

Bureau international des poids et mesures

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

(1 July 2008 – 30 June 2009)

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 2009

Member States

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

Associates of the General Conference

Albania	Ecuador
Belarus	Estonia
Bolivia	Georgia
CARICOM	Hong Kong, China
Chinese Taipei	Jamaica
Costa Rica	Kenya
Cuba	Latvia

.../...

Associates of the General Conference (cont.)

Lithuania	Philippines
Macedonia (the FYR of)	Slovenia
Malta	Sri Lanka
Moldova (Rep. of)	Tunisia
Panama	Ukraine
Paraguay	Viet Nam
Peru	

THE BIPM

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 world-wide 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 direction and 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. The CIPM has eighteen members each being of different nationality, and at present it meets every year. The CIPM submits to the Governments of the Member States an annual report on the administrative and financial situation of the BIPM.

The CGPM is made up of delegates from all Member States and at present meets every four years. Its mission 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 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 international comparisons of realizations of units, calibrations of standards and metrological research. 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 (CEEM), 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, charged particles), 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 meetings of the CGPM and the CIPM are published in the following series:

- *Comptes rendus des séances de la Conférence générale des poids et mesures;*
- *Procès-verbaux des séances du Comité international des poids et mesures.*

The CIPM decided in 2003 that the reports of meetings of the Consultative Committees should no longer be printed, but would be published 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 BIPM.

**STAFF OF THE
INTERNATIONAL BUREAU OF WEIGHTS AND MEASURES**

on 30 June 2009

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Deputy director: Prof. M. Kühne

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Workshop and site maintenance: Mr J. Sanjaime

Workshop: Mr F. Boyer, Mr M. de Carvalho, Mr S. Segura, Mr B. Vincent

Site maintenance: Mr P. Benoit, Mr P. Lemartrier

Emeritus directors: Prof. P. Giacomo, Dr T.J. Quinn

1 Also Mass.

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 2008 – 30 June 2009)

1 INTRODUCTION

1.1 General introduction and overview of the year

I am pleased to report on activities of the BIPM during the 2008/9 reporting year. This report is the most detailed annual account of our activities presented to Governments and is an important archive of the work of what is, I believe, the second oldest intergovernmental organization in the world.

The BIPM continues to meet its original 1875 mission – namely to ensure the equivalence of measurement standards world-wide. Its role and detailed mission have, of course, evolved dramatically over the years. In addition to meeting the metrological needs of Member States as expressed through their Governments and National Metrology Institutes (NMIs), I am struck by the number of intergovernmental organizations and international bodies with which we now work to achieve our mission. In some cases, such as with the International Organization for Legal Metrology (OIML) and the International Laboratory Accreditation Cooperation (ILAC), these are our natural metrology partners, but we are often approached by others and asked to set up collaborations. Among the links which have been particularly strengthened over the last year or so are those with the World Anti-Doping Agency (WADA), the Food and Agriculture Organization (FAO), and the International Federation of Clinical Chemistry (IFCC). The magnet that draws these bodies to us is the clear and authoritative role we have to play in traceable, accurate measurements based on stable international references. This approach, it seems to me, is testimony to the wisdom of decisions taken more than a decade ago to extend the BIPM's work into chemical metrology and it also reflects the success of the CIPM MRA. The achievements of the CIPM MRA in physics and engineering have demonstrated what can be done to add confidence to the world measurement system in these areas and the trend now is to adopt and adapt its principles in the new areas. This, I believe, is a sign to Member States of the importance of the BIPM's moves into new areas and the need to take bold steps to develop international collaborations and partnerships in order to achieve the goals of the Metre Convention. The benefits of the diversification so far achieved are beginning to show. As we start to prepare for the meeting of the General Conference in 2011, I hope that Member States will continue to give the BIPM, and its, by then, new Director, their full support.

1.2 BIPM's programme of scientific work

The year 2009 has seen the beginning of the four-year programme of work approved by the 23rd meeting of the General Conference on Weights and Measures (CGPM) in 2007. This last meeting of the CGPM decided on a dotation that was less than the CIPM had requested, and asked the CIPM to prioritize the activities proposed in the work programme.

It was immediately clear that the financial outcome of the 23rd meeting of the CGPM made it impossible to fully implement the increased programme of work originally proposed for the period 2009–2012. Priorities therefore had to be set to match the work and resources to the financial income expected from Member States, Associates, and other sources.

The prioritization requested by the CGPM was completed during the meeting of the CIPM in October 2008. Whilst I am pleased to say that most of the BIPM's core scientific work will continue, some projects of importance will be delayed until resources allow and some current activities will be terminated to allow the launch of higher priority projects.

As the BIPM has a unique role to play in dissemination of mass to all Member States and as a redefinition of the kilogram is expected within the next few years, the CIPM's top priority for the BIPM is to support mass metrology. This involves the continuation of the work on the development of a BIPM 'watt balance' facility which will be necessary for realizing the proposed redefinition of the kilogram and for improving the means of its dissemination to Member States to meet future needs. All the proposed activities will be carried out, and part of the mass activity connected with the preparation, using the best available 'new technology', of an ensemble of weights which will act as the BIPM's working standards, will be delivered through a collaboration with a number of NMIs with special expertise and interest in this area.

The CIPM's next highest priority was the maintenance of the BIPM activities related to creation of the world time scale and international time transfer. These will also be retained as proposed.

The Electricity programme will continue to provide on-site comparisons for NMIs using the BIPM's travelling standards and will complete the construction of a calculable capacitor as an international reference facility.

The core elements of the Ionizing Radiation programme in dosimetry and radioactivity will be maintained, centred on the BIPM's reference facilities.

The Chemistry programme will consolidate its activities in gas metrology and will expand its work in organic chemistry, particularly the characterization of pure calibrator materials for use in key comparisons.

The international liaison work will concentrate on promoting the benefits of association with the BIPM and supporting our links with the international accreditation and specification standards-making bodies.

However, in order to provide the resources to meet these priorities, other important activities had, unfortunately, to be reduced with the result that:

- fewer 'travelling standards' used in the on-site calibration of national time receiving equipment will be purchased. A new project will research alternatives to the current use of travelling standards in this process;
- the facility for iodine-cell preparation was closed at the end of 2008, and the BIPM liaised with a number of other NMIs that were interested in supplying users of this service who require iodine cells for stabilized lasers and gravimetry equipment;
- a project to develop a new voltage standard which would be used for on-site comparisons of electrical standards at NMIs will be re-organized so as to save staff resources;
- extension of the BIPM reference facilities for activity measurements on alpha particle emitters will be postponed;
- some projects on gas metrology will be cancelled or postponed. In particular, a project of relevance to air-quality monitoring will not now be launched.

Significant cuts in overheads have been made through savings, reorganization of support services, and delays to building maintenance.

In coming to decisions on the activities to be retained and launched in January 2009, the CIPM considered carefully the expected income from new Member States and Associates. The cautious funding scenario adopted by the CIPM anticipated two new Member States and five new Associates during the 2009–2012 period. Over the past few years, the BIPM has increased its efforts to attract new States and this hard work is starting to pay off so that the number of Members now stands at 53 (an increase of two) and the number of Associates at 27. We have, therefore, already met the Membership target and the BIPM is in discussion with several more States that have expressed interest in participating; more details are provided in §1.5. In addition, a number of NMIs of Member States have offered

additional voluntary financial contributions. I am especially grateful to them, as well as to a number of NMIs and Member States that have supported the BIPM in bilateral arrangements, in aligning programmes of work to achieve common objectives, and in the supply of staff on secondment.

1.3 The International System of Units (SI)

Little has changed in the overall approach to a potential redefinition of a number of SI units. The relevant Consultative Committees review the situation at each meeting and there is now firm consensus in favour of:

- a kilogram redefinition based on a fixed value of the Planck constant, h ;
- a definition of the ampere based on a fixed value of the elementary charge, e ;
- a redefinition of the kelvin based on a fixed value of the Boltzmann constant, k_B ; and
- a redefinition of the mole based on a fixed value of the Avogadro constant, N_A .

However, and despite some impressive progress made during the last year in the NMIs, there is not yet an adequate degree of convergence between the results from watt balance experiments and from the International Avogadro Coordination (IAC) project which would give confidence in the selection of a value for the Planck constant. Both approaches are expected to produce new results in the next year or so, and the CIPM will continue to consider whether the time is right for proposals of a redefinition of the SI base units to be made to the CGPM.

1.4 The CIPM Mutual Recognition Arrangement (CIPM MRA) and the JCRB

The CIPM MRA has now been signed by the NMIs of 47 Member States and 25 Associates, as well as by two international organizations, bringing the total number of signatory and other designated institutes committed to the CIPM MRA to 197. There are currently over 21 000 Calibration and Measurement Capabilities (CMCs), 659 key comparisons and 212 supplementary comparisons in the BIPM key comparison database (KCDB), compared with 620 and 181 key and supplementary comparisons at the time of the previous report.

The *KCDB Newsletter* – now in its tenth edition – continues to be used to promote the work of the BIPM and highlight the successes of the CIPM MRA in helping reduce costs through the use of local NMIs, as well as the scientific benefits of increased confidence in measurement capabilities.

The Joint Committee of the BIPM and the Regional Metrology Organizations (JCRB) continues to oversee the operational aspects of the CIPM MRA. As reported in §1.6 on the last meeting of the CIPM, I am pleased to note the evolution of AFRIMETS in the African continent. The creation of AFRIMETS has stimulated a number of its Members to express interest in becoming either a Member State of the BIPM or an Associate of the CGPM. Similar initiatives to create Regional Metrology Organizations (RMOs) are afoot in the Middle East and Gulf Region and the JCRB has met with representatives of GULFMET. The BIPM's position is that it encourages the formation of significant regional groupings and the role they can play in implementing the CIPM MRA and attracting additional Signatories.

During the last year, the CIPM approved two web-based documents on the CIPM MRA: a guide to current policy decisions in relation to the CIPM MRA, and a summary of the procedures for creating and processing CMCs. Both documents are available in the CIPM MRA area of the BIPM's website (www.bipm.org/en/cipm-mra/documents/).

As reported previously, the BIPM and ILAC have agreed on a common definition and understanding of the term Calibration and Measurement Capability (CMC), and this term will gradually replace Best Measurement Capability (BMC) which was formerly used in the accreditation community. This common nomenclature helps the NMI and accredited laboratory communities to work together to ensure robust traceability of measurement results from accredited laboratories to the units of the SI as realized by the NMIs. In response to user requests, the CIPM's Consultative Committees generally now endorse adding the contribution of the 'device under test' to the uncertainties which should be associated with calibrations. They and ILAC are also identifying a broader range of service level categories for CMCs, which will help meet the needs of a number of NMIs as well as harmonize the scopes of accredited laboratories with the CMCs declared by NMIs.

1.5 Member States and Associates

The previous increase in the number of Members of the BIPM occurred in 2001 with the accession of Greece and Malaysia. It is with great pleasure that I can report that the Republics of Croatia and Kazakhstan have acceded as Member States in 2008, after a period as Associates. This increase in status is strongly encouraged by the CIPM, as requested by Member States during the meeting of the last CGPM. In addition, Paraguay and Peru have become Associates of the CGPM during the reporting period 2008/9. The BIPM is in contact with a number of other States that have declared their intention to become either Members of the BIPM or Associates of the CGPM, as well as with some current Associates that are considering becoming Members.

1.6 Meeting of the CIPM

The 97th meeting of the CIPM took place in October 2008. Drs Kwang Hwa Chung, Hector Nava Jaimes, and Willie E. May took up their seats for the first time, and we welcome them to the Committee.

As reported above, the main decisions concerned the prioritization of the BIPM's programme of work for 2009–2012. The CIPM also approved the new Regional Metrology Organization AFRIMETS as a successor to SADCMET and as a member of the JCRB, and approved plans for a major event to mark a decade of the CIPM MRA through a special symposium to be held in conjunction with the Directors' Meeting in October 2009.

Other policy decisions and discussions included the criteria to be used to approve new RMOs, the policy to be adopted by NMIs when stating their traceability to the SI when they declare CMCs, and a number of issues relating to the application of the CIPM MRA.

The CIPM also held a workshop on the long-term direction for the BIPM and its science strategy. This helped identify priorities for the 2013–2016 programme of work of the BIPM to be presented to the CGPM in 2011. Potential activities in nanotechnology and the biosciences are amongst the issues that will be considered again by the CIPM in October 2009 when it discusses the first draft programme of work.

1.7 Joint Committee for Guides in Metrology (JCGM)

At the meeting of the JCGM in December 2008, approval was given to a proposal to review the *Guide to the Expression of Uncertainty in Measurement* (GUM) and a proposal to review and eventually update the *International Vocabulary of Metrology* (VIM). The latter is likely to take several years and initial consideration will be given to whether terms for nominal properties should be included. The original text of the GUM has been made openly available on the BIPM website with the reference JCGM 100:2008 (GUM 1995 with minor corrections): see www.bipm.org/en/publications/guides/. The JCGM also approved the establishment of an *ad hoc* working group to consider a number of activities in relation to metrological software.

1.8 Joint Committee for Traceability in Laboratory Medicine (JCTLM)

In December 2008, the Executive Committee of the JCTLM discussed reports from its two working groups and reviewed the status of the revisions of ISO 15194 and 15193, both of which are key to the Joint Committee's work. The Committee was also concerned to see faster progress on the accreditation of reference laboratories to ISO 15195. The Executive Committee meeting was followed by a workshop on the current state of national and international systems for traceability, and discussed options for the preparation of a policy and discussion paper for decision makers on the need for greater attention to traceability in the clinical and laboratory medicine communities.

1.9 Liaison with intergovernmental organizations and international bodies

International coordination and liaison continues to consume some 20 % of our resources, distributed between general liaison activity and that carried out by the science Sections in direct support of their missions and objectives.

I am pleased to report further progress on the study by the CIPM on measurement and traceability needs in materials science. The report of the study is openly available on the BIPM website (see <http://www.bipm.org/utills/common/pdf/WGMM2008.pdf>). In June 2008 a Memorandum of Understanding (MoU) was signed between the BIPM and the Versailles Project on Advanced Materials and Standards (VAMAS), and VAMAS was asked to identify priority topics and liaise with the relevant Consultative

Committees. The issue of materials metrology is now routinely considered by a number of Consultative Committees, and a special issue of *Metrologia* on the subject of materials metrology is being organized for publication in 2010.

Progress has also been made with the World Meteorological Organization (WMO) in moving towards agreement on the arrangements for their signature of the CIPM MRA. These special arrangements are necessary since the WMO, unlike the other international bodies that have become signatories, has no laboratories of its own. The BIPM is also working with the WMO to hold a workshop on metrology and climate change in February 2010.

Finally, the BIPM signed an MoU with the United Nations Industrial Development Organization (UNIDO) in December 2008. The aim of the MoU is to encourage collaboration between the two organizations and the OIML so as to help strengthen metrology infrastructures in a number of regions and to promote the relevance of metrology to trade and capacity building.

1.10 The BIPM and the International Organization for Legal Metrology (OIML)

As a result of discussions between the Directors of the BIPM and the BIML, a number of possibilities for closer liaison and rapprochement have been considered such as co-location at the BIPM site. The options were discussed by the OIML Member States and they considered that more thought was needed on this. The BIPM and the BIML will continue to work closely together.

1.11 BIPM Metrology Summer School

As reported last year, the BIPM Metrology Summer School 2008 was held at the BIPM from 29 June 2008 to 11 July 2008. The Co-Directors of the School were Prof. Andrew Wallard (Director of the BIPM), Dr Alan Steele (NRC-INMS, Canada) and Dr Mike Sargent (LGC, United Kingdom), and Dr Claudine Thomas (BIPM) acted as Scientific Secretary.

A total of 90 students from 34 Member States of the BIPM and Associates of the CGPM attended the School, and a total of 42 teachers were invited for lecture and workshop activities. The teachers were all experts in their fields, and included three Nobel laureates: Prof. Sir Harry Kroto, Prof. William

Phillips, and Prof. Klaus von Klitzing, as well as Mrs Dava Sobel, scientific journalist.

The staff of the BIPM were closely involved in the School. In addition to Prof. Wallard and Dr Thomas, several senior scientific staff members gave lectures, chaired sessions, and organized workshops. The School included detailed visits of the BIPM's scientific laboratories, and BIPM staff also attended a number of lectures as students.

The programme included 39 lectures on four main themes: 'From classical SI to new SI', 'The international organization of metrology', 'Metrology in physics and its applications', and 'Metrology in chemistry and its applications'. There were also four workshops, on 'Chemical methods', 'Calculation of uncertainties by Monte Carlo', 'Electricity: the quantum Hall effect', and 'Quality Systems, Accreditation, ISO Guide 34, and the KCDB'; comprehensive visits to the five scientific sections of the BIPM (including the fabrication of kilogram prototypes); a poster session where 20 posters were presented by the School students; a visit to the laboratories of the Laboratoire National de Métrologie et d'Essais (LNE) in Trappes (France), and cultural activities including a talk by Dava Sobel, author of *Longitude*, in the Cassini room of the Paris Observatory (OP). The latter two events were organized in partnership with the LNE and the OP, respectively.

The ambiance of the School was studious, hard-working, and friendly. The material related to the School was distributed to the students and teachers on BIPM-customized USB keys, and was also made available on the School's restricted-access website.

The responses to a questionnaire addressed to the students show that the BIPM Metrology Summer School 2008 was a great success, especially in achieving its primary purpose of encouraging interactions and friendship between the metrologists of the future.

1.12 World Metrology Day (WMD)

The 2009 theme of 'Measurement in Commerce' provided the BIPM with an opportunity to highlight the ten-year anniversary of the CIPM MRA. In collaboration with the NIST (United States of America henceforth USA), NMIJ AIST (Japan), NMISA (South Africa), NPL (United Kingdom of Great Britain and Northern Ireland henceforth UK), OIML and the NCSLI (NCSL International), the BIPM again produced a poster to support and promote the annual message from the Director. The 'WMD' material was widely distributed and also published on a new WMD website,

<http://www.worldmetrologyday.org>. Fifty different posters in 25 languages were produced as well as two supporting leaflets in English and French. We have received many reports of national activities in Member States and in Associates. In particular, it is interesting to hear that a number of NMIs in States which are neither Members nor Associates have also taken advantage of the WMD to hold national information events. These focus on drawing attention to the importance of metrology and persuading Governments of the value of becoming involved in the work of the BIPM.

1.13 BIPM's measurement services and Quality System

The BIPM continues to provide a limited number of measurement services for NMIs from Member States. All its external, as well as a number of its internal, services satisfy the requirements of the BIPM's self-declared ISO/IEC 17025 Quality System. In March 2009, the BIPM presented its Quality System to RMO experts and received a number of helpful comments. A link is now provided between the appropriate pages in the KCDB and the uncertainties associated with the BIPM's calibration and measurement services as published on the BIPM website. As a result, NMIs which take traceability to the SI through the BIPM can point clearly to the uncertainties they need to take into account when formulating their own CMCs. This has been widely welcomed.

1.14 Health and safety

I am pleased to report that no safety incidents occurred at the BIPM last year. The Health and Safety Commission (HSC) has met five times during the reporting period, and continues to follow up the study of risks carried out by Bureau Veritas (France). A new safety manual is approaching completion, and a safety hand-out for short-stay visitors is also being prepared. We are in the final stages of recruiting a staff member to be responsible for Quality, Health and Safety.

1.15 BIPM staff matters

Prof. Michael Kühne took up his post as Deputy Director and Director Designate in April 2009. Michael joins the BIPM from the PTB (Physikalisch-Technische Bundesanstalt) in Germany.

An Amendment to the Headquarters Agreement between the BIPM and the French Government was finally ratified by the French Parliament in June 2008. Amongst other things, the Amendment provides for the recognition of the jurisdiction of the international administrative tribunal of the International Labour Organization (ILO) for staff disputes.

The CIPM also approved a number of minor amendments to the Staff Rules and Regulations.

