulouse (France)
CODATA	Committee on Data for Science and Technology
Codex Alimentarius	Commission created by the FAO and WHO
CONICET	Argentine Council of Research
COOMET	Euro-Asian Cooperation of National Metrological Institutions
CPEM	Conference on Precision Electromagnetic Measurements
CRRD	Centro Regional de Referencia para la Dosimetria, Buenos Aires (Argentina)
DFM	Danish Institute of Fundamental Metrology, Lyngby (Denmark)
DI	Designated Institute
DMDM	(former ZMDM) Directorate of Measures and Precious Metals, Belgrade (Serbia)
DTI	Department of Trade and Industry (United Kingdom)
EC-JRC	European Community, Joint Research Centre, Brussels (Belgium)
EFTF	European Frequency and Time Forum
EIM	Hellenic Institute of Metrology, Athens (Greece)
ENEA	Ente per le Nuove Tecnologie, l'Energia e l'Ambiente, Rome (Italy)
ENFSI	European Network of Forensic Science Institutes
ESA	European Space Agency
ESA-ESTEC	European Space Agency, European Space Research and Technology Centre, Noordwijk (The Netherlands)
EURAMET	(the former EUROMET) European Association of National Metrology Institutes
EUROMET	European Collaboration in Measurement Standards
FAO	Food and Agriculture Organization of the United Nations
FCS	Frequency Control Symposium
FYROM	The Former Yugoslav Republic of Yugoslavia
GAWG	CCQM Working Group on Gas Analysis
GGOS	Global Geodetic Observing System of the International Association of Geodesy (IAG)
GT-RF	CCEM Working Group on Radiofrequency Quantities/ Groupe de travail du CCEM pour les Grandeurs aux Radiofréquences
GUM	Central Office of Measures/Główny Urząd Miar, Warsaw (Poland)

IAC	International Avogadro Coordination
IAEA	International Atomic Energy Agency
IAG	International Association of Geodesy
IAM	Inter-agency Meeting
IAU	International Astronomical Union
IBMETRO	Instituto Boliviano de Metrología, La Paz (Bolivia)
ICAG	International Comparison of Absolute Gravimeters
ICRM	International Committee for Radionuclide Metrology
ICRU	International Commission on Radiation Units and Measurements
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers, Piscataway, NJ (United States)
IERS	International Earth Rotation and Reference Systems Service
IFCS	International Frequency Control Symposium
IFIN	Institute of Physics of the Romanian Academy, Bucharest (Romania)
IGS	International GNSS Service
IKZ	Institut für Kristallzüchtung, Berlin (Germany)
ILAC	International Laboratory Accreditation Cooperation
iMERA	implementing Metrology in the European Research Area, EUROMET project
INM	National Institute of Metrology, Bucharest (Romania)
INM*	Institut National de Métrologie, see LNE-INM
INMETRO	Instituto Nacional de Metrologia, Normalização e Qualidade Industrial, Rio de Janeiro (Brazil)
INRIM	Istituto Nazionale di Ricerca Metrologica, Turin (Italy)
ION	Institute of Navigation, Alexandria, VA (United States)
IOP	Institute of Physics, London (United Kingdom)
IOPP	Institute of Physics Publishing, London (United Kingdom)
IRA-METAS	Institut Universitaire de Radiophysique Appliquée du METAS, see METAS
IRMM	Institute for Reference Materials and Measurements, European Commission
ISO	International Organization for Standardization
ISO CASCO	International Organization for Standardization, Conformity Assessment Committee
ISO REMCO	International Organization for Standardization, Committee on Reference Materials
ITN	Instituto Tecnológico e Nuclear, Savacém (Portugal)
ITU	International Telecommunication Union