One notable trend in recent years has been the increasing number of short-term or seconded staff. In 2008/9 we hosted eight secondees (there were four in 2006 and seven in 2007) and recruited two staff on short-term appointments. This way of working helps the BIPM maintain its direct links with the NMIs and other institutions that provide secondees, and is also an excellent way of helping us with the development of expertise in specific areas.

I would like formally to record my thanks to all members of the BIPM staff for their hard work during the last year. It has been – and continues to be – a time of change and I am proud of the way in which my colleagues have risen to the challenges.

1.16 BIPM staff commissions

The merger of a number of Commissions into a single Commission concerned with conditions of employment has generally been very successful. The main discussions this year have concerned preparations for modifications to the BIPM Staff Pension Scheme, to be proposed to the CIPM in October 2009; the Commission members have made valuable and constructive suggestions during the process.

Amongst the other commissions, I would like, in this report, to mention the work of the Social Affairs Commission. In recent years, a number of new young staff have been recruited from a number of different countries. Becoming an international civil servant in France – or indeed anywhere – involves a change of culture as the individual moves to a different country. The BIPM Social Affairs Commission plays a valuable role in organizing a variety of social and cultural events, which help bring new recruits into the ‘family’ of the BIPM and create friendships and support for the new staff as well as contributing to the overall team spirit.

I would like to record my thanks to all staff who work hard to represent their colleagues on all the Commissions.

1.17 Science at the BIPM

Mass: We continue to prepare for a probable redefinition of the kilogram, which may occur as early as 2011. The International Avogadro Coordination (IAC) project is moving rapidly toward its conclusion and we are supporting the mass metrology of this enterprise. We are now equipped with a fine vacuum balance, an external glove box and, this year, a vacuum transfer system (VTS). This ensemble of equipment will allow the transfer to our balance of mass standards maintained under vacuum or inert atmosphere by the BIPM or NMIs. The glove box contains a vacuum oven for the thermal treatment of silicon spheres in order to remove surface moisture that remains under vacuum at room temperature.

Through a bilateral comparison we have helped to confirm the uncertainty assigned by the NPL to the mass standards used in their watt balance. We are participating in a pilot study to support technical requirements of a *mise en pratique* for a new kilogram definition. A programme has been initiated to create a group of twelve artefact kilogram standards made of three different materials and stored under vacuum or inert atmosphere. The average mass of these artefacts, determined by a weighted average, is expected to be a more robust representation of the redefined kilogram than can be obtained from a single artefact.

Our calibration service continues to support requests from Member States. We have strengthened this service through a re-evaluation of the masses of our working standards. We are in the process of adding new capabilities for the calibration of relative humidity sensors. We have produced new artefacts that can be used for the gravimetric determination of air density. Automation of a comparator in the range 100 g to 5 g is almost complete and will improve our efficiency in this range (necessary for internal BIPM calibrations). A successful bilateral comparison with the PTB of the density of a 1 kg cylinder of platinum-iridium has been completed. We have joined a EURAMET comparison to test the principal techniques for determining the magnetic properties of secondary mass standards.

Three of our staff members have made essential contributions to the BIPM watt balance, devoting most of their time to that activity (see §7).

Time, frequency and gravimetry: The international time scales TAI and UTC are computed each month, and the results are published in *Circular T*, which serves as the monthly update of key comparison CCTF-K001.UTC. The stability of TAI, expressed in terms of an Allan deviation, is estimated to be at, or below, 4 parts in 10^{16} for averaging times of one month. During

the period of this report twelve primary frequency standards contributed to improving the accuracy of TAI, including eight caesium fountains (IT CSF1, LNE-SYRTE FO1, LNE-SYRTE FO2, LNE-SYRTE FOM, NICT CSF1, NIST-F1, NMIJ F1 and PTB CSF1). Throughout the year a total correction of -5.2×10^{-15} has been applied to $[f(EAL) - f(TAI)]$. Since July 2008, the scale unit of TAI has been estimated to match the SI second to about 1 part in 10^{15} .

Following the success of the pilot experiment on the use of phase measurements along with the code measurements of geodetic-type GPS receivers, at its meeting in June 2009 the CCTF approved the inclusion of this method in the clock comparisons for TAI. The solutions based on this method (TAI PPP) will be used in the routine computation of *Circular T* from October 2009, with data from at least 25 laboratories.

The Section continues to organize and run round-trips to calibrate GPS receivers, with the aim of characterizing the relative delays of the time-transfer equipment in the contributing laboratories. The first measurements of relative delays of GLONASS equipment have also been made, and more are being organized.

Support has been provided to the various CCTF and CCL working groups, for which a number of members of staff have responsibilities. The Section provides the executive secretariat of the CCTF and the CCL, and has been active in the organization of the meetings of the two Committees in June 2009.

As part of the project to improve the algorithm used to calculate TAI and UTC, a new model for the frequency prediction of hydrogen maser clocks has been tested. The new model provides a partial explanation of the drift observed between the industrial clocks and the caesium primary standards.

A limited programme of research in the Section is dedicated to space-time reference systems. The cooperation with the USNO for the provision of the Conventions Product Centre of the International Earth Rotation and Reference Systems Service (IERS) is continuing; updates to the Conventions (2003) have been posted on the website (<http://tai.bipm.org/iers/>). Concerning the realization of reference frames for astrogeodynamic applications, staff of the Section have participated in the construction of a new international celestial reference frame in the scope of IAU activities.

The Section continues to provide technical advice in relation to the key comparison of stabilized lasers CCL-K11. The question of how best to validate optical frequency combs remains open, and forms the subject of a

questionnaire which will be circulated to NMIs, as requested by the CCL/CCTF Frequency Standards Working Group. The Section has also provided laser calibration and measurement services for both internal and external users.

Reacting to the announced closure of the BIPM's iodine cell service, many NMIs and other users have requested the provision of cells. More than twenty cells have been filled and tested within the period of this report.

The work on the gravimeter FG5-108 being undertaken in cooperation with the VNIIM (Russian Fed.) has been concluded. Preparations for the forthcoming International Comparison of Absolute Gravimeters, ICAG-2009, have been completed and the technical protocol of the key comparison CCM.G-K1 has been drawn up. About 25 gravimeters will participate in the international comparison, of which 17 will provide results for the key comparison.

Members of staff participate in activities linked to the watt balance and calculable capacitor projects at the BIPM.

The staff remain very active in the field of international coordination needed to accomplish the tasks conferred by the Member States. As part of this activity, the physicists of the Section have been widely invited to visit national laboratories and to lecture at conferences. A significant number of articles have been written within the period of this report, and 18 have recently been published with another ten or so in press at the time of writing.

Electricity: The work of the Electricity Section has been focused on its comparison programme to validate national primary standards for fundamental electrical quantities, on calibrations for NMIs of Member States, on support for the BIPM watt balance, and on the calculable capacitor, being developed together with the National Measurement Institute of Australia (NMIA).

In total nine comparisons were carried out with NMIs in the fields of voltage, resistance and capacitance. The BIPM is collaborating with the PTB on the choice of capacitance transfer standards for a comparison which is carried out within the framework of the EURAMET Joint Research Project on the redefinition of the ampere (REUNIAM).

The laboratory for voltage metrology has been refurbished and now provides better control of temperature and humidity. The new automated system for calibration of Zener voltage standards against Josephson arrays has been demonstrated to function correctly. A new transportable Josephson system for on-site comparisons with NMI Josephson voltage standards has been

developed over the last few years. This system is now functioning, but its reliability still needs to be improved.

In the field of impedance metrology, the long-term absence of two staff members obliged us to concentrate on the maintenance of the equipment needed for the realization of the resistance and capacitance units, derived from the quantum Hall effect, and on the comparisons and calibrations for NMIs. A new cryostat with a superconducting magnet, needed for the quantum Hall resistance standard, has been specified and ordered to replace the existing system which has a cold leak.

Together with the NMIA, the BIPM is developing two calculable capacitors of an improved design to measure the von Klitzing constant with an uncertainty of the order of 1 part in 10^8 to contribute to the next CODATA adjustment of the fundamental constants. The fabrication of a large number of mechanical parts in the BIPM workshop has been completed. Progress has been made by the NMIA on the polishing of the electrode bars, which are the most crucial components of the instruments. We expect to receive the electrode bars and the lead screw from the NMIA in the first half of 2010. The BIPM has tested the optical configuration of the Fabry-Perot interferometer and has worked on the optics needed to couple the laser beam into the cavity of the interferometer. Of particular importance is the development of a technique to determine the optical power in higher cavity modes. We expect that this technique will allow sufficient alignment of the laser beam with the optical axis of the cavity and estimation of the related measurement uncertainty.

Work has started on the development of a dedicated Josephson voltage standard for the BIPM watt balance. The Section Head is project leader of the watt balance experiment and the members of the Section have provided consultancy on several questions related to electrical measurements for the watt balance experiment.

During the reporting year 2008–2009 the Section has provided 35 Calibration Certificates and 1 Study Note for 13 NMIs of Member States. This is somewhat below the average of the last five years (50 certificates), but within the normal fluctuations. Calibrations are carried out for voltage (1.018 V and 10 V), resistance (1 Ω , 100 Ω and 10 k Ω) and capacitance (1 pF, 10 pF and 100 pF) and are requested mainly by NMIs that do not possess their own primary standards.

Watt balance: We have continued the development of the room temperature experiment to test the feasibility of simultaneous force and velocity measurements. Since the end of 2008 all the main components of the

experiment are available, but in many cases not yet in their final version. This allows us to test the various aspects of the experiment and to improve it stepwise.

A large amount of work was dedicated to improving the measurement of the voltage–velocity ratio during the coil movement. The reduction of noise requires a detailed understanding of the operation of the voltmeters and the interferometer, and in particular of their timing. Preliminary measurements have been carried out with the weighing cell and have led to the discovery of undesired magnetic forces, which potentially affect all watt balances. A mechanical system for real-time alignment of the moving coil has been developed and is under test.

The work on the magnetic circuit has continued in collaboration with the Technical University of Aachen (RWTH), Germany. The mechanical drawings for the magnet and the assembly system are nearly finished and the next steps will be the fabrication and assembly.

We have characterized the geometry of the winding of the large precision solenoid which will become our reference for the alignment of the magnetic field and found it adequate for this purpose.

A new laboratory with a large concrete base has been set up. A second, smaller, concrete base is available for measurement of the gravitational acceleration close to the watt balance. As a prerequisite for transferring the measured gravitational acceleration to the site of the watt balance test mass, the relative distribution of the gravitational acceleration in the laboratory has been determined with our relative gravimeter. Preliminary measurements of the vibration level indicate that the new laboratory is very quiet.

Ionizing radiation: The new values for air kerma in low- and medium-energy x-ray beams (based on a significant study published on aperture effects) and in ^{137}Cs gamma beams (based on measurements and incorporating Monte Carlo studies) were approved by the CCRI in May 2009 and have been submitted for publication. A new series of BIPM graphite cavity primary standards has been constructed with a volume agreement better than 3 parts in 10^4 ; one chamber is now operational as a primary air-kerma standard and two others are now part of the new BIPM absorbed dose to water standard based on the graphite calorimeter. Additionally, a plastic chamber is under study for continuing research into the effects of low atmospheric pressure. A study of the I -value for graphite has been submitted for publication and this could have significant consequences for all NMI graphite cavity standards.

The graphite calorimeter for absorbed dose to water has been operated in the ^{60}Co beam with a satisfactory reproducibility of 2 parts in 10^3 and a BIPM report on its construction has been published. The calorimeter has been tested in the LNE-LNHB ^{60}Co and linear accelerator beams to confirm both its suitability and certain parameters for the accelerator dosimetry comparison protocol. The first in the planned series of BIPM ongoing comparisons took place at the NRC (Canada) in June 2009 and the results are currently under analysis; the preliminary assessment looks successful.

Good progress has been made with the primary standard for mammography dosimetry. However, the unidentified cause of the discrepancy of 2 parts in 10^3 compared with the present low-energy standard is causing some delay in finalizing the mammography comparison facility.

Significant improvements to the x-ray facilities have been incorporated to improve stability and extend the overlap between the low- and medium-energy beams. Maintaining and improving the radiation standards' facilities, including the necessary Quality System measurements, represents a significant part of the Section's work. An internal audit was held at the end of 2008 and a satisfactory external audit in May 2009.

Nine dosimetry comparisons have been carried out and three other comparison reports have been published. In addition, a pilot study was made of the free-air chamber of the NIS (Egypt) for its future use as their primary standard. The BIPM is grateful to the guest scientist from the ININ (Mexico) who enabled significant progress to be made towards the CCRI brachytherapy comparisons. The BIPM piloted and took a partial role in a high-dose comparison and the results are being analysed. Twenty-three national secondary standards have been calibrated and support for the IAEA continues with regular irradiations of their dosimeters for the IAEA/WHO measurement service.

The Section contributed three papers on radiation dosimetry standards to the second *Metrologia* special issue on ionizing radiation (issue 46(2), 2009), which has already attracted a significant number of downloads.

Compared with only nine ampoules in 2008 submitted to the BIPM ongoing activity comparisons using the International Reference System (SIR), thirteen ampoules have already been received in the first half of 2009. This is a positive response by the NMIs to compensate for the planned phased removal from the KCDB of results pre-dating 1984. Six new results have been registered in the SIR master file and four comparison reports were published, covering seven results. There are now only a few measurements awaiting publication, some of these results requiring completion by the

NMIs and the others pending due to a lack of manpower. Impurity activity levels were measured using the BIPM Ge(Li) gamma spectrometer for three ampoules submitted for comparisons and good progress has been made towards the calibration of the replacement HPGe spectrometer. The new SIR measurement system has been verified and was adopted with effect from 1 January 2009. A successful internal audit of the SIR within the BIPM Quality System was carried out in late 2008 with a second external audit in June 2009.

The trial comparison of the short-lived $^{99}\text{Tc}^{\text{m}}$ radionuclide at the NPL using the SIR Transfer Instrument (TI) was successful and this enabled the TI to be transported to the NIST in May 2009 for the first in the series of ongoing comparisons of short-lived radionuclides for distant NMIs. The results of this comparison are currently being analysed and the preliminary assessment is that the comparison has been very successful in linking the NIST result to the other NMIs that have taken part in the SIR for this radionuclide.

Much effort has been devoted again this year to the preparation of liquid scintillation (LS) cocktails for the extension of the SIR to cover pure beta emitters. Now that the discrepancies in cocktail production seem to have been resolved, their efficiencies will be tested. In parallel with the LS chemistry, the equipment for the triple-to-double coincidence ratio technique (TDCR) has been modified to improve the signal-to-noise ratio and a Compton scatter coincidence method is also being implemented. The computational methods in use at the BIPM are being currently verified through a comparison with other NMIs.

The BIPM is currently piloting and participating in the ^3H comparison and the results of the previously piloted ^{85}Kr gas comparison are being analysed. The necessary SIR measurements to enable the ^{177}Lu comparison results to be linked to the KCRV have been made although we were unable to participate directly due to lack of resources. A number of earlier CCRI(II) comparison reports are awaiting publication, the work on extending the SIR to beta emitters having taken priority.

Chemistry: Activities in the Chemistry Section up to the end of 2008 completed the work programme for the period 2005–2008, during which BIPM-coordinated comparisons engaged 124 NMI participations in the areas of gas metrology and organic compound purity. Comparisons CCQM-P20.e (purity of theophylline) and CCQM-20.f (purity of digoxin), coordinated by the BIPM, provided good models for primary calibrator comparisons, enhanced laboratory performance, and provided support for reference measurement systems in laboratory medicine. The BIPM–NIST

programme to maintain the comparability of the world-wide network of ozone reference standards was supported by the results from BIPM.QM-K1 (ozone ambient level) for which the spread of laboratory results is now consistent with reported measurement uncertainties of the order of 1 part in 10^3 . This was a considerable improvement in performance compared to earlier comparisons such as EUROMET 414 (spread of results over 1 % of measured value) and the preceding pilot study CCQM-P28. Comparison CCQM-P73 (nitrogen monoxide) examined the degree of equivalence of 24 standards using a dedicated measurement system and repeatability conditions at the BIPM. The measurement uncertainties obtained were considerably smaller than in previous studies such as CCQM-K1.c and EUROMET-K1.c. Differences from the reference value due to systematic effects in the preparation of six cylinders were confirmed by additional FTIR measurements performed by the BIPM and the quantification of N_2O and NO_2 impurities.

The Chemistry Section 2009–2012 activities have started in earnest. In the area of primary calibrator comparisons, an assessment of purity for 17 β -estradiol was undertaken (CCQM-K55.a/P117.a). Subsequent key comparisons will include CCQM-K55.b (purity of aldrin) and CCQM-K55.c (purity of tetracycline). The development of methods to be used in the preparation and characterization of the study material for the CCQM-K55.b (aldrin) comparison has been started. This set of three purity comparisons coordinated by the BIPM has been designed to underpin all CMCs for pure organic calibrator materials. The BIPM has also started to investigate pure material characterization methods for compounds of higher molecular weight and complexity that are of interest to the CCQM Working Groups on Organic Analysis (OAWG) and Bioanalysis (BAWG). Peptides have been chosen as model systems as they are of direct relevance to the work programmes of both working groups. The protocol for an organic calibration solution study (CCQM-K78) is currently being developed at the BIPM.

The BIPM gas metrology programme continues to target analytically challenging species of relevance to air-quality and greenhouse-gas monitoring. A new cycle for the ozone reference standard comparison (BIPM.QM-K1) has started, with the majority of Ozone Standard Reference Photometers (SRPs) having now been upgraded with corrections for systematic effects arising from cell design and temperature control. Final validation studies for CCQM-K74/P110 (NO_2 in nitrogen, 10 $\mu\text{mol/mol}$) are being completed and have attracted 16 NMI participants who will submit 32 results. The pilot study will investigate the accuracy of FTIR

measurement methods with traceability either to gravimetric standards or to reference spectra, and has been organized in response to previous CCQM-GAWG workshops on spectroscopic measurements. Studies to characterize the uncertainties of gas-phase titration and nitrogen monoxide mole fraction analysis have continued, and the development of facilities for the comparison of methane and formaldehyde standards has started. An argon ion laser, which will be used for laser-based absorption measurements of ozone concentration and for a new measurement of the absorption cross section of ozone, has been recharacterized in terms of power stability.

A report on measurement infrastructure needs for metrology in the biosciences and biotechnology is in progress and input is being solicited as to which measurement services are required or will be developed by NMIs, what the current industry requirements may be, which international comparisons may be required to demonstrate equivalence of measurement services, and what research and development activities for higher metrological order measurement standards and methods for the biosciences should be considered. The Chemistry Section continues to support the JCTLM Database. The JCTLM Database was updated in January 2009 to include WG1 Cycle 5 reference materials, and WG2 Cycle 3 reference measurement laboratory service nominations approved by the Executive Committee during its meeting in December 2008. As of May 2009 the JCTLM Database contains 208 available certified reference materials, 146 reference measurement methods or procedures, and 128 reference measurement services.

1.18 Publications, lectures and travel of the Director and Deputy Director*

1.18.1 External publications

1. Wallard A.J., News from the BIPM – 2008, *Metrologia*, 2009, **46**, 137-143.

* From 1 April 2009.

1.18.2 Travel (conferences, lectures and presentations, visits)

A.J. Wallard to:

- Teddington, (UK), 29-31 July 2008, for a meeting of the UK Measurement Board of the Department of Innovation, Universities and Skills;
- Orlando, Florida (USA), 1-10 August 2008, for the NCSLI Conference and for a meeting of the NCSLI Board;
- San Pedro Sula (Honduras), 29 September to 2 October 2008, for the SIM General Assembly;
- Stockholm (Sweden), 20-21 October 2008, for the ILAC General Assembly;
- Jakarta (Indonesia), 2-8 November 2008, for the APMP General Assembly;
- Dubrovnik (Croatia), 10-13 November 2008, to give the keynote address to an IMEKO meeting on Metrological Infrastructures;
- Vienna (Austria), 2 December 2008, to sign a Memorandum of Understanding between the BIPM and UNIDO;
- San Diego (USA), 22-29 January 2009, for a meeting of the NCSLI Board and discussions with representatives of the US Navy;
- Derby (UK), 19-21 February 2009, for a meeting of the Measurement Board of the Department of Innovation, Universities and Skills;
- Ottawa (Canada), 14-17 April 2009, for a meeting of the scientific Advisory Board of NRC-INMS;
- Dubai (United Arab Emirates), 3-5 May 2009, for a meeting to discuss the formation of an RMO with the Gulf Cooperation Council (GCC) Standardization Organization;
- Teddington (UK), 7 May 2009, to give a seminar on international metrology.

M. Kühne to:

- San Anton (Malta), 8-10 June 2009, for the 3rd General Assembly of EURAMET e.V., to provide an overview of the CIPM MRA and report on recent activities at the BIPM;
- NIS, Gizeh (Egypt), 20-22 June 2009, to visit NIS and participate in the establishment of the Sub-RMO NEWMET (North-East and West Africa Metrology Programme) as part of AFRIMETS, and to provide

information about the BIPM to the participating states (Ghana, Egypt, Ethiopia, Libya, Nigeria);

- PTB, Braunschweig (Germany), 8 July 2009, to discuss the possibility of using a PTB linear electron accelerator for anticipated BIPM activities related to accelerator-based dosimetry.

1.19 Activities of the Director and Deputy Director related to external organizations

The Director is a member of the Scientific Council of 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 at the Institute of Mathematics and Physical Sciences of the University of Wales at Aberystwyth; a member of the Board of NCSLI; a member of the Metrology Academy of Russia and the Scientific Academy of Turin; a member of the UK's Pathfinder Programme Working Group and of the Measurement Board of the Department for Business, Innovation, and Skills; a member of the Advisory Board of NRC-INMS, Ottawa; and Chairman of the JCRB and the JCGM.

The Deputy Director is a member of the German Physical Society (DPG), a Fellow of the Institute of Physics (UK), and an editorial board member of the journal *Measurement Science and Technology*. He is an adjunct Professor at the Faculty of Mathematics and Physics of Leibniz University (Hanover, Germany), and a member of the Scientific Advisory Board of the Kiepenheuer Institute of Solar Physics (Freiburg, Germany).

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. 49 (Austria), No. 55 (Germany), No. 66 (Brazil) and No. 69 (Portugal) (see §12). Calibrations of prototypes for China (two), and the Czech Republic are under way.

Certificates for 1 kg standards in stainless steel were issued: one for CEM (Spain) and one for NMC, A*STAR (Singapore). Calibrations have been completed for two 1 kg standards from NML-SIRIM (Malaysia). Two standards from VSL (Netherlands) are in the process of calibration.

Monitoring of the mass of three new 1 kg prototypes in platinum-iridium, Nos. 93, 94 and 95, is ongoing. These will be provided to Member States within the next six months.

A recalibration of the BIPM working standards in platinum-iridium and stainless steel with respect to prototype No. 25 was carried out in April 2009.

Calibrations of magnetic susceptibility were made for 1 kg standards in stainless steel: two for NML-SIRIM and two for VSL.

The previous report mentioned that a study had been undertaken on the mass stability of two 1 kg standards in stainless steel during shipment between laboratories. These two standards will be used in an upcoming key comparison, and the stability study was inspired by rough security and/or customs inspections encountered at many international airports. Two 1 kg standards in stainless steel were therefore shipped to the NIST (USA), where the difference in their mass was measured. Their mass difference had also been measured by the BIPM before and was repeated after their travel to the USA. According to the BIPM results, the masses both increased by 2.4 μg , with standard uncertainty $u_c = 2 \mu\text{g}$; thus this test showed that the mass difference remained constant during shipment. As a result, shipping might be offered as an alternative to hand-carrying as a means of transport between participating laboratories in the forthcoming comparison.

2.1.2 BIPM susceptometer (R.S. Davis)

The BIPM has joined a EURAMET 'Cooperation in Research' on the magnetic properties of mass standards as determined using techniques recommended for legal metrology. As one of these techniques is, essentially, use of the susceptometer developed within the BIPM Mass Section, we are pleased to participate. There are currently 23 participating laboratories and the exercise is expected to run for two years. The pilot laboratory (PTB, Germany) has recently delivered the test package to the first participant (BIPM). In addition we have provided updated susceptometer software and auxiliary standards to the watt balance team at NIST (USA), and we are manufacturing a susceptometer for delivery to INRIM (Italy) in the near future. Finally, the magnetic susceptibility of a sample of platinum-iridium

alloy received from Johnson-Matthey was checked before onward shipment of the ingot to the NMIJ AIST (Japan).

2.2 100 g balance to support calibration programme (C. Goyon-Taillade and R.S. Davis)

The purpose of the 100 g balance is to improve the efficiency of our mass calibrations for standards ranging from 100 g to 5 g. The system is composed of a commercial Mettler-Toledo AX106 mass comparator and an automatic mass exchanger fabricated in the BIPM workshop from plans provided by R. Spurný (SMU, Slovakia). In this design, all standards and unknowns are placed on pans in a vertical column, suspended from the balance. Software kindly provided by I. van AnDEL of VSL (Netherlands) was adapted to our instruments for temperature, pressure and humidity acquisitions.

The balance is enclosed in a glass case, and the vertical temperature gradient is about 0.1 °C from top to bottom of the mass exchanger. Some improved isolation schemes were investigated. The gradient was halved by the addition of a Plexiglas screen. The first encouraging tests for the decade 10 g to 100 g have been performed. For the 1 g to 10 g decade we have already acquired auxiliary mass standards made to our specifications in order to be easily accommodated on the mass exchanger. The purpose of this set is to be used as a transfer mass. Calibration of the set can be automated on the 100 g balance. For standards below 5 g, subsequent calibration is made manually using our Mettler-Toledo UMT5 balance. We expect this system to be fully commissioned during the next year.

2.3 Balances to support development programmes (P. Barat and A. Picard)

Last year, we mentioned that we have evaluated the positioning errors under vacuum of the Sartorius CCL1007 mass comparator in order to reduce the uncertainties of mass determinations. This year the positioning errors in air have been evaluated. The positioning errors among the eight possible mass locations are within 1.7 µg with an associated uncertainty of the same magnitude. These results are not sufficiently accurate to take full advantage of the capability of the mass comparator, and a new evaluation of positioning errors in air is therefore under way; this time two stainless steel mass standards with essentially equal volumes are used in order to minimize the air buoyancy correction and the effects of zero-drift of the balance.

Our LabVIEW software has been updated. As a consequence, programmes have been rewritten as required. These programmes are used to acquire the data coming 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 in air x_{CO_2}).

Last year we reported that some anomalies in air density determination have been observed since the complete renovation of our laboratory late in 2006. Indeed, by measuring the air density by means of air buoyancy artefacts (gravimetric method) and by using the latest CIPM formula for air density determination, we are able to track the air density difference between the two methods. Early in 2007 the relative difference was 2.5 parts in 10^4 . No critical contaminant in the laboratory air was detected (the NPL had carried out a scan for volatile organic compounds (VOCs) in the ambient air) and no clear explanation was proposed. As a function of time, the difference of the air density determined between the two methods has decreased and in September 2008 it was less than 9 parts in 10^5 . When it is possible, our preferred procedure is to evacuate the enclosure and inject fresh air from outside the building. The relative air density difference obtained by this procedure between the two methods is 2.5 parts in 10^5 , which is within the uncertainties. The evolution of this difference remains a concern and is a subject of continuing study.

This year has seen three major projects (see §§2.5, 2.6 and 2.7). We have demonstrated the capability of the Sartorius CCL1007 mass comparator to carry out mass comparisons in air or under vacuum at the highest accuracy.

2.4 Vacuum Transfer System (P. Barat and A. Picard)

We have received delivery of the vacuum transfer system (VTS) ordered from Sartorius AG. This accessory to our CCL1007 comparator will permit us to load artefacts, stored in inert gas or under vacuum, into the comparator without contact with the ambient laboratory air. An automatic loadable container (ALC) permits the transfer between an external glove box and the VTS. The ensemble of the mass comparator, the VTS, the glove box with its associated vacuum oven and the ALC are essential for the IAC mass comparisons for which the BIPM is responsible. With this equipment we will be able to determine the amount of water adsorbed on the surface of a silicon sphere. In addition, this unique set-up will be used for the future dissemination of the mass unit based on a pool of mass standards kept under

controlled neutral gas or in vacuum. The first vacuum–vacuum transfer of artefacts has been successfully carried out during commissioning of the new equipment.

2.5 Bilateral comparison of test masses used in the NPL watt balance (P. Barat and A. Picard)

The NPL (UK) has developed a watt balance for which test masses are used under vacuum (2 mPa) in order to carry out the force measurements in the static phase of the experiment. The last determination of the Planck constant h obtained by the NPL differs by about 3 parts in 10^7 from the NIST watt balance result. One possible, though admittedly unlikely, explanation for this difference could be that the values assigned to the test masses used in the NPL and/or NIST watt balances are not compatible. The test masses used as references in the NPL watt balance are two cylinders: 1 kg of gold-plated copper, named 1000B, and 500 g of single-crystal natural silicon, named C4.

At the 2008 Conference on Precision Electromagnetic Measurements (CPEM, held in Broomfield, Co., USA, in June 2008) the BIPM proposed to carry out mass calibrations under vacuum to verify the values of these two test masses. At the same time, the NPL mass laboratory would also calibrate these two masses under vacuum. Good agreement between the two laboratories was obtained (within 20 μg and 2 μg for the 1000B and C4 artefacts, respectively). The combined standard uncertainties obtained by the NPL (and BIPM) are 7 μg (5.4 μg) for the 1000B and 4 μg (2.8 μg) for the C4 artefacts. Thus differences of 300 parts in 10^9 (300 $\mu\text{g}/1\text{ kg}$; 150 $\mu\text{g}/0.5\text{ kg}$) can not be explained by mass metrology at the NPL (UK).

2.6 International Avogadro Coordination project (P. Barat and A. Picard)

The BIPM remains active in the CCM Working Group on the Avogadro Constant and the IAC. We are the pilot laboratory for the international mass comparison under vacuum of the two isotopically enriched silicon 1 kg spheres named AVO28#5 and AVO28#8. The other laboratories involved in this comparison are the NMIJ AIST (Japan) and the PTB (Germany). The protocol of the comparison is based on experience gained from the previous comparison, reported two years ago. The BIPM received the AVO28#8 sphere in September 2008, and the AVO28#5 in October 2008. Comparisons were carried out under vacuum with respect to

our sorption artefacts, and these could be transferred to air for comparison against our working standards (thereby effecting an indirect comparison between the silicon artefacts maintained in vacuum and Pt-Ir artefacts maintained in air). Such comparisons were carried out four times for the sphere AVO28#8 and three times for the sphere AVO28#5. Preliminary results obtained at the BIPM demonstrate that the relative uncertainty target fixed by the IAC, which requires a mass determination with an uncertainty of about 5 μg for a 1 kg silicon sphere, has been reached. Indeed, the combined standard uncertainty for the mass determination under vacuum for both spheres, is 5.4 μg . This international mass comparison is ongoing.

2.7 CCM WGM-TG1: Mass comparison with sorption artefacts (P. Barat and A. Picard)

To anticipate the *mise en pratique* for the new definition of the kilogram, Task Group 1 (TG1) of the CCM Working Group on Mass Standards (CCM-WGM) is investigating practical methods of carrying out mass comparisons under vacuum or in inert gas. A pilot study of such a mass comparison has been initiated by the Steering Committee in order to prepare a wider vacuum mass comparison among the participants of the TG1. The laboratories involved in this pilot study are the BIPM, LNE, PTB, METAS and the NPL, which is the pilot laboratory.

The NPL surface artefacts used for this comparison are of stainless steel and consist of two stacks with increased geometrical surface area and one classical cylinder with minimum surface area.

The difference in surface area between the two stacks is about 48 cm^2 , and that between the stacks and the classical cylinder is about 145 cm^2 . The goal of this particular comparison is to determine the mass under vacuum of the classical standard and, with the same data, to determine the amount of water reversibly adsorbed per unit surface area between vacuum and moist air.

The BIPM received the artefacts in November 2008 and we have already completed our measurements. The pilot study is still under way and should be completed before the end of 2009.

2.8 Storage set-up for an ensemble of mass standards (F. Idrees and A. Picard)

One of the objectives for the future *mise en pratique* for the new definition of the kilogram is to create a pool of twelve 1 kg artefacts of different

materials, all of them thought to be stable in time. Monitoring the evolution of such an ensemble of new mass standards as a group, rather than the evolution of a single standard (the international prototype) currently used as both the definition and the realization of the kilogram, will enable a more robust system of representing the kilogram. In order to conserve this group under vacuum or in a controlled inert atmosphere, we are developing an ensemble of containers to store the standards. The storage bench will include instruments to monitor the quality of the vacuum as well as the purity of the gas injected into the containers. The containers should be modular, and thus easily removable from the storage bench in order to transfer the artefacts to the glove box for future mass measurements at the BIPM using the CCL1007 mass comparator and its associated VTS. The whole transfer system, including the glove box and transportable container, will allow us to transfer a mass standard from the BIPM to another NMI for mass comparison. The development of this storage bench is ongoing and will be completed by the end of 2009.

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

This year, densities were determined for one mass standard in stainless steel belonging to NML-SIRIM (Malaysia) and a pair of air buoyancy artefacts, which will be used for gravimetric determinations of air density. One artefact has the form of a thick-walled tube and the other is a hollow cylinder. They have a volume difference of the order of 82 cm^3 . The pair will be used in mass comparators for direct determination of the air buoyancy. This will be used periodically to check results obtained using the CIPM-2007 formula. (Since the artefacts occupy two positions of an automatic mass exchanger, it is impractical to use them continuously in exchangers that have only four positions, such as those of our calibration balances.)

Determinations of the densities of three new 1 kg prototypes have been carried out. One of these was used for a bilateral density comparison with the PTB (Germany) while its mass was still 16 g above 1 kg (prior to its final adjustment at the BIPM). The results obtained at the BIPM and PTB are consistent within their combined uncertainties. To our knowledge, this is the first modern bilateral comparison of Pt-Ir density at the 1 kg level.

Acceptance tests were performed on two 300 g samples of Pt-Ir ingot under the terms of our protocol with our supplier, Johnson Matthey. As mentioned above (see §2.1.2), these tests were made in part for the NMIJ AIST.

2.10 Pressure (P. Barat, R.S. Davis and C. Goyon-Taillade)

Calibrations of BIPM manometers with respect to the pressure balance maintained in the Mass Section have been carried out four times this year. Thirty-one internal certificates were issued.

2.11 Humidity generator (H. Fang and C. Goyon-Taillade)

Our goal is to introduce a service for humidity calibrations for instruments measuring ambient air conditions, and to have this service integrated into the BIPM Quality Management system. No progress has been made in recent years due to the higher priority of the watt balance and IAC work. However, in June 2008 C. Goyon-Taillade took a one-week training course in humidity metrology in order to continue development of the humidity generator, started by H. Fang and A. Picard.

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

Following termination of this experiment in May 2008, much of the apparatus has been transferred to the University of Birmingham (UK) in accord with a pre-existing agreement. The apparatus is now functional in its new location. Results of the *G* experiment are still being evaluated by Prof. Speake.

2.13 Publications, lectures, travel: Mass Section

2.13.1 External publications

1. Picard A., Bignell N., Borys M., Downes S., Mizushima S., Mass comparison of the 1 kg silicon sphere AVO#3 traceable to the International Prototype K, *Metrologia*, 2009, **46**(1), 1-10.

* Director Emeritus of the BIPM.

** University of Birmingham (UK).

2. Davis R.S., Redefining the kilogram: How and Why?, *MAPAN-Journal of the Metrology Society of India*, 2008, **23**(3), 131-138. (Note: R.S. Davis was one of two guest editors for this issue of *MAPAN*.)
3. Harvey A.H., Span R., Fujii K., Tanaka M., Davis R.S., Density of water: roles of the CIPM and IAPWS standards, *Metrologia*, 2009, **46**(3), 196-198.

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

R.S. Davis to:

- NCSLI 2008 Workshop and Symposium (Orlando, USA), 4 August 2008, to deliver keynote lecture: 'Why the kilogram should be redefined?';
- NIST, Gaithersburg (USA), 8 August 2008, to visit the mass and thermometry groups and present a seminar: 'Minimizing magnetic errors in measurements of small forces and torques';
- NPL, Teddington (UK), accompanied by A. Picard, 26 August 2008, to discuss the NPL-BIPM cooperation for technical preparations for a *mise en pratique* for the new definition of the kilogram;
- VSL (Netherlands), 2 October 2008, to give an invited talk 'Redefining the kilogram, Why? How? When?' as part of a one-day conference;
- INMETRO, Xerém-RJ (Brazil), 6 October 2008, for technical talks with personnel of the mass Section;
- Rio de Janeiro (Brazil), 8-10 October 2008, to attend the 1st International Congress on Mechanical Metrology (CIMMEC) and give an invited lecture on 8 October: 'The proposed redefinition of the kilogram – consequences for the metrological community';
- NPLI, New Delhi (India), 30-31 October 2008, to serve as technical expert for a peer review;
- Laboratoire d'Annecy-le-Vieux de Physique de Particules (LAPP, France), 16 January 2009, to present an invited seminar: 'Redefinition of the kilogram based on a physical constant';
- St George's Bay (Malta), 2-3 April 2009, to attend the EURAMET TC-T (thermometry) meeting;
- St Louis (USA), 13-14 April 2009, to attend the annual meeting of the National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCCChE) and present an invited

talk: 'Is the kilogram losing mass? Redefining the kg through a fundamental constant';

- NIST, Gaithersburg (USA), 15-17 April 2009, to visit the mass, watt balance, and thermometry groups and present a seminar on 16 April: 'Realizing the new kilogram';
- Prague (Czech Rep.), 11-12 May 2009, to accompany L. Vitushkin, Z. Jiang and L. Robertsson for a meeting of the ICAG-2009 Steering Committee;
- Bad Honnef (Germany), accompanied by E. de. Mirandés, 15-17 June 2009, to attend the 434. WE-Heraeus Seminar and present an invited talk: 'Experiments to underpin a new SI'.

A. Picard to:

- BIPM, 24-25 November 2008, to attend an IAC meeting for which he was also local organizer;
- BIPM, 26 November 2008, to attend the CCM-WGM/TG1 meeting;
- Technische Universität Ilmenau (Germany), 16 December 2008, to oversee progress on the VTS and refine its specifications;
- PTB, Braunschweig (Germany), 17 December 2008, to visit the new mass laboratory and discuss BIPM participation in the CCM-WGM/TG1;
- METAS, Bern (Switzerland), 18-19 February 2009, to discuss future cooperation between METAS and BIPM on gravimetry measurements (for the watt balance) and XPS surface analysis (for the future *mise en pratique* of the kilogram);
- Malta, 4-6 March 2009, to attend the EURAMET TC-M (mass) meeting;
- NMIJ AIST, Tsukuba (Japan), 15-16 April 2009, to attend an IAC meeting;
- BIPM, 25 May 2009, to attend the CODATA TGFC meeting and report on the status of the watt balances activities;
- Paris, 22-25 June 2009, to attend the 14th International Congress of Metrology, at which P. Barat presented a co-authored poster on the mass determination of silicon spheres for the Avogadro project.

C. Goyon-Taillade to:

- PTB, Braunschweig (Germany), 3 March 2009, to deliver a Pt/Ir standard for a bilateral density comparison, and to visit the density and mass laboratories;
- LNE-CETIAT, Villeurbanne (France), 25-29 May 2009, to attend a training course on 'Humidity in Gases';
- Paris (France), 22-25 June 2009, to attend the 14th International Congress of Metrology and present a poster (co-authored by R.S. Davis), on 'Density determination of prototypes and mass standards at the BIPM'; C. Goyon-Taillade won the prize for best poster at this congress.

2.14 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 is a member of the CCM-WGSI-kg, CCM-WGM/TG2 and CCT-TG-SI, which are charged with aspects of developing a *mise en pratique* for the kilogram and the kelvin.