IUPAC	International Union of Pure and Applied Chemistry
IUPAP	International Union of Pure and Applied Physics
IVS	International VLBI Service
JCDCMAS	Joint Committee on Coordination of Assistance to Developing Countries in Metrology, Accreditation and Standardization
JCGM	Joint Committee for Guides in Metrology
JCRB	Joint Committee of the Regional Metrology Organizations and the BIPM
JCTLM	Joint Committee for Traceability in Laboratory Medicine
JILA	Joint Institute for Laboratory Astrophysics, Boulder, CO (United States)
JWG	Joint Working Group
KCWG	Key Comparison Working Group
KRISS	Korea Research Institute of Standards and Science, Daejeon (Rep. of Korea)
LATU	Laboratorio Tecnológico del Uruguay, Montevideo (Uruguay)
LGC	Laboratory of the Government Chemist, Teddington (United Kingdom)
LISA	Laser Interferometer Space Antenna, ESA mission
LNE	Laboratoire National de Métrologie et d'Essais, Paris (France)
LNE-CETIAT	Laboratoire National de Métrologie et d'Essais, Centre Technique des Industries Aéronautiques et Thermiques, Villeurbanne (France)
LNE-CNAM	Laboratoire National de Métrologie et d'Essais, Conservatoire National des Arts et Métiers, Paris (France)
LNE-INM	Laboratoire National de Métrologie et d'Essais, Institut National de Métrologie, Paris (France)
LNE-LNHB	Laboratoire National de Métrologie et d'Essais, Laboratoire National Henri Becquerel, Gif-sur-Yvette (France)
LNE-SYRTE	Laboratoire National de Métrologie et d'Essais, Systèmes de Référence Temps Espace, Paris (France)
LNHB*	Laboratoire National Henri Becquerel, see LNE
LNMRI	Laboratório Nacional de Metrologia das Radiações Ionizantes, Rio de Janeiro (Brazil)
LNMRI-IRD	Laboratório Nacional de Metrologia das Radiações Ionizantes, Instituto de Radioproteção e Dosimetria, Rio de Janeiro (Brazil)
LSDG	Laboratory for Standard Dosimetry, Gent (Belgium)

MAC	UK Department of Trade and Industry Measurement Advisory Committee
METAS	Federal Office of Metrology, Bern-Wabern (Switzerland)
MetChem	EUROMET Technical Committee: Metrology in Chemistry
MIKES	Mittatekniikan Keskus/Centre for Metrology and Accreditation, Helsinki (Finland)
MITI	Ministry of International Trade and Industry, Tokyo (Japan)
MKEH	(the former OMH) Hungarian Trade Licensing Office, Budapest (Hungary)
MRA	Mutual Recognition Arrangement
MSL	Measurement Standards Laboratory of New Zealand, Lower Hutt (New Zealand)
NAB	National Accreditation Body
NCM	National Centre of Metrology, Sofia (Bulgaria)
NCSLI	National Conference of Standards Laboratories, Boulder, CO (United States)
NIM	National Institute of Metrology, Beijing (China)
NIS	National Institute for Standards, Cairo (Egypt)
NIST	National Institute of Standards and Technology, Gaithersburg, MD (United States)
NMi VSL	Nederlands Meetinstituut, Van Swinden Laboratorium, Delft (The Netherlands)
NMI	National Metrology Institute
NMIA	National Measurement Institute, Australia, Lindfield (Australia)
NMIJ/AIST	National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology, Tsukuba (Japan)
NMISA	National Metrology Institute of South Africa, Pretoria (South Africa)
NMIT	National Measurement Institute of Thailand, Bangkok (Thailand)
NML	National Metrology Laboratory, Dublin (Ireland)
NML-SIRIM	National Metrology Laboratory, Standards and Industrial Research Institute, Shah Alam (Malaysia)
NOAA	National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Washington DC (United States)
NPL	National Physical Laboratory, Teddington (United Kingdom)
NRC	National Research Council of Canada, Ottawa (Canada)

NRC-INMS	National Research Council of Canada, Institute for National Measurement Standards, Ottawa (Canada)
NTSC	National Time Service Centre, Lintong (China)
OIML	International Organization of Legal Metrology/ Organisation Internationale de Métrologie Légale
OMH*	Országos Mérésügyi Hivatal/National Office of Measures, Budapest (Hungary), see MKEH
OMP	Observatoire Midi-Pyrénées, Toulouse (France)
ON	Observatoire de Neuchâtel (Switzerland)
ONERA	Office National d'Études et de Recherches Aérospatiales, Châtillon (France)
ORB	Observatoire Royal de Belgique, Brussels (Belgium)
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig and Berlin (Germany)
PTTI	Precise Time and Time Interval Applications and Planning Meeting
RAB	Regional Accreditation Body
RMO	Regional Metrology Organization
RSC	Royal Society of Chemistry
RWTH	Rheinische-Westfälische Technische Hochschule, Aachen (Germany)
SADCMET	Southern African Development Community Cooperation in Measurement Traceability
SIM	Sistema Interamericano de Metrología
SIRIM*	Standards and Industrial Research Institute, Shah Alam (Malaysia), see NML
SPIE	International Society for Optical Engineering
SPRING*	Standards, Productivity and Innovation Board, Singapore (Singapore), see A*STAR
SRC	Synchrotron Radiation Centre, Stoughton WI (United States)
SSDL	Secondary Standards Dosimetry Laboratories
SUNAMCO	Symbols, Units, Nomenclature, Atomic Masses and Fundamental Constants, IUPAP Commission
SYRTE*	Systèmes de Référence Temps Espace, see LNE
TC	Technical Committee
TCEM	Technical Committee on Electricity and Magnetism
TempMeko	International Symposium on Temperature and Thermal Measurements in Industry and Science
TG	Task Group
UKAS	United Kingdom Accreditation Service