A. Picard is coordinator for mass measurements in the International Avogadro Coordination project/CCM Working Group on the Avogadro Constant (see §2.6). He is a member of the Steering Committee of CCM-WGSI-kg and CCM-WGM/TG1, which are charged with developing a *mise en pratique* for a future redefinition of the kilogram.

Three members of the Mass Section devote a substantial fraction of their time to the watt balance, which is one of the BIPM's projects:

- A. Picard, 80 %;
- H. Fang, 80 %. Remaining time is divided between the Mass Section (see §2.11) and duties as interim BIPM Safety Officer;
- A. Kiss, 100 %.

In addition, since joining the BIPM on 23 February 2009, F. Idrees devotes 50 % of his time to projects in the Chemistry Section.

Note: Progress on the BIPM watt balance is reported in §7.

2.15 Visitors to the Mass Section

- Prof. C.C. Speake, University of Birmingham (UK), 1-2 July 2008, to effect the transfer of key elements of the BIPM apparatus for

determining the Newtonian gravitational constant to the Univ. of Birmingham;

- Mr P. Conceição, IPQ (Portugal), 22-26 September 2008;
- Mr Martin Firlus, PTB (Braunschweig, Germany), 28 October 2008, for advice on servicing a mass comparator;
- Dr T. Froehlich, Sartorius AG, 21 January 2009, to make adjustments to the CCL1007 mass comparator;
- Messrs T. Froehlich, D. Heydenbluth and M. Schreiber, Sartorius AG, 5 May 2009, to make modifications and adjustments to the CCL1007 mass comparator;
- Messrs T. Froehlich, D. Heydenbluth, M. Schreiber and S. Schwetschenau, Sartorius AG, 8-12 June 2009, to deliver and install the VTS;
- Dr Wang Jian and Ms Yao Hong of NIM (China), 26 June 2008, to deliver two prototypes for calibration.

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

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

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. The BIPM Annual Report on Time Activities for 2008*, volume 3, complemented by computer-readable files on the BIPM website (<http://www.bipm.org>), provides the definitive results for 2008.

* Assistant since 3 November 2008.

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

The algorithm ALGOS used for the calculation of the time scales is an iterative process that starts by producing a free atomic scale (*Échelle atomique libre*, 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.

The effects of the linear prediction algorithm have been studied for the different types of clocks in TAI. ALGOS predicts the clock frequency with a linear model that is well adapted to the caesium clock, but not to the hydrogen maser clock. A test version of EAL without H-masers has been calculated to evaluate the effects of this equal modelling of the clock frequencies. A new mathematical expression for the prediction of the H-maser frequencies is proposed, taking into account the drift. Tests over a 3-year period have been performed, applying a linear prediction to the caesium clocks and a quadratic prediction to the H-masers. A version of EAL on the basis of the proposed frequency prediction for H-masers, but with the classical clock weighting, has been evaluated. The results seem to indicate that non-modelling of the frequency drift of H-masers could be responsible for 20 % of the drift of EAL. In this test one month of past data were used to evaluate the frequency drift; longer periods still need to be tested. EAL still shows a significant drift; and further work is required on the EAL weighting algorithm.

3.2.1 EAL stability

Some 87 % of the clocks used in the calculation of time scales are either commercial caesium clocks of the Symmetricom/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. During 2008, on average, about 15 % of the participating clocks have been at the maximum weight. This procedure generates a time scale which relies upon the best clocks.

The stability of EAL, expressed in terms of an Allan deviation, has been about 4 parts in 10^{16} for averaging times of one month. Slowly varying, long-term drifts limit the stability to around 2 parts in 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 2008, individual measurements of the TAI frequency have been provided by twelve primary frequency standards, including eight caesium fountains (IT CSF1, LNE-SYRTE FO1, LNE-SYRTE FO2, LNE-SYRTE FOM, NICT CSF1, 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 at most 7 parts in 10^{16} is applied as deemed necessary. Since July 2008, 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 $+2.6 \times 10^{-15}$ to $+5.7 \times 10^{-15}$, with a standard uncertainty of less than 1×10^{-15} . Over the year, twelve steering corrections have been applied, giving a total correction to $[f(EAL) - f(TAI)]$ of -5.2×10^{-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(BIPM08), valid until December 2008, which has an estimated accuracy of about 5 parts in 10^{16} . Studies aiming at improving the computation of TT(BIPM) have been undertaken, in order to keep it in line with improvements in the primary frequency standards.

3.3 Primary frequency standards and secondary representations of the second (E.F. Arias, G. Petit, R. Felder and L. Robertsson)

Members of the BIPM Time, Frequency and Gravimetry Section actively participate in the work of the CCL/CCTF Frequency Standards Working Group, seeking to encourage comparisons, knowledge-sharing between laboratories, the creation of better documentation, and the use of high-accuracy primary frequency standards (Cs fountains) for TAI.

The CCL/CCTF Frequency Standards Working Group proposes various other microwave and optical atomic transitions as secondary representations of the second. Changes to the list, containing frequency values and uncertainties for transitions in Rb, Hg⁺, Yb⁺, Sr⁺ and Sr, have been recommended by the Consultative Committee for Time and Frequency (CCTF) in 2009. BIPM staff continue to participate in the rapidly evolving field of optical frequency standards, addressing, for example, the issue of their comparison at the level of parts in 10¹⁷.

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

TAI currently relies on data from 68 participating time laboratories equipped with GNSS receivers and/or operating TWSTFT stations.

The GPS all-in-view method is widely used and takes advantage of the increasing quality of the International GNSS Service (IGS) products (clocks and IGS time). Clock comparisons are possible with C/A code measurements from GPS single-frequency receivers; dual-frequency, multi-channel GPS geodetic-type receivers (P3); and two-way satellite time and frequency transfer through geostationary telecommunications satellites (TWSTFT). The older GPS single-channel single-frequency receivers represent today only 6 % of the total number and have mostly been replaced by either multi-channel single- or dual-frequency receivers. Ten TWSTFT links are officially used for the computation of TAI, representing 15 % of the time links. Additional TW links exist in the Asia-Pacific region but have not yet been officially introduced into the calculation; various other European laboratories are also close to contributing.

Following Recommendation CCTF 4 (2006), in April 2008 the Section started a pilot experiment 'TAIPPP', where time laboratories contribute GPS phase and code data and the BIPM uses the Precise Point Positioning (PPP) technique to generate monthly solutions, in slightly deferred time after the regular TAI computation. At its meeting in June 2009, the CCTF approved the report on the pilot experiment and agreed on the inclusion of TAIPPP links in the calculation of TAI. The number of laboratories regularly participating today is 25; the links will be introduced into TAI before the end of 2009. Comparisons of the TAIPPP links with others obtained by TWSTFT and P3 are published monthly on the Section's ftp server.

Testing continues on other time and frequency comparison methods and techniques.

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 post-processed, precise satellite ephemerides, and those links using single-frequency receivers are corrected for ionospheric delays using IGS maps.

3.4.2 Phase and code measurements from geodetic-type receivers

In addition to GPS and GLONASS code measurements, time and frequency transfer may also be carried out using dual-frequency, carrier-phase measurements. This technique, already widely used by the geodetic community, can be adapted to the needs of time and frequency transfer. A study is being 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 world-wide, and calibration campaigns began in January 2001. Since 2006, calibration results have also been issued for the Septentrio PolaRx2 receiver, and other types of receivers are being investigated in collaboration with laboratories equipped with them. A new receiver recently developed and commercialized (GTR50) has been purchased by the BIPM and is included in our calibration procedures since 2008. In all cases, 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 world-wide are collected for TAI computation, using procedures and software developed in collaboration with the Observatoire Royal de Belgique (ORB). These P3 time links are now routinely computed and compared to other available techniques, notably 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 time laboratories which are also part of the IGS network. A comparative study of geodetic-type receivers and processing techniques for time links was carried out during a 6-week secondment at the AIUB (Bern) and METAS (Wabern) in mid-2008. The BIPM has computed its own solutions for such time links since October 2007, using PPP software. As reported above, it is planned to introduce such PPP time links into the TAI computation before the end of 2009.

3.4.3 Two-way time transfer

Two meetings of the TWSTFT participating stations have been held since July 2008, and the CCTF WG on TWSTFT met at the SP (Borås, Sweden) in October 2008. The TWSTFT technique is currently operational in twelve European, two North American and seven Asia-Pacific time laboratories. Ten TWSTFT links are routinely used in the computation of TAI; four others are in preparation for their introduction or re-introduction into TAI, or are used for particular studies such as the T2L2 experiment. The TWSTFT technique applied to clock comparisons in TAI is reaching its maximum potential with sessions scheduled every two hours.

The BIPM is also involved in the calibration of two-way time-transfer links by comparison with GPS.

Results of time links and link comparison using GPS single-frequency, dual-frequency and TW observations are published monthly on the Section's ftp server (<http://tai.bipm.org/TimeLink/LkC>).

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 *Circular T*, together with information on the time links used in each monthly calculation. The values of u_A are updated as necessary, depending on the noise level present in the links.

3.4.5 Calibration of delays of time-transfer equipment

The BIPM continues to organize and run campaigns for measuring the relative delays of GPS time equipment in time laboratories that contribute to TAI. From July 2008 to June 2009, GPS time equipment for single- and dual-frequency reception has been calibrated. The BIPM is also organizing TWSTFT calibration trips, supported by a GPS receiver from our time laboratory.

Progress has also been made on the measurement of relative delays of GLONASS equipment thanks to cooperation with the Space Research Centre (SRC) in Warsaw (Poland). The measurements have already started, with a TTS-3 receiver having visited VNIIFTRI in the third trimester of 2008.

Work on the absolute calibration of GNSS receivers has been started by a Ph.D. student through a collaboration co-financed with the CNES and also

involving the LNE-SYRTE. In addition to hardware developments carried out at the CNES, this work includes a comprehensive study of all calibration results available, including past and new absolute calibrations, the series of differential calibrations carried out by the BIPM and other information available from the IGS.

3.5 **Key comparisons** (E.F. Arias, W. Lewandowski, G. Panfilo, L. Tisserand and A. Harmegnies)

Results of the key comparison in time, CCTF-K001.UTC, involving the time laboratories participating in the CIPM MRA, have been regularly published in the KCDB after publication of the monthly *Circular T*.

Following a decision of the CCTF at its 17th meeting (2006), the BIPM has cooperated with the CCTF WG on the CIPM MRA, and implemented the calculation of the frequency offsets and their uncertainties for a new key comparison in frequency, CCTF-K002.FREQ. In June 2009 the 18th meeting of the CCTF decided that CCTF-K001.UTC will remain the unique key comparison in the field of time and frequency, that it will be directly represented by the results in *Circular T*, and that the participating laboratories should derive the necessary results and uncertainties to support their CMCs in frequency following the guidelines provided by the BIPM TFG Section to the CCTF WG on the CIPM MRA.

3.6 **Pulsars** (G. Petit)

Collaboration continues with the Observatoire Midi-Pyrénées (OMP, Toulouse, France), and other radioastronomy groups observing pulsars and analysing pulsar data to study the potential capability of using millisecond pulsars as a means of sensing the very long-term stability of atomic time. The TFG Section provides these groups with its post-processed realization of Terrestrial Time, TT(BIPM).

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

The BIPM maintains the web and ftp sites for the *IERS Conventions* (<http://tai.bipm.org/iers/>). 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 points at the millimetre level, which are 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. Following the conclusions of the Workshop on the IERS Conventions, held at the BIPM on 20-21 September 2007, a new registered edition of the IERS Conventions will be compiled within the next year.

Activities related to the realization of reference frames for astronomy and geodesy are developing in cooperation with the IERS. In these domains, improvements in accuracy will increase the need for a full relativistic treatment and it is essential to continue to participate in international working groups on these matters, for example through the new IAU Commission 'Relativity in Fundamental Astronomy'. Cooperation continues for the maintenance of the international celestial reference system, and work has progressed in the framework of the IAU, IVS and IERS for the construction of a new conventional reference frame to be submitted to the IAU in August 2009.

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

As a result of the reorganization of activities in the Section, BIPM comb activities are limited to the maintenance of the BIPM frequency comb for internal applications (see §3.10).

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

Following the termination of BIPM.L-K11 and a period of preparation of the ensuing key comparison CCL-K11, the latter is now under way. Measurements have already taken place at MIKES (Finland) and the BEV (Austria), and two larger campaigns at the NMIJ AIST (Japan) and NRC (Canada) are being planned. The BIPM continues to provide technical advice and also assures a BIPM presence during the measurements whenever it is possible and requested. Related to this activity is the question of how best to validate the optical frequency combs themselves. The BIPM continues to take part in this discussion and to examine possible ways to provide support for this process on an international basis.

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

The Section has provided a comb and laser calibration and measurement service to meet the internal needs of the BIPM. These include the periodic

absolute frequency determination of our reference lasers at 633 nm and 532 nm, which are used for testing the quality of iodine cells, for the calculable capacitor project, and for the gravimeter instrumentation at the BIPM. The combs are passively kept in running condition and are used as necessary.

Preparations are well under way for ICAG-2009 (see §3.13), during which some 20 lasers will be measured. Furthermore, a study of the beam characteristics in the interferometers of the participating gravimeters is planned, in order to account for small corrections related to diffraction effects.

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

As described in §1.2, in 2008 the CIPM took the decision to stop the provision of iodine cells by the BIPM. The activity of the BIPM iodine cell service will cease definitively by the end of July 2009.

A letter was sent to our customers in order to explain the situation, to ask which laboratories would be interested in continuing the service (which is essential for many activities in science), and to propose the transfer of technology from the BIPM. Four NMIs, one institute and one private company expressed interested in taking up this activity from the BIPM.

About twenty iodine cells have been sold during the period of this report.

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

The laser head of the compact Nd:YVO₄/KTP/I₂ laser at 532 nm has been modified and the optical fibre system for light delivery to the interferometer of the FG5-108 gravimeter has been tested. The broken motor of the dropping chamber has been replaced and the dropping controller is being re-adjusted.

* Guest scientist from VNIIM.

3.13 8th International Comparison of Absolute Gravimeters, ICAG-2009 (L. Vitushkin, Z. Jiang, L. Robertsson, J. Labot and L. Tisserand)

The evaluation of the results of ICAG-2005 has been completed and provides valuable input to the design and preparation of ICAG-2009, which will be held at the BIPM in the third quarter of 2009.

Two meetings of the ICAG-2009 Steering Committee were organized: in November 2008 at the BIPM and on 11-12 May 2009 at the Research Institute of Geodesy, Topography and Cartography in Prague (Czech Rep.). Twenty-seven absolute gravimeters are expected to participate in the comparison. Of these, seventeen gravimeters will take part in the new key comparison CCM.G-K1, which forms part of ICAG-2009. The measurements of the remaining subset of gravimeters will be organized as a Pilot Study, again within ICAG-2009.

The technical protocols have been drawn up and define the strategy of the absolute and relative measurements, the data processing and the evaluation of the comparison reference values with their uncertainties. Separate protocols have been developed for the CCM.G-K1 part and for the ICAG-2009 overall. The results of all of the participating gravimeters will be included in the evaluation of ICAG-2009 as a whole, while only the results of the gravimeters from the KC subset will be used to calculate the KCRV for CCM.G-K1, published in the KCDB.

Preliminary schedules for the absolute and relative measurements have been prepared and distributed to the participants. Five gravity stations of the microgravity network will be used; this is considered a suitable number in terms of their homogeneous measurement and optimal adjustment.

As reported in §3.10, the BIPM will verify the frequencies of the lasers used for the interferometric measurement of the displacement of the falling test body, as well as the frequencies of the rubidium reference clocks of the absolute gravimeters. The stability of the gravity field at the BIPM will be monitored using the BIPM's gravimeter FG5-108.

3.14 Preliminary gravimetry study for the watt balance project (Z. Jiang)

The watt balance requires an uncertainty of 1 part in 10^8 in the absolute gravity value. Preliminary studies have been carried out on the equipment and the influence of the local and global environment for accurate gravity measurements.

3.15 Publications, lecture, travel: Time, Frequency and Gravimetry Section

3.15.1 External publications

1. Petit G., Arias F., Use of IGS products in TAI applications, *J. Geodesy*, 2009, **83**, 327-334.
2. Petit G., Klioner S., Does relativistic time dilation contribute to the divergence of Universal Time and Ephemeris Time?, *Astron. J.*, 2008, **136**, 1909-1912.
3. Petit G., Relativistic aspects in astronomical standards and the IERS Conventions, *Proc. Journées 2008 Systèmes de référence spatio-temporels* (Dresden, Germany; 22-24 September 2008), Ed. by Soffel M. and Capitaine N., Paris : Observatoire de Paris, 2009, 41-45.
4. Petit G., Atomic time scales TAI and TT(BIPM): present status and prospects, *Proc. 7th Symposium on Frequency Standards and Metrology* (Pacific Grove, CA, USA; 5-11 October 2008), Ed. by L. Maleki, World Scientific, 2009, 475-482.
5. Petit G., The TAIPPP pilot experiment, *Proc. EFTF-IFCS 2009* (Besançon, France; 20-24 April 2009), IEEE, 2009, 116-119.
6. Petit G., Bernier L.-G., Uhrich P., Time and frequency transfer by geodetic GPS: comparison of receivers and computation techniques, *Proc. EFTF-IFCS 2009* (Besançon, France; 20-24 April 2009), IEEE, 2009, 269-273.
7. Lewandowski W., Matsakis D., Panfilo G., Tavella P., Analysis of Correlations, and Link and Equipment Noise in the Uncertainties of [UTC – UTC(*k*)], *UFFC*, 2008, **4**, 750-760.
8. Lui Y., Jiang Z., Precise time transfer activities in Singapore, *Proc. EFTF-IFCS 2009* (Besançon, France; 20-24 April 2009), IEEE, 2009, 634-638.
9. Panfilo G., Tavella P., Atomic clock prediction based on stochastic differential equations, *Metrologia*, 2008, **45**(6), 108-116.
10. Bibbona E., Panfilo G., Tavella P., The Ornstein-Uhlenbeck process as a model of a low-pass filtered white noise, *Metrologia*, 2008, **45** (6), 117-126.
11. Panfilo G., Arias E.F., Studies and possible improvements on EAL algorithm, *Proc. EFTF-IFCS 2009* (Besançon, France; 20-24 April 2009), IEEE, 2009, 110-115.

12. Arias E. F., Panfilo G., International time scales at the BIPM: impact and applications, *Proc. 14th International Metrology Congress* (Paris; 22-25 June 2009), Paris, 2009, CD-Rom.
13. Jiang Z., Lewandowski W., Piester D., Calibration of TWSTFT links through the Triangle Closure Condition, *Proc. 40th PTTI* (Reston, VA, USA; 1-4 December 2008), Curran Associates, 2009, 467-484.
14. Jiang Z., Niessner A., Calibrating GPS with TWSTFT for accurate time transfer, *Proc. 40th PTTI* (Reston, VA, USA; 1-4 December 2008), Curran Associates, 2009, 577-586.
15. Lewandowski W., Arias F., Nawrocki J., Nogaś P., Use of GLONASS for International Time Keeping, *Proc. Inst. Appl. Astron.* (St Petersburg, Russia Fed.; 5-9 April 2009), 2009, Vol. 20, 358-366.
16. Vitushkin L., Current Status and Perspectives of Absolute Ballistic Gravimetry, *Proc. Inst. Appl. Astron.* (St Petersburg, Russia Fed.; 5-9 April 2009), 2009, Vol. 20, 303-308.
17. Li H., Zhang H., Lewandowski W., Jiang Z., TWSTFT Activities at Chinese National Time Service Centre, *Proc. EFTF-IFCS 2009* (Besançon, France; 20-24 April 2009), IEEE, 2009, 1206-1208.
18. Jiang Z., Full use of the redundancy in TWSTFT and GNSS time and frequency transfer, *Proc. EFTF-IFCS 2009* (Besançon, France; 20-24 April 2009), IEEE, 2009, 1194-1197.

3.15.2 BIPM publications

19. *BIPM Annual Report on Time Activities for 2008*, 2009, 3, 102 pp.
20. *Circular T* (monthly), 7 pp.
21. Lewandowski W., Tisserand L., Determination of the differential time corrections for GPS time equipment located at the OP, PTB, NPL and VSL, 2008, *Rapport BIPM-2008/01*, 19 pp.
22. Lewandowski W., Tisserand L., Determination of the differential time corrections for GPS time equipment located at the OP, NTSC, HKO, TL, SG, AUS, KRIS, NMIJ, and NICT, 2008, *Rapport BIPM-2008/02*, 27 pp.
23. Lewandowski W., Tisserand L., Determination of the differential time corrections for GPS time equipment located at the OP, TCC, ONBA, IGMA and CNMP, 2008, *Rapport BIPM-2008/03*, 18 pp.

24. Lewandowski W., Tisserand L., Determination of the differential time corrections for GPS time equipment located at the OP, PTB, NPL and VSL, 2008, *Rapport BIPM-2008/04*, 21 pp.

3.15.3 Travel (conferences, lectures and presentations, visits)

E.F. Arias to:

- Borås (Sweden), 2-3 October 2008, for a meeting of the CCTF WG on TWSTFT;
- Geneva (Switzerland), 8-13 October 2008, for a meeting of the ITU-R WP 7A;
- Washington DC (USA), 4-5 December 2008, for a meeting of the IAU and IVS Working Groups on the ICRF2;
- Pasadena (USA), 8-12 December 2008, to attend the 3rd meeting of the ICG and give a lecture;
- San Francisco (USA), 14-15 December 2008, for meetings of the GGOS Steering Committee and the Governing Board of the ICG;
- Besançon (France), 20-24 April 2009, to attend the EFTF/FCS and for meetings of the CCTF working group chairmen and the CCTF WG on the CIPM MRA;
- Virginia Beach (USA), 27 April to 1 May 2009, for the IAU Symposium 261 on Relativity in Fundamental Astronomy, to act as session chair and give an invited lecture;
- Paris (France), 24 June 2009, for the International Congress of Metrology.

Z. Jiang to:

- Borås (Sweden), 2-3 October 2008, for a meeting of the CCTF WG on TWSTFT;
- Besançon (France), 20-24 April 2009, to attend the EFTF/FCS;
- Prague (Czech Rep.), 11-12 May 2009, for the 2nd meeting of the ICAG-2009 Steering Committee.

W. Lewandowski to:

- Warsaw (Poland), several trips of a few days each to the Space Research Centre (SRC) and the Central Office of Measures (GUM);
- Toulouse (France), 10-12 September 2008, to visit the CNES and EADS/Astrium;

- Savannah, Ga. (USA), 13-20 September 2008, for the 48th CGSIC (chairmanship of the Timing Sub-Committee) and ION GNSS conference;
- Borås (Sweden), 1-4 October 2008, for the 16th meeting of the CCTF Working Group on TWSTFT;
- Geneva (Switzerland), 7-13 October 2008, for a meeting of the Working Group on the Future of UTC Leap Seconds at the ITU;
- Brussels (Belgium), 11 November 2008, for a visit to the European Commission and Galileo Supervising Authority;
- Riyadh (Saudi Arabia), 22-28 November 2008, for a Workshop on International Time Metrology;
- Washington DC (USA), 2-4 December 2008, for the 40th PTTI Meeting and a meeting of the TWSTFT participating stations;
- Pasadena, Ca. (USA), 8-12 December 2008, for the 3rd Meeting of the International Committee on GNSS;
- ICG, Vienna (Austria), 15-16 February 2009, for the 1st Preparatory Meeting for the 4th Meeting of the International Committee on GNSS;
- NPLI, New Delhi (India), 18-21 February 2009, for the AdMet Symposium;
- Bangalore (India), 23-24 February 2009, for a Workshop on Time Structure for GNSS at the Indian Space Research Organization;
- Brussels (Belgium), 11 March 2009, for Timing Meeting of EURAMET;
- St Petersburg (Russian Fed.) 5-9 April 2009, for a Conference on GLONASS;
- Besançon (France), 19-25 April 2009, for the EFTF Symposium and for a meeting of the TWSTFT participating stations;
- London (UK), 19-21 May 2009, to discuss the Meeting European Antiparliamentary Group on Space;
- Brussels (Belgium), 28 May 2009, to give tutorial on GNSS time for the Galileo Supervising Authority;
- ICG, Vienna (Austria), 2 June 2009, for the 2nd Preparatory Meeting for the 4th Meeting of the International Committee on GNSS.

G. Panfilo to:

- Washington DC (USA), 1-5 December 2008, for the 40th PTTI with a poster presentation;

- Turin (Italy), 5 March 2009, for a meeting on key comparisons in frequency for the CMCs;
- Besançon (France), 20-24 April 2009, to attend the EFTF/FCS meeting, and for meetings of CCTF WG on the CIPM MRA and of the TWSTFT participating stations, with a tutorial presentation and a lecture;
- Paris (France), 24 June 2009, for the International Congress of Metrology, with a presentation.

G. Petit to:

- Wabern and Bern (Switzerland), 28 July to 5 September 2008, on secondment at the METAS and the AIUB;
- Dresden (Germany), 22-24 September 2008, to attend the *Journées Systèmes de Référence Spatio-temporels*, and give an invited lecture;
- Pacific Grove (USA), 5-10 October 2008, to attend the 7th Symposium on frequency standards and metrology, and give an invited lecture;
- Noordwijk (the Netherlands), 16 December 2008, for a meeting of the GNSS Scientific Advisory Committee;
- Paris (France), 12 January 2009, for a meeting of the Fundamental Physics Group of the CNES;
- Biarritz (France), 17-19 March 2009, for the *Séminaire de prospective du CNES*;
- Besançon (France), 21-24 April 2009, to attend the EFTF/FCS, and give two lectures;
- Virginia Beach (USA), 27 April to 1 May 2009, to attend the IAU Symposium 261 on Relativity in Fundamental Astronomy, act as session chair and give an invited lecture;
- Paris (France), 12 May 2008, for a meeting of the GNSS Scientific Advisory Committee.

L. Robertsson to:

- Prague (Czech Rep.), 11-12 May 2009, for the 2nd meeting of the ICAG-2009 Steering Committee.

L. Vítushkin to:

- St Petersburg (Russian Fed.), 6-9 April 2009, for the Symposium 'Coordinate and time assurance in navigation, KVNO-2009';
- Prague (Czech Rep.), 11-12 May 2009, for the 2nd meeting of the ICAG-2009 Steering Committee;

- Brussels (Belgium), 16-17 March 2009, to attend a workshop on hydrological and other local effects in gravity measurements, COST ES0701;
- Dresden (Germany), 4-5 June 2009, to attend the workshop 'Aerogravimetry: Technology and Applications'.

3.16 Activities related to external organizations

E.F. Arias is a member of the IAU and participates in two of its working groups: on Nutation and on the International Celestial Reference System. She is an associate member of the IERS, a member of the International Celestial Reference System Centre, and of the Conventions 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 to the Governing Board of the IGS. She is the BIPM representative to the International Committee for GNSS and she is the chairperson of the Task Force on Time References. She is a member of the Argentine Council of Research (CONICET) and an associated astronomer at the LNE-SYRTE, Paris Observatory. She is a 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.

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 the Space Research Centre of the Polish Academy of Sciences. He also chairs a Working Group on Scientific Metrology at the 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. 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, of the GNSS Scientific Advisory Committee of the ESA, and of the Fundamental Physics Group of the CNES.

L. Vitushkin is president of the IAG sub-commission '1. Gravimetry and Gravity Networks' and chairman of the Study Group 2.1.1 on Comparison of Absolute Gravimeters, reporting to the IAG Commission 2 'Gravity field'.

3.17 Activities related to the work of Consultative Committees

E.F. Arias is Executive Secretary of the CCTF and shares with R. Felder the Secretariat of the CCL/CCTF Frequency Standards Working Group. She is a member of the CCTF WG on TWSTFT, the CCTF WG on Primary Frequency Standards (WGPFS) and the CCTF WG on TAI.

R. Felder is the Executive Secretary of the CCL and Joint Secretary of the CCL/CCTF Frequency Standard WG.

Z. Jiang is a member of the CCTF WG on TWSTFT.

W. Lewandowski is Secretary of the CCTF WG on TWSTFT and Secretary of the CCTF WG on Global Navigation Satellite Systems Time-Transfer Standards (CGGTTS).

G. Panfilo is a member of the CCTF WGPFS and of the Sub-Group on Algorithms of the CCTF WG on TAI.

G. Petit is a member of the CCTF WG on TAI and its Sub-Group on Algorithms, of the WGPFS, and of the CGGTTS.

L. Vitushkin is Chairman of the CCM Working Group on Gravimetry (CCM-WGG).

The 18th meeting of the CCTF was held at the BIPM on 4-5 June 2009, preceded by meetings of the CCL/CCTF Frequency Standards WG and the CCTF WG on TAI.

The 14th meeting of the CCL was held at the BIPM on 10-11 June 2009, preceded by a meeting of its WG on Dimensional Metrology (WGDM).

A significant amount of time was devoted to the organization of these meetings of the Consultative Committees and their respective working groups. The Section's staff prepared a number of documents and reports for discussion at the CCL and CCTF meetings.

3.18 Visitors to the Time, Frequency and Gravimetry Section

- Drs Ernst Boyarsky and Larisa Afanasieva (O. Yu. Schmidt Institute for the Physics of the Earth, Moscow, Russian Fed.), 13, 23 and 24 October 2008, to test the software for processing the raw data from absolute gravity measurements and discuss methods of data adjustment.
- Drs J. Ray (NGS-NOAA) and K. Senior (NRL, USA), 8 June 2009, to discuss GNSS time transfer and the IERS Conventions.

- Dr S. Junqueira (ONRJ, Brazil), 22 May 2009, to discuss GPS time transfer.
- Dr M. Zucco (INRIM, Italy), 15 June 2009, to discuss optical frequency transfer.
- Dr M. Higgins (FIG) and Dr Z. Altamimi (IGN), 10 February 2009, for a meeting of Working Group D of the ICG.

3.19 Guest workers

- Miss A. Proia (Ph.D. student), 3 November to 20 December 2008 and 8-12 June 2009.
- Dr Oleg Orlov (VNIIM, St Petersburg, Russian Fed.), 6 February to 20 March 2009, to modify the BIPM's compact Nd:YVO₄:KTP/I₂ lasers.

4 ELECTRICITY (M. STOCK)

4.1 Electrical potential (R. Chayramy, S. Solve)

Renovation of the voltage laboratory was started in October 2007 and completed in September 2008. We now have a modern voltage laboratory with improved temperature and humidity control. The primary and secondary voltage standards and their respective measurement facilities have been moved back to the refurbished laboratory. A long series of experiments was carried out in order to validate the measurement capabilities and to verify the estimated uncertainties. An internal audit in the framework of the BIPM Quality System was passed in November 2008.

During this validation process the correct operation of the new automatic system for the calibration of electronic Zener voltage standards at 1.018 V was also demonstrated. Saturated standard cells as well as Zener voltage standards were calibrated using the conventional Josephson voltage measurement set-up and the new automatic measurement system. The results were in very good agreement, well within the uncertainties.

During these tests, however, a systematic voltage offset of 100 nV was observed in the readings of the analogue detector of the new facility. Further investigations showed that the output connector of the 10 MHz frequency

reference was responsible for a ground loop that induced this systematic offset. The set-up is currently being modified to isolate the potential of the body of the microwave synthesizer from that of the output of the BNC connector.

The new transportable conventional Josephson voltage standard (JVS) operated at the 10 V level has been compared to the present Josephson primary standard. The results are in very good agreement: $(U_{\text{transportable}} - U_{\text{reference}}) / U_{\text{reference}} = 8.7 \times 10^{-11}$, with a standard uncertainty of 8.3×10^{-11} . It is planned to operate this compact primary voltage standard in the framework of BIPM on-site Josephson comparisons. The internal comparison has shown that some modifications are, however, required to improve the reliability of the new system, which is crucial for the on-site comparison programme.

The power distributed by the microwave source is not uniform over the full frequency band over which the array should operate. Preliminary investigations have shown that the installation of an additional microwave amplifier could lead to a significant improvement. This investigation has to be finalized.

Regarding the dc bias source, the visualization of the Shapiro steps requires a high-speed digital oscilloscope to replace the heavy analogue oscilloscope used until now. We have not yet identified such an instrument that creates sufficiently low noise for this application.

The new waveguide delivers significantly more power than the probe operated on the primary JVS; nevertheless occasionally no voltage steps are developed. It was discovered that this is due to trapped magnetic flux, which could not be detected in the static mode due to the very strong electronic filters in the connecting leads. The filters have been modified in order to allow a better visibility of the I - U characteristic in the static mode. A screen made of niobium, which strongly shields against magnetic fields at cryogenic temperatures due to the Meissner effect, will be added to the probe.

Work has started on the development of a dedicated JVS for the BIPM watt balance.

The staff of the Electricity Section are also involved, together with staff from the Ionizing Radiation Section, in restarting the in-house calibration service for standard platinum resistance thermometers (SPRTs). The performance of the thermometry bridge has been checked and the quality of the gallium fusion cells tested (see §5.3).

4.2 Electrical resistance and impedance

4.2.1 DC resistance and quantum Hall effect (N. Fletcher, R. Goebel, A. Jaouen)

Due to the long-term absence of two members of the Section, work was concentrated on the development and maintenance of the facilities dedicated to the calibration of standard resistors, the international comparisons and the preparation of future on-site comparisons of quantum Hall standards as requested recently by several NMIs. A dc cryogenic current comparator probe was reconstructed and a new one is under construction.

Since the present QHE cryostat has developed a cold leak, a new cryostat equipped with a superconducting magnet has been specified and ordered, with a design optimized for transportability and reliability which are crucial in on-site comparisons. One of the tasks for the near future is to duplicate and to replace several of the key BIPM-built electronics devices that were constructed many years ago. The electronics are being developed for a second 1 Hz bridge to compare 100 Ω resistors with the quantized Hall resistance, to be used with the new cryostat.

One more laboratory room was refurbished this year, bringing the refurbishment programme of the Electricity Section to an end.

4.2.2 Maintenance of a reference of capacitance (R. Chayramy, N. Fletcher, R. Goebel)

The capacitance reference based on the quantum Hall effect has been actively maintained, and well used for calibrations for NMIs, but no major development has been necessary for this purpose. The BIPM has been collaborating with the PTB on the evaluation of travelling 10 pF capacitance standards for use in the comparison EURAMET.EM-S31 planned for 2010, within the framework of the EURAMET Joint Research Project REUNIAM for the redefinition of the ampere. This comparison, specifically for traceability based on R_{K-90} , should be the best test yet performed in this area, and will enable the BIPM to verify the improvements to the uncertainty of the capacitance chain resulting from the ongoing calculable capacitor project.

4.3 **Calculable capacitor** (N. Fletcher, R. Goebel, L. Robertsson*, J. Sanjaime**, M. Stock)

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 make a direct electrical measurement of the von Klitzing constant, R_K , before the next CODATA adjustment of the fundamental constants. A comparison of the results obtained by direct electrical measurements with those derived from measurements of the fine structure constant will allow conclusions to be drawn on the validity of the equation $R_K = h/e^2$, where e is the elementary charge and h the Planck constant. The future *mise en pratique* for the electrical units will in part be based on this equation. Besides this, the calculable capacitor will significantly shorten the traceability chain for our capacitance calibrations and comparisons. Staff of the Electricity Section, the Time, Frequency and Gravimetry Section and the BIPM Workshop are contributing to this work.

The BIPM Workshop has completed the construction of a large number of parts for both instruments. The NMIA is still working on the machining of the electrode bars and the lead screws. A long delay has occurred due to the difficulty in producing bars with the required cylindricity of 0.1 μm , but recently progress has been made on shaping the bars by polishing, without lapping. We expect to receive the bars and the lead screw in the first half of 2010. In the meantime four less-perfect electrode bars and a simplified screw have been made by the BIPM Workshop to enable us to test the assembly of the parts.

The BIPM has set up a test bench for the interferometer which will measure the displacement of the moving electrode. Another important component is the mode-matching optics to couple the laser beam into the cavity of the Fabry-Perot interferometer. This cavity has been optimized for small diffraction effects. The two mirrors have a very large radius of curvature, so that the cavity is close to one having two flat mirrors. It will therefore be sensitive to errors of the surface figure, and the presence of higher order cavity modes is of concern.

* Time, Frequency and Gravimetry Section.

** BIPM Workshop.

With the present finesse of the cavity, higher order modes would not be resolved in the transmission spectrum of the interferometer. Nonetheless, they would cause the intensity in the detector plane to deviate markedly from the fundamental mode. Calculations have been made to establish whether this phenomenon could be used to identify the presence of higher order modes. The results indicate that this technique will indeed give a clear indication if higher order modes are present.

We have agreed with our colleagues from the NMIA that a second set of mirrors with higher reflectivity should be procured to furnish a cavity with higher resolving power. This will allow checking for systematic effects related to the optical configuration.

The capacitance of the calculable capacitor will vary from 0.2 pF to 0.6 pF. In order to test our capacitance bridge, two capacitors with these values have been constructed. Simulating the calculable capacitor, they will be used to check the transfer procedure to a conventional 1 pF standard, using the coaxial bridge which has already been constructed.

4.4 Ongoing BIPM key comparisons in electricity (R. Chayramy, N. Fletcher, R. Goebel, A. Jaouen, S. Solve, M. Stock)

The on-site comparison of Josephson voltage standards with the NIST was completed successfully in March 2009. The results are not yet officially available but the agreement between the BIPM and the NIST is excellent.

The results of the comparison carried out with the LNE in December 2007 have been published:

$$\text{At 10 V: } (U_{\text{LNE}} - U_{\text{BIPM}}) = -0.1 \text{ nV} \qquad u = 0.1 \text{ nV}$$

Two voltage comparisons using Zener voltage standards as transfer standards were carried out with the NML (Ireland) in May 2008 and May 2009. The results of the most recent exercise are not yet available.

$$\text{At 10 V (June 2008): } (U_{\text{NMLI}} - U_{\text{BIPM}}) = -0.56 \text{ } \mu\text{V} \qquad u = 1.32 \text{ } \mu\text{V}$$

In the ongoing BIPM key comparison programme for resistance, bilateral comparisons were carried out with the NML (Ireland), the NMIA (Australia) and the NIMT (Thailand). The comparisons with the NMIA and the NIMT are at Draft A stage.

In the framework of BIPM.EM-K13.a, based on the circulation of 1 Ω travelling standards, the relative difference in calibrations between the NML (Ireland) and the BIPM were:

$$(R_{\text{NMLI}} - R_{\text{BIPM}}) / (1 \text{ } \Omega) = +0.042 \times 10^{-6} \qquad u = 0.11 \times 10^{-6}$$

In the framework of BIPM.EM-K13.b, concerning 10 k Ω standards:

$$(R_{\text{NMLI}} - R_{\text{BIPM}}) / (10 \text{ k}\Omega) = +0.039 \times 10^{-6} \quad u = 0.60 \times 10^{-6}$$

Measurements are under way for a comparison of 10 pF and 100 pF standards with the CMI (Czech Rep.), organized within the framework of BIPM.EM-K14.a and K14.b.

4.5 Calibrations

During the period from July 2008 to June 2009, the Electricity Section calibrated the following standards:

- Zener diode voltage standards at 1.018 V and 10 V for the GUM (Poland), BIM (Bulgaria; 10 V only), DMDM (Serbia) and INM (Romania).
- 1 Ω resistors for the BEV (Austria), Metrology Division (Belgium), MSL (New Zealand), INM (Romania) and NMC, A*STAR (Singapore); 100 Ω resistors for the MSL (New Zealand) and GUM (Poland); 10 k Ω resistors for the BEV (Austria), DFM (Denmark), NML-SIRIM (Malaysia), INM (Romania) and NMC, A*STAR (Singapore).
- capacitance at 1 pF for the CEM (Spain) and INMETRO (Brazil); at 10 pF for the CEM (Spain), INMETRO (Brazil), BEV (Austria), EIM (Greece), MSL (New Zealand) and CENAM (Mexico); and at 100 pF for the CEM (Spain), INMETRO (Brazil), BEV (Austria), EIM (Greece), MSL (New Zealand) and CENAM (Mexico).