UME	Ulusal Metroloji Enstitüsü/National Metrology Institute, Marmara Research Centre, Gebze-Kocaeli (Turkey)
UNIDO	United Nations Industrial Development Organization
USNO	U.S. Naval Observatory, Washington DC (United States)
VERMI	Virtual European Radionuclide Metrology Institute
VNIIFTRI	All-Russian Research Institute for Physical, Technical and Radiophysical Measurements, Rostekhnregulirovaniye of Russia, Moscow (Russian Fed.)
VNIIM	D.I. Mendeleev Institute for Metrology, Rostekhnregulirovaniye of Russia, St Petersburg (Russian Fed.)
VNIIMS	Russian Research Institute for Metrological Service of Rostekhnregulirovaniye of Russia, Moscow (Russian Fed.)
VSL*	Van Swinden Laboratorium, see NMI VSL
WBTM	Watt Balance Technical Meeting
WG	Working Group
WGACQHR	CCEM Working Group on Measurements of the Quantized Hall Resistance with Alternating Current and Related Measurements
WGDM	CCL Working Group on Dimensional Metrology
WGG	CCM Working Group on Gravimetry
WGLF	CCEM Working Group on Low-Frequency Quantities
WGRMO	Working Group on Regional Metrology Organizations
WGSP	Working Group on Strategic Planning
WGUV	Working Group on Ultraviolet
WHO	World Health Organization
WMD	World Metrology Day
WMO	World Meteorological Organization
WMO CIMO	World Meteorological Organization, Commission for Instruments and Methods of Observation
ZMDM*	Bureau of Measures and Precious Metals, Beograd (Serbia and Montenegro), see DMDM

2 Acronyms for scientific terms

ALC	Automatic Loadable Container
BMC	Best Measurement Capability
CCC	Cryogenic Current Comparator
CMC	Calibration and Measurement Capabilities
CRM	Certified Reference Material
DSC	Differential Scanning Calorimetry
EAL	Free Atomic Time Scale/Échelle Atomique Libre
FTIR	Fourier Transform Infrared Technique

GB	Glove Box
GC	Gas Chromatography
GLONASS	Global Navigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GUM	<i>Guide to the Expression of Uncertainty in Measurement</i>
IT	Information Technology
IVD	<i>In vitro</i> Diagnostic
JAVS	Josephson Array Voltage Standard
KCDB	BIPM Key Comparison Database
KCRV	Key Comparison Reference Value
LC	Liquid Chromatography
LS	Liquid Scintillation
MC	Measurement Capability
MS	Mass Spectrometry
NMR	Nuclear Magnetic Resonance
PFS	Primary Frequency Standard
PPT	Precise Point Positioning
QHR	Quantum Hall Resistance
QM	Quality Management System
QS	Quality System
SI	International System of Units/Système International d'Unités
SINIS	Superconductor-insulator-normal metal-insulator-superconductor
SIR	International Reference System for gamma-ray emitting radionuclides/Système International de Référence pour les mesures d'activité d'émetteurs de rayonnement gamma
SNS	Superconductor-normal metal-superconductor
SRP	Standard Reference Photometer
TAI	International Atomic Time/Temps Atomique International
TDCR	Triple-to-Double Coincidence Ratio Technique
TT	Terrestrial Time
TWSTFT	Two-way Satellite Time and Frequency Transfer
UTC	Coordinated Universal Time
UV	Ultraviolet
VIM	<i>The International Vocabulary of Metrology, Basic and General Concepts and Associated Terms</i> (3rd edition)
VLBI	Very Long Baseline Interferometry
VOC	Volatile Organic Compound

VTS	Vacuum Transfer System
YAG	Yttrium Aluminium Garnet

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