A list of Calibration Certificates and Study Notes is given in §12.

4.6 Publications, lectures, travel: Electricity Section

4.6.1 External publications

1. Power O., Murray J., Solve S., Chayramy R., Bilateral comparison of 10 V standards between the NML (Ireland) and the BIPM, May to June 2008 (part of the ongoing BIPM key comparison BIPM.EM-K11.b), *Metrologia*, 2008, **45**, *Tech. Suppl.*, 01008.
2. Djordjevic S., Séron O., Solve S., Chayramy R., Direct comparison between a programmable and a conventional Josephson voltage standard at the level of 10 V, *Metrologia*, 2008, **45**(4), 429-435.

3. Solve S., Chayramy R., Stock M., Kim K.-T., Song W., Kim M.-S., Chong Y., Comparison of the Josephson voltage standards of the KRISS and the BIPM (part of the ongoing BIPM key comparison BIPM.EM-K10.b), *Metrologia*, 2008, **45**, *Tech. Suppl.*, 01006.
4. Goebel R., Chrobok P., Fletcher N., Stock M., Bilateral comparison of 10 k Ω standards (ongoing BIPM key comparison BIPM.EM-K13.b) between the CMI (Czech Rep.) and the BIPM, *Metrologia*, 2008, **45**, *Tech. Suppl.*, 01010.
5. Solve S., Chayramy R., Stock M., Kim K.-T., Song W., Kim M.-S., Chong Y., Bilateral comparison of 1.018 V and 10 V standards between the KRISS (Republic of Korea) and the BIPM, February 2008 (part of the ongoing BIPM key comparison BIPM.EM-K11.a and b), *Metrologia*, 2008, **45**, *Tech. Suppl.*, 01007.
6. Solve S., Chayramy R., Djordjevic S., Séron O., Comparison of the Josephson voltage standards of the LNE and the BIPM (part of the ongoing BIPM key comparison BIPM.EM-K10.b), *Metrologia*, 2009, **46**, *Tech. Suppl.*, 01002.

4.6.2 Travel (conferences, lectures and presentations, visits)

M. Stock to:

- Jakarta (Indonesia), 3-4 November 2008, for the APMP TC-EM meeting;
- Sofia (Bulgaria), 23-24 April 2009, for the EURAMET TC-PR meeting.

N. Fletcher to:

- Dublin (Ireland), 16-17 October 2008, to participate in the EURAMET-TC-EM meeting;
- LNE, Paris (France), 4-5 June 2009, to participate in the EURAMET-TC-EM meeting of experts on quantum electrical metrology.

S. Solve to:

- LNE, Trappes (France), 18 July 2008, to discuss future work on JVS with Dr Sophie Djordjevic (LNE) and Dr Ralf Behr (PTB);
- LNE, Trappes, (France), 7-8 October 2008, to participate as a technical expert in the audit of LNE activities in voltage measurements;
- LCIE, Fontenay aux Roses (France), 16 October 2008, for a seminar on electromagnetic compatibility;

- CEA, Saclay (France), 21 November 2008, to discuss his doctoral thesis with Prof. Daniel Estève;
- METAS, Bern (Switzerland), 26-27 November 2008, to attend a seminar on accurate measurements of RF signals;
- CNAM, Paris (France), 4 December 2008, to support his doctoral thesis;
- PTB, Braunschweig (Germany), 4-5 May 2009, for technical discussions on JVS;
- S-Pulse Workshop, Braunschweig (Germany), 5-7 May 2009, to give a presentation on the role of the BIPM and its activities in dc voltage metrology;
- ESM, Douai (France), 12 May 2009, to give a presentation on the role of the BIPM and its activities in dc voltage metrology;
- LNE, Paris (France), 4-5 June 2009, to attend the DC & Quantum metrology expert EURAMET meeting.

S. Solve and R. Chayramy to:

- NIST, Gaithersburg (USA), 19-26 March 2009, for a BIPM on-site Josephson comparison.

R. Goebel to:

- LNE, Trappes (France), 7-8 October 2008, to participate as a technical expert in the audit of the LNE activities in impedance measurements.

E. de Mirandés to:

- Santander (Spain), 1 June 2009, to give a presentation on the New SI at the IV Congreso Español de Metrología;
- Bad Honnef (Germany), 15-17 June 2009, to attend a conference on Precision Experiments at Lowest Energies for Fundamental Tests and Constants.

4.7 Activities related to external organizations

M. Stock is a member of the Executive Committee of the CPEM and a member of the Programme Committee of the CPEM Conference 2010.

N. Fletcher is a member of the Programme Committee of the CPEM 2010.

4.8 Activities related to the work of Consultative Committees

M. Stock is Executive Secretary of the CCEM and the CCPR and a member of several of their working groups. The 26th CCEM meeting was held at the BIPM on 12-13 March 2009.

R. Goebel organizes the review of comparison reports and protocols within the CCPR Key Comparison Working Group (WG-KC).

4.9 Visitors to the Electricity Section

- Dr S. Djordjevic and Mr O. Seron (LNE), 3 July 2008, to discuss future collaborative work on JVS.
- Ms R. Vasconcellos (INMETRO), 23-24 October 2008, for discussions and training on capacitance measurements and coaxial bridges.
- Prof. M. Himbert (LNE-INM), 21 November 2008, to discuss the preparation of S. Solve's Ph.D. *viva voce*.
- Dr L. Palafox (PTB), 3 December 2008, to visit the Electricity Section and give a presentation entitled '1 V and 10 V SNS Programmable Voltage Standards for 70 GHz'.
- Ing. H. Martinez (DIGENOR, Dom. Rep.) and Mr Moritz Ackermann (PTB), 2 February 2009.
- Mr H. Bothe (PTB), 23 to 27 March 2009, to perform measurements and exchange experiences in preparation for the capacitance comparison EURAMET.EM-S31.
- A delegation from LNE Tunis, 27 March 2009.
- Mrs J. Lee (NMC, A*STAR, Singapore), 2 June 2009, to visit the dc voltage laboratory.
- Dr Yi-hua Tang (NIST), 2 June 2009, to discuss the bilateral NIST-BIPM Josephson comparison report.
- Dr M. Goetz (PTB), 2 June 2009, for technical discussions on resistance bridges.

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

5.1 X- and γ -rays (P.J. Allisy-Roberts, D.T. Burns, C. Kessler, S. Picard, P. Roger and J. Alvarez Romero*)

5.1.1 Dosimetry standards and equipment

Following the re-evaluation of the air-kerma standard for ^{60}Co , a corresponding re-evaluation was made of the ^{137}Cs air-kerma standard, with changes proposed for the wall and axial non-uniformity corrections, the cavity volume and the correction for ion recombination. A short paper was approved by the CCRI(I) and will be published in *Metrologia*.

A series of cavity standards was constructed and the chamber volumes measured using the 3D coordinate measuring machine (CMM). Each chamber was tested by comparison with the ^{60}Co primary standard for air kerma. After applying the appropriate correction factors, including the effect of chamber orientation, the results agree at the level of around 3 parts in 10^4 . The existing primary standard (CH5-1) developed a leakage current and was replaced by one of the new chambers (CH6-1). Two of the new chambers, slightly modified in design, were constructed for use with the calorimeter standard in the dose conversion from graphite to water. Following on from work last year at low air pressures, the components for one of the chambers were constructed from an 'air-equivalent' plastic material and are currently under test. While the material itself is not electrically conducting, when polished there appears to be sufficient surface conduction for the material to be suitable. Measurements at low air pressure will proceed as time permits.

The graphite calorimeter was operated several times in the ^{60}Co reference beam, where the graphite absorbed-dose rate at 5 g cm^{-2} is around 0.4 Gy min^{-1} , and a statistical uncertainty of 2 parts in 10^3 has been achieved. The introduction of reflecting surfaces reduced heat losses to a low level, as demonstrated by the close agreement between the temperature rise of the core and that of the jacket. Modifications to the cabling and the incorporation of the bridges into the measuring voltmeters reduced the typical noise level from $12\text{ }\mu\text{K}$ to $8\text{ }\mu\text{K}$. A BIPM report describing the

* On secondment from the ININ (Mexico) from 22 September 2008 until 23 January 2009.

calorimeter construction has been published. The transfer ionization chambers, one replacing the graphite core and the other for use in the water phantom, were also measured on several occasions. Preliminary Monte Carlo calculations for the graphite-to-water dose conversion were made for the ^{60}Co reference beam. As a result of the complex geometry, the calculations run relatively slowly and a statistical standard uncertainty of around 0.07 % has been achieved to date.

In April 2008, the Accelerator Dosimetry Working Group (ADWG(I)) recommended the use of the BIPM calorimeter in a series of bilateral comparisons at the eight NMIs having accelerators. The calorimeter was modified to meet the required geometry for use in accelerator beams and a protocol was prepared for these comparisons, which have the reference BIPM.RI(I)-K6 in the KCDB. Trial measurements were made in the ^{60}Co and accelerator beams of the LNE-LNHB (France). These measurements provided valuable information, notably on noise, reproducibility and beam monitoring. The first comparison took place at the NRC-INMS (Canada) in June 2009, using three accelerator beam qualities. The Monte Carlo calculations for the dose conversion in these beams are in progress, using phase-space files supplied by the NRC-INMS.

A paper was published in *Physics in Medicine and Biology* on diaphragm corrections for the free-air chamber standards. A related short paper has been prepared for *Metrologia* and was approved by the CCRI(I). This proposes a change to the air-kerma determination in x-rays resulting from the new diaphragm corrections and also from the measured correction for scatter from the medium-energy diaphragm support.

A cylindrical free-air chamber of variable volume was received from the NIS (Egypt) for a preliminary characterization study. The chamber was found to be suitable for use as a primary standard only if certain procedures are followed. The measurements carried out at the BIPM and the procedures recommended for use at the NIS will be documented in a forthcoming BIPM report.

The temperature coefficient of the voltage dividers was measured to high accuracy, with the result that the voltage measurement at 250 kV is more stable than previously. A new water cooling system serving both low-energy x-ray tubes was installed and the anode current measurement system was modified to correct for the parasitic current passing through the cooling system, which increases as the water purity decreases. The medium-energy generator was adjusted to provide two new 50 kV qualities for the purpose of comparing the low- and medium-energy standards.

An analysis was made of the results of a number of published measurements and calculations that have an impact on the *I*-value for graphite, with the conclusion that a value of around 82 eV fits the observations. This potentially important result, which implies a change of more than 0.8 % to cavity standards world-wide, was presented to the CCRI(I) and a technical note has been submitted for publication in *Metrologia*.

Three papers by members of the Section were published in the *Metrologia* Special Issue on Radiation Dosimetry, (46(2), 2009).

Work on the BIPM mammographic facility is still in progress. Horizontal and vertical beam profiles were measured using a thimble ionization chamber; these data will be used to determine the size and position of the collimator required to obtain a 10 cm diameter field at the reference plane. Further measurements with the new primary standard for mammography were made to identify the source of the discrepancy with the existing low-energy standard: a study of the effect of contact potentials by applying a few volts to the guard plate while keeping the collector at ground potential; the temperature measurement and stability inside the chamber by adding a temporary thermistor at the centre of the collecting volume; and the planarity of the collector-guard plate, established using a CMM. An initial acceptance limit of 50 μm was tested by raising and lowering the upstream edge of the collector by around 100 μm with respect to the guard plate; this resulted in significant discrepancies, indicating that the tolerance of 50 μm was too high and might explain the fluctuating results. A new collector support was designed, allowing the collector to be adjusted to better than 5 μm with respect to the guard plate. With this new configuration, the discrepancy between the standards was reduced to less than 2 parts in 10^3 . Studies to explain the remaining discrepancy are in progress.

Primary measurements and reference chamber calibrations have continued in all of the reference x- and gamma-ray beams, including the simulated mammographic radiation qualities. Comparisons and calibrations are underpinned by a significant effort in equipment calibration and maintenance, which is also required by the BIPM Quality System.

5.1.2 Dosimetry comparisons

Three comparisons in terms of air kerma in the ^{137}Cs gamma-ray beam were carried out: with the ITN (Portugal) in July 2008, the LNE-LNHB (France) in November 2008 and the BEV (Austria) in March 2009. The reports have been drafted.

Three comparisons in terms of absorbed dose to water in the ^{60}Co gamma-ray beam were carried out with the BEV (Austria) in March 2009, the VNIIFTRI (Russian Fed.) in April 2009 and the NRC (Canada) in May 2009. The reports for the BEV and VNIIFTRI have been drafted.

Two comparisons in terms of air kerma in the ^{60}Co gamma-ray beam were carried out with the BEV (Austria) in March 2009 and the NRC (Canada) in May 2009. The report for the BEV has been drafted.

One comparison in terms of air kerma in low-energy x-ray beams was carried out with the ARPANSA (Australia) in November 2008. This report is being prepared by the ARPANSA.

Reports of previous comparisons were published in the *Metrologia Technical Supplement* for the NMIJ AIST (Japan) and the VSL (Netherlands), both in x-ray beams, and for the ITN (Portugal) in the ^{60}Co gamma-ray beam. Reports of x-ray comparisons with the ARPANSA (Australia), NPL (UK) and the NRC (Canada) are in preparation, and reports are still under discussion for the BARC (India) and the NIM (China).

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 transfer chamber is calibrated periodically in terms of air kerma in the BIPM ^{60}Co beam and in the 250 kV x-ray quality; this chamber 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.

The BIPM piloted a high-dose comparison together with the NIST (USA) and the NPL (UK) who provided the transfer alanine dosimeters. The BIPM also provided reference irradiations at the lowest dose level of 1 kGy. All the results have been received and are now being analysed.

Following a meeting of the CCRI(I) Brachytherapy Working Group, which had requested two different types of brachytherapy comparison, the BIPM was finally successful in attracting a secondee from the ININ (Mexico) to undertake this work. The protocols were drafted and the necessary equipment for the first comparison was purchased and commissioned. However, pending further secondments to undertake the related stability measurements and ^{125}I seed characterizations, the comparisons have not yet been launched.

5.1.3 Calibration of national standards for dosimetry

Following an internal audit in November 2008, a review of calibration procedures and an external audit of the calibration services were completed in May 2009. No non-compliance was recorded.

Three series of calibrations of national standards were made in medium-energy x-rays: for the CRRD (Argentina), the LNMRI (Brazil) and the NRPA (Norway). One series of calibrations and one study were made in low-energy x-rays for the NRPA (Norway).

Eighteen calibrations of national standards were carried out in the BIPM gamma-ray beams in terms of air kerma, ambient dose equivalent and absorbed dose to water, as requested by the IAEA (Vienna), the LNMRI (Brazil), the CRRD (Argentina) and the NRPA (Norway).

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

5.2 Radionuclides (P.J. Allisy-Roberts, S. Courte, C. Michotte*, M. Nonis, G. Ratel and D. Kryeziu**)

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

During 2008, the BIPM received nine ampoules filled with eight different radionuclides from five laboratories: two ampoules from the BEV (one containing ^{134}Cs and one ^{139}Ce), two ampoules from the IFIN-HH (one ampoule containing ^{57}Co and one ^{131}I); one ampoule containing ^{99}Mo from the NIST; two ampoules from the NPL (one ampoule containing ^{56}Mn and one $^{99}\text{Tc}^{\text{m}}$); and two ampoules from the PTB (one ampoule containing ^{88}Y and one ^{139}Ce).

All the submissions had been made to generate equivalence values in the respective key comparisons. One radionuclide, ^{139}Ce , had been standardized by two different methods by the same laboratory and, with their agreement, the weighted mean of the two methods was used to generate an equivalence value. With the newly registered measurements for 2008, the cumulative number of ampoules measured since the beginning of the SIR (in 1976), is

* On maternity leave until September 2008 and then part-time (80 %).

** On secondment from Tirana University (Albania) until November 2008.

now 914, corresponding to a total of 670 independent results for 63 different radionuclides.

The results for the new submissions have been registered in the SIR master file, for five different radionuclides: ^{56}Mn (NPL), ^{88}Y (PTB), ^{131}I (IFIN-HH), ^{134}Cs (BEV) and ^{139}Ce (BEV and PTB). Update reports of four comparisons were published in 2008 (for ^{54}Mn , ^{131}I , ^{186}Re and ^{201}Tl), and the results for ^{99}Mo (NIST) and ^{134}Cs (NPL) are pending. A further four update reports have been published since the beginning of 2009.

There are currently seven results from 2006 still awaiting publication in the KCDB. Of those submitted after 2006, 16 % have been published, and 59 % are at Draft A or Draft B stage; we are still awaiting the NMI activity results for the remaining 25 % of the submissions. In accordance with the 2005 recommendation of the CCRI, comparison results that are more than 25 years old are being deleted from the KCDB and each NMI is informed as this happens. The additional SIR results that now date prior to 1989 are being coloured black in the KCDB.

The project to identify the effects of gas pressure on the SIR, using gas ampoules filled with ^{85}Kr prepared by the LNE-LNHB, is pending receipt of the activity values. Once these are received, the BIPM will be able to produce its report on the effect of gas pressure.

A successful internal audit of the SIR within the BIPM Quality System was carried out in the second half of 2008, followed by a second external audit in June 2009. The Quality System has been updated to include the new electronic system currently in use. The linearity of the new electronics has been measured using a ^{64}Cu source.

5.2.2 Gamma spectrometry

A ^{103}Ru impurity was identified in the ^{99}Mo solution measured using the Ge(Li) spectrometer in 2008. No impurity was detected in the recent ^{64}Cu solution submitted to the SIR by the PTB. As expected, a $^{177}\text{Lu}^{\text{m}}$ impurity has been identified in the two ^{177}Lu ampoules received from the IRMM and the NPL.

Work is well in hand to calibrate the high-purity germanium spectrometer. The uncertainty related to the ampoule base has been evaluated. The pile-up correction has been measured by the two-source method. The analysis of all the data is in progress, as are the efficiency measurements.

5.2.3 Extension of the SIR to short-lived radionuclides

The analysis of measurements of short-lived radionuclides has involved the link to the SIR using $^{99}\text{Tc}^{\text{m}}$ solutions from the LNE-LNHB and the NPL, the response of the transfer instrument (TI) to any ^{99}Mo impurity using a solution from the NIST, and a trial comparison at the NPL. The weighted mean of the ^{94}Nb stability measurements made since March 1997 is $8492.4 (8) \text{ s}^{-1}$. The linking factors to the SIR measured using the NPL and LNE-LNHB solutions agree to within 3 parts in 10^4 when the ^{99}Mo impurity content in the LNE-LNHB solution is adjusted to obtain constant results. The trial comparison at the NPL was successful: the equivalent activity obtained using the TI together with the linking factor to the SIR agrees to within 2 parts in 10^4 with the NPL's registered SIR result. The three NPL activity measurements involved in this exercise are traceable to the same primary measurement. The trial comparison at the NPL brought to light the significant influence of a possible droplet in the 'shoulder' or 'neck' of the ampoule so that extra care is being taken in all subsequent measurements.

Having decided to transport the NaI(Tl) detector and the brass liner as hand luggage, new crates were purchased for cargo transportation of the rest of the equipment including the Nb source. Two spare copies of the brass liner were made at the BIPM workshop and their thickness adjusted so that all three liners have identical count rates for a ^{57}Co ampoule.

The TIWG(II) met at the BIPM in March 2009. The above results were discussed as well as the preliminary uncertainty budget and the comparison protocol.

A first $^{99}\text{Tc}^{\text{m}}$ comparison (BIPM.RI(II)-K4.Tc-99m) took place at the NIST in May 2009. The ^{94}Nb stability measurements were successful although the temperature in the laboratory reached $26 \text{ }^\circ\text{C}$. Again, the presence of droplets on the wall of the ampoule perturbed the measurements but the problem was solved by centrifuging the ampoule. The results of the comparison are being analysed.

5.2.4 Extension of the SIR to pure beta emitters

Some progress has been made towards the extension of the SIR to pure beta emitters by identifying the cause of the persistent difference observed between the CIEMAT and BIPM home-made scintillators using the same recipes and identical components. A further batch of scintillator XAN6040 was prepared recently while the humidity in the BIPM balance room was

only 37 % instead of the 60 % normally maintained to reduce static. Aliquots of 15 ml of this preparation were poured into low-potassium glass vials and count measurements were made using the two commercial liquid-scintillator spectrometers of the BIPM. About 30 mg of purchased tritiated water was added to each of these vials and they were counted again using the same devices. The results are quite promising, with the values obtained for the quenching and the deduced efficiencies being in close agreement with the values obtained at the CIEMAT. However, further tests are needed to validate the XAN6040 scintillator definitively prior to use as the basis of the extension of the SIR to pure beta emitters.

5.2.5 Improvements to the BIPM TDCR counting system

This year some further improvements have been brought to the BIPM TDCR counting system. Following the advice of the LNE-LNHB, a new design of the bias supplies for the three photomultipliers has been developed to enable them to operate with a positive voltage, to reduce the noise. The high-voltage supplies have been changed so the three photomultipliers are fed by identical power supplies. To enable the TDCR method to standardize pure beta emitters in the frame of the extended SIR, a rapid and reliable determination of the quenching level of the samples is required. A method developed by P. Cassette (LNE-LNHB) is being implemented; this is based on the Compton scattering of the photons, produced by an external γ -emitting source, which are deflected downwards in the scintillator at an angle of 90° . A transportable hyper-pure Ge detector has been placed in the vertical position to detect the photons scattered through the base of the glass vial placed in the TDCR spectrometer. The measurements will start as soon as a source of ^{241}Am of suitable activity has been purchased.

The BIPM participated in an ICRM comparison organized by the NIST of software used for the TDCR computation. The comparison consisted of evaluating a set of TDCR experimental data produced by the NIST. The aim of participation is to ensure the validity of the computational procedures in use at the BIPM. The results are promising although the exercise has identified the general need for a more robust evaluation of uncertainties.

5.2.6 CCRI activity comparison of ^{85}Kr

The BIPM had previously sent ampoules prepared by the LNE-LNHB to the nine potential participants for the ^{85}Kr gas activity comparison. Two

laboratories have resigned from participation, and the last of the seven sets of results has recently been received at the BIPM. The results are currently under analysis.

5.2.7 CCRI activity comparisons of ^3H

The comparison of activity measurements of a solution of tritiated water is in progress. The LNE-LNHB had sent 18 ampoules to the 16 declared participants. To allow the NMIs to complete their measurements under the best conditions it was proposed and accepted that the deadline of the comparison be postponed until the end of June 2009.

5.2.8 Measurements of ^3H

The BIPM is taking part in the above comparison and is applying the CIEMAT/NIST method with measurements in the two commercial liquid-scintillation spectrometers using ^{54}Mn as an external standard. The BIPM TDCR facility is also being used and this will be the first experimental validation of this system in the frame of an international comparison.

5.3 Thermometry (P.J. Allisy-Roberts, M. Stock*, S. Picard, M. Nonis and S. Solve*)

Since January 2009, the Ionizing Radiation Section has taken on the task of maintaining the BIPM thermometry standards, in collaboration with the Electricity Section, so as to enable BIPM calibrations of SPRTs for in-house use at the uncertainty levels required for calorimetry and mass standards. The BIPM calibration activity had been suspended in 2006 but has now been restarted. The performance of the thermometry precision bridge has been checked and the quality of the gallium fusion-cells tested.

* M. Stock and S. Solve are members of the Electricity Section

5.4 Publications, lectures, travel: Ionizing Radiation Section

5.4.1 External publications

1. Allisy P.J., Burns D.T., Andreo P., International framework of traceability for radiation dosimetry quantities, *Metrologia*, 2009, **46(2)**, S1-S8.
2. Allisy-Roberts P.J., Burns D.T., Kessler C., Cardoso J., Comparison of the standards for air kerma of the ITN (Portugal) and the BIPM for ^{60}Co Y-rays, *Metrologia*, 2009, **46**, *Tech. Suppl.*, 06007.
3. Allisy-Roberts P.J., Day M., Uncertainty evaluation and expression in dose and risk assessment, *J. Radiol. Prot.*, 2008, **28**, 265–269.
4. Büermann L., Burns D.T., Air-kerma cavity standards, *Metrologia*, 2009, **46(2)**, S24–S38.
5. Burns D.T., Kessler, C., Diaphragm correction factors for free-air chamber standards for air kerma in x-rays, *Phys. Med. Biol.*, 2009, **54**, 2737–2745.
6. Burns D.T., Büermann L., Free-air ionization chambers, *Metrologia*, 2009, **46(2)**, S9–S23.
7. Burns D.T., de Prez L.A., Key comparison BIPM.RI(I)-K3 of the air-kerma standards of the VSL, Netherlands and the BIPM in medium-energy x-rays, *Metrologia*, 2009, **46**, *Tech. Suppl.*, 06002.
8. Burns D.T., Nohtomi A., Saito N., Kurosawa T., Takata N., Key comparison BIPM.RI(I)-K2 of the air-kerma standards of the NMIJ and the BIPM in low-energy x-rays, *Metrologia*, 2008, **45**, *Tech. Suppl.*, 06015.
9. Kessler, C., Allisy-Roberts P.J., Burns D.T., de Prez L.A., de Pooter J.A., Damen P.M.G., Comparison of the standards for absorbed dose to water of the VSL and the BIPM for ^{60}Co γ -rays, *Metrologia*, 2009, **46**, *Tech. Suppl.*, 06009.
10. Lee J.H., Hwang W.S., Kotler L.H., Webb D.V., Büermann L., Burns D.T., Takeyeddin M., Shaha V.V., Srimanoroth S., Meghzifene A., Hah S.H., Chun K.J., Kadni T.B., Takata N., Msimang Z., APMP/TCRI key comparison report of measurement of air kerma for medium-energy x-rays (APMP.RI(I)-K3), *Metrologia*, 2008, **45**, *Tech. Suppl.*, 06012.

11. Michotte C., Courte S., Ratel G., Kossert K., Nähle O.J., BIPM comparison BIPM.RI(II)-K1.Cu-64 of the activity measurements of the radionuclide ^{64}Cu , *Metrologia*, 2009, **46**, *Tech. Suppl.*, 06010.
12. Michotte C., Ratel G., Courte S. Hino Y., Yunoki A., Bobin C., Moune M., Activity measurements of the radionuclide ^{57}Co for the NMIJ, Japan and the LNE-LNHB, France in the ongoing comparison BIPM.RI(II)-K1.Co-57, *Metrologia*, 2009, **46**, *Tech. Suppl.*, 06005.
13. Michotte C., Ratel G., Courte S., Nedjadi Y., Bailat C., Johansson L., Hino Y., Update of the BIPM comparison BIPM.RI(II)-K1.Ho-166m activity measurements to include the IRA and the NPL and a re-evaluation of the degrees of equivalence for the APMP.RI(II)-K2.Ho-166m comparison, *Metrologia*, 2009, **46**, *Tech. Suppl.*, 06008.
14. Ratel G., Michotte C., Kryeziu D., Moune M., Iwahara A., Update of the BIPM comparison BIPM.RI(II)-K1.Cr-51 to include new activity measurements for the LNE-LNHB (France) and the pilot study result of the LNMRI (Brazil), *Metrologia*, 2009, **46**, *Tech. Suppl.*, 06001.

5.4.2 BIPM reports

15. Picard S., Burns D.T., Roger P., Measurement of the specific heat capacity of synthetic sapphire ($\alpha\text{-Al}_2\text{O}_3$) from 293 K to 301 K, *Rapport BIPM-2008/05*, 12 pp.
16. Picard S., Burns D.T., Roger P., Construction of an absorbed-dose graphite calorimeter, *Rapport BIPM-2009/01*, 12 pp.

5.4.3 Travel (conferences, lectures and presentations, visits)

P.J. Allisy-Roberts to:

- London (UK), 2 July 2008, for a meeting of the editorial board of *Journal of Radiological Protection*; 30 July 2008, to attend the Measurement Board of the UK National Measurement System (NMS); 4 November 2008, to attend a meeting on radiation protection concerning radioactive unsealed sources; 18 March 2009, to attend a meeting on room shielding for linear accelerators;
- Teddington (UK), 30 September to 1 October 2008 and 23 February 2009, to chair meetings of the Acoustic and Ionizing Radiation Working Group of the UK NMS; 13 November 2008, to make a

presentation at the official opening of the new NPL linear accelerator facility; 20 March 2009, to attend the launch of the UK strategy for metrology and the official opening of the National Measurement Office;

- Vienna (Austria), 16-19 February 2009, to co-chair the IAEA Scientific Programme Committee in preparation for the 2010 Dosimetry Symposium;
- LNE (France), 8 April 2009, to attend the *Comité Scientifique* for ionizing radiation; 2 June 2009, to attend a meeting of the editorial board of the *Revue Française de Métrologie*.

D.T. Burns to:

- Geneva (Switzerland), 22-27 September 2008, to attend a meeting of the Main Commission of the ICRU;
- Rome (Italy), 9-10 October 2008, to attend a meeting of the EURAMET Contact Persons for Ionizing Radiation;
- Saclay (France), 20-24 October 2008, for a trial comparison of calorimeter standards in the LNE-LNHB ^{60}Co beam;
- Risø (Denmark), 9-10 December 2008, to act as a Technical Assessor for the Danish Technical Safety Authority;
- Saclay (France), 5-9 January 2009, with S. Picard and P. Roger, for a trial comparison of calorimeter standards in the LNE-LNHB accelerator laboratory;
- Ottawa (Canada), 2-11 June 2009, for a comparison of absorbed dose standards in the NRC linear accelerator beams;
- Oxford (UK), 29 June to 1 July 2009, to attend a meeting of the ICRU Fundamental Quantities and Units Committee.

S. Picard to:

- Saclay (France), 16-24 October 2008, with P. Roger, for a trial comparison of calorimeter standards in LNE-LNHB ^{60}Co beam;
- Lymm (UK), 20-21 January 2009, to attend a course given by Inrad on *In Vivo* and Pre-treatment Patient Dosimetry;
- Ottawa (Canada), 2-20 June 2009, with P. Roger, for a comparison of absorbed dose standards in the NRC linear accelerator beams.

C. Kessler to:

- Vienna (Austria), 27-29 April 2009, to attend the International Conference on Advances in Radiation Oncology (ICARO).

G. Ratel to:

- Saclay (France), 1 July 2008, to take part in the jury for the *Diplôme d'habilitation à diriger les recherches* of P. Cassette;
- Paris (France), 11-12 December 2008, to attend the *Sixièmes rencontres des personnes compétentes en radioprotection* (PCR) to maintain his PCR certification;
- Saclay (France), 15 December 2008, to discuss the results of a comparison of activity measurements of a solution of ^{124}Sb ;
- Bratislava (Slovakia), 5-6 March 2009, to attend the ICRM Scientific Committee and then the ICRM Executive Board.

C. Michotte to:

- Gaithersburg (USA), 18-24 May 2009, to undertake an SIR-linked comparison of $^{99}\text{Tc}^m$ activity measurements with the NIST using the BIPM SIR TI.

5.5 Activities related to external organizations

P.J. Allisy-Roberts is Chairman of a Working Group for the UK NMS programme for ionizing radiation and acoustics and Chairman of the UK Ionising Radiation Health and Safety Forum. She is the BIPM representative on the IAEA SSDL Scientific Committee which she currently chairs, a member of the *Comité scientifique rayonnements ionisants* (LNE, France), and on the editorial board of the *Journal of Radiological Protection* and the *Revue Française de Métrologie*.

D.T. Burns is the BIPM representative at the ICRU, a member of the ICRU Committee on Fundamental Quantities and Units (currently preparing a revision of ICRU Report 60) and a member of the ICRU Report Committee on Key Data for Dosimetry. He is the BIPM contact person for the EURAMET-TC for ionizing radiation and a consultant to the IAEA (currently preparing a revision of TRS-374).

G. Ratel is the BIPM representative on the International Committee for Radionuclide Metrology (ICRM) of which he is joint Vice-President.

5.6 Activities related to the work of Consultative Committees

P.J. Allisy-Roberts is Executive Secretary of the CCRI and its three Sections, which held meetings at the BIPM in April, May and June 2009, celebrating 50 years of international collaboration in the field of ionizing

radiation. In addition she organized a Workshop and arranged seven WG meetings during this period. She is also Executive Secretary of the CCAUV, which met at the BIPM in October 2008. This last year has also seen the publication of a new volume of *Monographie 5* in support of the CCRI(II), and the organization of a Workshop on Activity Uncertainties and Comparisons held in September 2008 attended also by C. Michotte and G. Ratel.

P.J. Allisy-Roberts and D.T. Burns are members of the KCWG(I), ADWG(I) and BSWG(I). Both the KCWG(I) and the ADWG(I) met in April 2008 and a Brachytherapy Workshop was organized for May 2009 in conjunction with the CCRI(I). P.J. Allisy-Roberts and D.T. Burns contributed to the special issue of *Metrologia* for radiation dosimetry, as principal authors respectively on international aspects and free-air chambers, and D.T. Burns as co-author on cavity standards.

C. Michotte is the coordinator of the TIWG(II), which met in March 2009. She is also the BIPM contact person and rapporteur for the JCGM-WG1, which met at the BIPM in November 2008 and April 2009.

G. Ratel is a member of the CCRI(II) working group on the extension of the SIR to beta emitters, which met in April and June 2009, the KCWG(II) which met in September 2008 and June 2009, the UCWG(II), which met in June 2009, and the BqWG(II), which met in June 2009 and for which he is the rapporteur. He made several presentations at the Activity Comparisons Workshop in September 2008.

5.7 Visitors to the Ionizing Radiation Section

- Dr U. Wätjen (IRMM), 19 September 2008.
- Mrs O. Garcia Diaz (ININ), 19 September 2008.
- Dr A. Ostrowsky (LNE-LNHB), 1 December 2008.
- Dr M. Mc Ewen (NRC), 23 January 2009.
- Dr H. Bjerke (NRPA), 30 January 2009.
- Messrs L. Énard (LNE), B. Chauvenet, F. Damoy, J.-M. Bordy (LNE-LNHB), 6 February 2009.
- Dr X. Mougeot and Dr M.-M. Bé (LNE-LNHB), 19 February 2009.
- Dr P.-O. Hetland (NRPA), 24 February 2009.
- Dr A. Steurer (BEV), 12 March 2009.
- Mrs E. Renaot (LNE-INM), 15 April 2009, for thermometry.

- Dr T. Steele (ANSTO), 21 April 2009.
- Dr I. Csete (MKEH), 19 May 2009.
- Dr Ming-Chen Yuan (INER), 11 June 2009.

5.8 Guest workers

- Dr J. Cardoso (ITN), 21-25 July 2008.
- Mr L. Czap (IAEA), 25-29 August 2008.
- Mr D.B. Kulkarni (BARC), 16-20 September 2008.
- Dr J. Lye (ARPANSA), 7-14 November 2008.
- Dr M. Donois (LNE-LNHB), 24 November to 1 December 2008.
- Dr M.T. Carlos (LNMRI-IRD), 28 November to 8 December 2008.
- Dr A. El-Sersy (NIS), 19-26 January 2009.
- Dr V. Berlyand and Dr A. Berlyand (VNIIFTRI), 20-23 April 2009.

6 CHEMISTRY (R.I. WIELGOSZ)

6.1 Gas metrology programme (J. Viallon, E. Flores, M. Petersen, P. Moussay, F. Idrees, R.I. Wielgosz)

6.1.1 Ozone photometer comparison programme

The first two-year cycle of the ongoing key comparison BIPM.QM-K1 (ozone at ambient level) was completed in December 2008. It included a total of 15 participants.

Since July 2008, three laboratories have brought or sent their national ozone standard to the BIPM for a direct comparison with the BIPM-SRP27 reference standard: METAS (Switzerland) and the NMISA (South Africa) in July 2008, and the VSL (Netherlands) in September 2008. The report of the comparison with METAS was published in the *Metrologia Technical Supplement* in June 2009. The report of the comparison with the NMISA is in preparation, and the report of the comparison with the VSL is in Draft B stage.

In November 2008 members of the CCQM Gas Analysis Working Group (GAWG) agreed to link the laboratories that performed a comparison with the NIST travelling standard SRP0 to the comparison BIPM.QM-K1. This

linkage is based on the results of the comparison between the BIPM and the NIST SRP0 performed in January 2007 and the subsequent comparison performed between the NIST SRP0 and the laboratory standard. The reports of linkages with the UBA (Germany), NIM (China), and JRC (European Union) have been reviewed and published in the *Metrologia Technical Supplement*. Eight other reports of comparisons performed at the BIPM between July 2007 and June 2008 have also been reviewed this year and published in the *Metrologia Technical Supplement*; a full list of publications is given in §6.8.

The ozone standard calibration programme started in July 2008 with the calibration of the ozone photometer of the NMISA (South Africa). A second calibration was performed for the SP (Sweden) in March 2009.

In October 2008, a comparison following the BIPM.QM-K1 protocol was performed with the Department of Environment and Climate Change (NSW Australia). The report of this comparison will be published as a BIPM report.

In May 2009, 'NIST SRP upgrade kits' were successfully installed in the two standard reference photometers (SRPs) maintained by the BIPM (SRP27 and SRP28). The effect of the upgrade on the agreement between the key comparison reference standard BIPM-SRP27 and the laboratories' national standards will be reported in a special report of the comparison, showing very small changes in the degrees of equivalence. A report summarizing all upgrades performed by the NIST and by the BIPM is also in preparation. This will show how NIST SRP upgrades have improved the general agreement between ozone national standards between the pilot study CCQM-P28 performed in 2003–2004 and the first cycle of the key comparison BIPM.QM-K1 performed in 2007–2008.

The second cycle of the key comparison BIPM.QM-K1 started with a comparison with the NIST in June 2009.

6.1.2 Comparisons using the gas-phase titration facility

Studies of the BIPM's gas-phase titration (GPT) system were performed by Mr Ochman on secondment from the GUM (Poland) from September to November 2008. The oxygen content of the reference air was analysed and shown to differ from expected ambient values by 1%. This required corrections to be applied to flow measurements within the system. Helium leak testing was performed to ensure that there were no systematic effects in the flow measurements. Preliminary measurements of the ozone mole

fraction assessed by the GPT facility appear to reconfirm the difference previously observed compared to the UV photometry method reported in the comparison CCQM-P28.

6.1.3 NO gas standard comparison facility

Eight primary standards were analysed with the nitrogen monoxide (NO) facility to further study the measurement uncertainty of the two analysers used in the CCQM-P73 comparison. Measurements were performed in December 2008 and June 2009. Reports of these analyses are currently in draft form.

6.1.4 Maintenance of NO₂ facility and coordination of CCQM-K74, CCQM-P110, CCQM-P120

The BIPM's nitrogen dioxide (NO₂) facility was optimized by reducing the number of laminar flow elements and mass flow controllers within the system in order to decrease the background moisture levels. A validation study has been completed and included the comparison of NO₂ primary gas standards to dynamic gas mixtures produced by the NO₂ facility, the validation of the flow measurements by means of a primary gas flow calibrator, comparison of measurement results, and establishment of the complete uncertainty budget. The NO₂ facility will be used to value-assign 25 cylinders of NO₂ in air at nominally 10 mmol/mol; these will be distributed to NMIs participating in the CCQM-K74 and CCQM-P120 comparisons.

Progress has been made in characterizing the BIPM's Fourier Transform Infrared (FTIR) spectroscopy facility for use as an accurate analytical method for gas metrology. Studies have included FTIR measurements made by means of a well-characterized multi-pass White cell and improved gas cell temperature measurements. The optical path lengths of the multi-pass White cell were recently validated by means of a single-pass gas cell and gas standards of known mole fraction. The uncertainty sources and use of synthetic spectra for FTIR calibrations based on line-strength databases have been studied and a procedure and uncertainty budget have been developed for measuring gas concentrations through the calibration of synthetic spectra. The FTIR facility will be used in the CCQM-P110 comparison open to laboratories maintaining FTIR spectroscopy facilities to study sources of uncertainty and bias in the operation of spectroscopic and potentially primary methods.

6.1.5 Key comparison on methane standards

A new activity to develop facilities for determining the international comparability of methane in air standards at ambient level was started at the beginning of 2009. Methane is the second most important greenhouse gas and the differences between primary standards of methane revealed by CCQM-P41 (2003) need to be resolved.

The facility will be designed to allow the consistency of methane in air standards to be determined under repeatability conditions. This approach will allow analytical measurement uncertainties to be minimized. Measurement standards will be analysed using two separate measurement techniques, namely cavity ring-down spectroscopy (CRDS) and gas chromatography (GC-FID).

6.1.6 Development of a formaldehyde facility

The programme to establish a facility for the generation of formaldehyde (HCHO) in nitrogen started this year. The facility is based on the continuous weighing of a permeation tube containing the substance under study. The magnetic suspension balance has been purchased and delivery is expected in September 2009. Meanwhile, new gas lines have been installed in a dedicated laboratory. A call for tenders for the analytical instrument led to the purchase of a cavity ring-down spectrometer (CRDS) for the detection of formaldehyde in nitrogen at mole fractions in the range 100 nmol/mol to 20 μ mol/mol. Cylinder standards of formaldehyde in nitrogen have been purchased and will be used with the dilution system recently developed for the NO₂ facility to validate the characteristics of the CRDS analyser as soon as it is delivered.

6.1.7 Development of a laser-based SRP

The argon ion laser, which will be used for laser-based absorption measurements of ozone concentration and for a new measurement of the absorption cross section of ozone, has been recharacterized in terms of power stability.

An acoustic optic modulator (AOM) and additional optical equipment have been acquired for AOM-based power stabilization of the laser light. LabVIEW programs have been created to monitor the light stability in terms of the Allan deviation as well as the temperature around the experimental set-up. The power stabilization electronics have been assembled and through

a number of iterations have achieved satisfying characteristics. A spatial filter of the laser beam has been added in front of the power stabilization system to avoid issues with the non-Gaussian-shaped laser output. The power stabilization system has been mounted, first using a simple photodiode and then a light-trap as a locking photodiode. The power stabilization now shows promising values close to 1 part in 10^5 (Allan deviation) between 1 s and 30 s.

6.2 **Organic analysis programme** (S. Westwood, R. Josephs and A. Daireaux, T. Choteau, R.I. Wielgosz)

The organic analysis programme has focused on the coordination of CCQM comparisons for the assignment of the mass fraction content of organic compound pure substances that are intended for use as primary calibrators. As part of its overall planning for future key comparison studies, the CCQM Organic Analysis Working Group (OAWG) identified purity assessment of this type as being a core technical capability for all NMIs providing measurement services in organic analysis. The OAWG has recommended that participation in the CCQM-K55 comparison coordinated by the BIPM be compulsory for all NMIs providing services in the area of organic analysis under the CIPM MRA or having CMC claims in this area in Appendix C of the KCDB.

The facilities established at the BIPM are used for the handling, preparation, characterization and storage of CCQM study materials. The analytical capabilities within the programme were enhanced in 2008/2009 by the acquisition of a charged aerosol detection (CAD) system for use in tandem with and to complement existing HPLC-UV capabilities. Where appropriate the programme at the BIPM is supported by external collaborations and secondments from NMIs. A significant effort this year has also been devoted to the development and documentation of Quality System procedures covering the organic analysis programme activities. These are being progressively incorporated within the overall BIPM Quality System.

Following a proposal originally made to the OAWG at the November 2008 meeting in Bangkok and revised and discussed further at the April 2009 meeting in Sèvres, agreement was reached for the organic analysis programme to expand the scope of its activities to include the coordination of comparisons for the assignment of the mass fraction content of organic substances in solution. In 2010 the BIPM will coordinate key comparison

CCQM-K78 for the assignment of the mass fraction content of aldrin in solution.

6.2.1 Method development

The development and validation of analytical methods was completed in view of the characterization and production of the comparison material for CCQM-K55.a (estradiol). For the estradiol material the focus was the identification and quantification of the major impurities present in the study sample. These were found to consist primarily of structurally related impurities and also water.

Procedures developed or investigated for the CCQM-K55.a study included:

- LC-UV methods for the identification and quantification by external calibration of estradiol and related compounds. The procedures were used both for the characterization of the candidate material and for the estimation of the BIPM submission for the comparison;
- Protocols based on LC-UV analysis for testing the stability and homogeneity of the CCQM-K55.a study material;
- LC-MS/MS methods using photoionization detection for the qualitative identification and quantification of steroids related to estradiol. The procedures were used both for the characterization of the candidate material and for the estimation of the BIPM submission for the comparison;
- Development of suitable Karl Fischer titration conditions, ultimately using direct addition to the titration cell and an optimized titration time, for the determination of water content. The validated procedure was used to characterize the candidate material and to estimate the water content of the study sample provided for the BIPM submission for the key comparison;
- GC-MS method for determination of volatile organic impurities;
- Thermogravimetric analysis as a supporting method for the estimation of the total volatile impurities and water content;
- NMR spectroscopy and elemental microanalysis to provide confirmatory data for the characterization of the candidate material and the estimation of the BIPM submission for the comparison.

6.2.2 Pesticide primary calibrator (aldrin) purity analysis

The development of methods that will be used in the preparation and characterization of the study material for the CCQM-K55.b (aldrin) comparison started at the BIPM in 2008. The source material is technical-grade aldrin donated to the BIPM by the NMIA. Development of an analytical method to characterize the material and initial studies on its purification to a suitable level for the comparison commenced at the BIPM in 2008 and are continuing.

Procedures developed or investigated to date for use in the characterization of CCQM-K55.b candidate materials include:

- Procedures for the purification of the technical-grade aldrin source material to a level suitable for use in the CCQM-K55.b comparison;
- GC-MS and GC-FID methods for quantification of aldrin and related compounds;
- LC-UV methods for quantification of aldrin and related compounds;
- GC-MS methods for the determination of volatile organic impurities in CCQM-K55.b candidate materials;
- NMR spectroscopy and elemental microanalysis to provide confirmatory data for the characterization of the candidate material.

These studies were greatly assisted by the secondment of Dr Chen Dazhou from the NIM (China) to the BIPM during the final quarter of 2008.

6.2.3 Peptide calibrator studies

The BIPM has started to investigate pure material characterization methods for molecules of higher molecular weight and increased complexity that are of interest to both the CCQM OAWG and BAWG. Peptides have been chosen as model systems as they are of direct relevance to the programmes of both working groups. A secondment to the PTB provided an opportunity to discuss the practicability of taking up work on amino acids, peptides and proteins with colleagues who are already experienced in the field of larger molecules, and to learn about related key methods, techniques and instruments required to develop pure material characterization facilities.

6.2.4 Coordination of CCQM comparisons for mass fraction purity assessment

At the request of the OAWG, a proposal for the assignment of a reference value for the CCQM-P20.f (digoxin) study material was made by the BIPM. This value was obtained from a summation of estimates of the mass fraction contribution due to each of the orthogonal classes of impurity present in the sample. The estimates for each class of impurity were consensus values derived from the individual participant results. This approach was approved by the OAWG at its meeting in November 2008. A Draft Summary Report A for the CCQM-P20.f (digoxin) comparison was circulated to participants and was discussed by the OAWG at its meeting in April 2009.

6.2.5 Purity comparison CCQM-K55.a (estradiol)

Homogeneity and stability assessments of the estradiol candidate material for CCQM-K55.a were completed in late 2008. Twelve institutes participated in CCQM-K55.a and eight in the parallel pilot study CCQM-P117.a., making it the largest single comparison undertaken to date by the CCQM OAWG. The BIPM was one of the participating laboratories. In December 2008 two units of the study material, each containing a minimum of 300 mg of material, were shipped to each of the twenty participating laboratories. Participants were required to assign the mass fraction content of estradiol in each material and in addition, if possible, to provide estimates of the mass fractions of all major impurities.

Results were collected at the end of March 2009 and an initial summary was circulated to all participants. The comparison results were discussed in detail at the OAWG meeting in April 2009.

The preliminary results show good agreement between most participants in their estimates of the mass fractions of related structure impurities, volatile organic solvent residues and non-volatile content in the study samples. However individual water content estimates varied significantly. From the discussion at the April OAWG meeting these variations most likely resulted from the use of unsuitable conditions by some participants for water estimation by Karl Fischer titration. In particular there was strong evidence that methods relying on heated oven transfer to release water from the material underestimated the water content when transfer temperatures below the melting point of the material (176 °C) were used.

The BIPM is coordinating follow-up studies to resolve these differences, which if successful will allow the proposal of a KCRV and associated

uncertainty for the CCQM-K55.a results based on a consensus estimate mass balance approach similar to that used for the CCQM-P20.f comparison.

An additional problem with the analysis was *in situ* formation under neutral conditions of estradiol dimer artefacts observable at longer retention times during HPLC. Two participants identified and excluded these peaks as artefacts rather than impurities, while the overall BIPM result was biased low relative to other participants because they included them as true impurities. Other participants either did not detect them or the extent of artefact formation was too low under their conditions to affect their result significantly.

6.2.6 Purity comparison CCQM-K55.b (aldrin)

The BIPM will coordinate the second round of the purity assignment comparison CCQM-K55.b (aldrin). Distribution of the study material to participant laboratories, in the form of a two vials each containing about 500 mg of aldrin, is proposed for late 2009, with the initial discussion of results scheduled for the CCQM meeting in April 2010.

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 coordinates the development of the JCTLM Database.

The annual joint meeting of the JCTLM Working Groups 1 and 2 was held at NIST in July 2008, and was followed by a workshop on 'Identifying the Needs of the IVD Industry for Higher Order Reference Materials and Measurement Procedures for Nucleic Acid Testing and Immunodiagnostics'.

The 7th meeting of the Executive Committee of the JCTLM was held at the BIPM on 11 December 2008, and was followed on 12 December 2008 by a meeting of JCTLM Members and Stakeholders on 'International and National Systems for Traceability in Laboratory Medicine – Future Challenges and Activities'.

The list of the JCTLM review teams of Working Groups 1 and 2 was updated to include the review team members appointed for the review of nominations for Blood Cell Counting, and a timetable was approved for the review of the outstanding WG1 Cycle 3 nominations for reference measurement procedures for Blood Cell Counting.

The paper from the JCTLM review team for Nucleic Acid on '*Criteria to assess the quality of nominated nucleic acid reference materials with stated nominal properties*' was approved, and a timetable was agreed for the review of the outstanding WG1 Cycle 3 nominations for Nucleic Acid reference materials.

The JCTLM Database was updated in January 2009 to include WG1 Cycle 5 reference materials and WG2 Cycle 3 reference measurement laboratory services approved by the Executive Committee in December 2008. As of May 2009 the JCTLM Database contains:

- 208 available certified reference materials covering nine categories of analyte. Amongst these reference materials, 33 are included in List II (reference materials value-assigned using internationally agreed protocols);
- 146 reference measurement methods or procedures that represent about 75 different analytes for eight categories of analyte;
- 128 reference measurement services that can be delivered by 16 reference laboratories from ten countries, covering six categories of analyte.

The total number of external connections to the JCTLM Database corresponds to about 1000 visits each month for the period June 2008 to May 2009.

The WG1 Cycle 6 call for nominations of higher order reference materials and reference measurement methods or procedures, and the WG2 Cycle 4 call for nominations of reference measurement laboratory services, were announced on the JCTLM website in January 2009, and an email notification was sent to about 200 potential contributors.

Procedures for the operation of the JCTLM Secretariat and procedures based on the JCTLM Executive decisions, developed in collaboration with Dr C. Jackson (JCTLM WG1 Quality Manuals Review Team Leader), were presented to the JCTLM Executive for approval. These two sets of procedures will be accessible from the JCTLM web pages by the end of 2009.

6.4 Activities related to metrology in bioanalysis

The development of international metrology activities for the biosciences is in its early stages compared to the physical sciences. However, due to the impact of biotechnology on health, manufacturing, agriculture, energy and

the environment, national metrology programmes are paying increasing attention to improved measurement science in this area. The BIPM has developed a study entitled 'Study of Measurement Service and Comparison Needs for an International Measurement Infrastructure for the Biosciences and Biotechnology: Input for the BIPM Work Programme'. The goal of the study is to complete a report on:

1) Measurement services required to establish an international measurement infrastructure for the biosciences that are:

- expected to be delivered and/or developed in the next 3 to 5 years as well as the next 5 to 10 years by NMIs or other organizations developing measurement standards or methods for the biosciences;
- required by industry over the next 3 to 5 and 5 to 10 years.

2) International comparisons that are required to demonstrate the degree of equivalence of the measurements services that are or will be developed and delivered;

3) Research and development activities necessary for the development of higher metrological order measurement standards and methods for the biosciences.

The report will provide input for BIPM proposals on future requirements for BIPM laboratory activities in metrology for biotechnology and the biosciences, and be a useful reference for NMIs developing programmes in these fields. A call for tenders was launched in early June 2009, and the project is expected to start in 2009, with preliminary results available in 2010 and the final report published in early 2011.

6.5 Activities related to the work of Consultative Committees

R.I. Wielgosz is the Executive Secretary of the CCQM. The CCQM held its 15th meeting at the BIPM from 22-24 April 2009, and this was preceded by meetings of its working groups. A CCQM workshop on 'Measurement Traceability in Pharma and Bio-Pharma' was organized on 4-5 December 2008 in collaboration with the USP.

- S. Westwood is a member of the CCQM Working Group on Organic Analysis.
- R. Josephs is a member of the CCQM Working Groups on Bioanalysis and Organic Analysis.
- J. Viallon is a member of the CCQM Working Groups on Gas Analysis and Surface Analysis.

- E. Flores is a member of the CCQM Working Group on Gas Analysis.
- S. Maniguet is a member of the CCQM Working Group on Surface Analysis.

6.6 CCQM comparisons coordinated by the BIPM

The BIPM is the coordinating laboratory for the following CCQM comparisons:

- CCQM-P20.f – Digoxin, purity analysis series
- CCQM-K55.a – 17 β -Estradiol, purity analysis
- CCQM-K55.b – Aldrin, purity analysis
- BIPM.QM-K1 – Ozone, ambient level (ongoing)
- CCQM-K74 – Nitrogen dioxide value assignment (10 μ mol/mol)
- CCQM-P11 – Nitrogen dioxide (10 μ mol/mol) FTIR spectroscopic study
- CCQM-P120 – Nitrogen dioxide value assignment (10 μ mol/mol)
- CCQM-K78 – Aldrin calibration solution

6.7 Activities related to external organizations

R.I. Wielgosz is a BIPM representative to the Codex Alimentarius Commission, and to ISO TC 212, Clinical laboratory testing and *in vitro* diagnostic test systems, Working Group 2 on Reference Systems, and ISO TC 146 on Air Quality. He is a member of the editorial board of *Accreditation and Quality Assurance*.

S. Westwood is the BIPM and CCQM liaison to the ISO-REMCO, and is a member of the WADA Laboratory Expert Group.

R. Josephs is the BIPM representative to the Inter-Agency Meeting and the Codex Committee on Methods of Analysis and Sampling (CCMAS) of the Codex Alimentarius Commission, and is a member of the related electronic working groups on measurement uncertainties.

J. Viallon is the BIPM representative to ISO TC 229 on Nanotechnologies and ISO TC 146/SC 3 on Air Quality – Ambient Atmospheres.

6.8 Publications, lectures, travel: Chemistry Section

6.8.1 External publications

1. Viallon J., Moussay P., Wielgosz R., Norris J.E., Guenther F., Final report of the ongoing key comparison BIPM.QM-K1: Ozone at ambient level, comparison with NIST, 2007, *Metrologia*, 2008, **45**, *Tech. Suppl.*, 08008.
2. Viallon J., Moussay P., Wielgosz R., Konopelko L.A., Kustikov Y.A., Selyukov D., Final report of the ongoing key comparison BIPM.QM-K1: Ozone at ambient level, comparison with VNIIM, 2007, *Metrologia*, 2008, **45**, *Tech. Suppl.*, 08009.
3. Viallon J., Moussay P., Wielgosz R., Walden J., Kuronen P., Final report, ongoing key comparison BIPM.QM-K1: Ozone at ambient level, comparison with FMI, 2007, *Metrologia*, 2009, **46**, *Tech. Suppl.*, 08009.
4. Viallon J., Moussay P., Wielgosz R., Woo J.C., Final report, ongoing key comparison BIPM.QM-K1: Ozone at ambient level, comparison with KRIS, 2007, *Metrologia*, 2009, **46**, *Tech. Suppl.*, 08010.
5. Viallon J., Moussay P., Wielgosz R., Quincey P., Sweeney B., Final report, ongoing key comparison BIPM.QM-K1: Ozone at ambient level, comparison with NPL, 2008, *Metrologia*, 2009, **46**, *Tech. Suppl.*, 08011.
6. Viallon J., Moussay P., Wielgosz R., Sassi M., Malgeri E., Revel L., Final report, ongoing key comparison BIPM.QM-K1: Ozone at ambient level, comparison with INRIM, 2007, *Metrologia*, 2009, **46**, *Tech. Suppl.*, 08012.
7. Viallon J., Moussay P., Wielgosz R., Macé T., Couette J., Sutour C., Final report, ongoing key comparison BIPM.QM-K1: Ozone at ambient level, comparison with LNE, 2008, *Metrologia*, 2009, **46**, *Tech. Suppl.*, 08013.
8. Viallon J., Moussay P., Wielgosz R., Stummer V., Norris J.E., Guenther F., Final report, ongoing key comparison BIPM.QM-K1: Ozone at ambient level, comparison with UBA, 2007, *Metrologia*, 2009, **46**, *Tech. Suppl.*, 08014.
9. Viallon J., Moussay P., Wielgosz R., Morillo Gomez P., Sánchez Blaya C., Final report, ongoing key comparison BIPM.QM-K1: Ozone at ambient level, comparison with ISCIII, 2007, *Metrologia*, 2009, **46**, *Tech. Suppl.*, 08015.

10. Viallon J., Moussay P., Wielgosz R., Niederhauser B., Final report, ongoing key comparison BIPM.QM-K1: Ozone at ambient level, comparison with METAS, 2008, *Metrologia*, 2009, **46**, *Tech. Suppl.*, 08016.
11. Viallon J., Moussay P., Wielgosz R., Borowiak A., Lagler F., Norris J.E., Guenther F., Final report, ongoing key comparison BIPM.QM-K1: Ozone at ambient level, comparison with JRC, 2008, *Metrologia*, 2009, **46**, *Tech. Suppl.*, 08017.
12. Viallon J., Moussay P., Wielgosz R., Zhou Z., Norris J.E., Guenther F., Final report, ongoing key comparison BIPM.QM-K1: Ozone at ambient level, comparison with NIM, 2008, *Metrologia*, 2009, **46**, *Tech. Suppl.*, 08018.
13. Westwood S., Josephs R., Daireaux A., Wielgosz R., Davies S., Kang M., Ting H., Phillip R., Malz F., Shimizu Y., Frias E., Pérez M., Apps P., Fernandes-Whaley M., De Vos B., Wiangnon K., Ruangrittinon N., Wood S., Duewer D., Schantz M., Bedner M., Hancock D., Esker J., Final report on CCQM-P20.e: International comparison of mass fraction purity assignment of theophylline, *Metrologia*, 2009, **46**, *Tech. Suppl.*, 08019.
14. Buttinger G., Harbeck S., Josephs R.D.: Certification of mass fractions of aflatoxin B1, B2, G1 and G2 in peanut butter (BCR-385R and BCR-401R), *IRMM Information*, 2008, Report EUR 23522 EN.
15. Buttinger G., Harbeck S., Josephs R.D., The certification of the aflatoxin mass fractions in peanut butter, *World Mycotoxin Journal*, 2008, **1** (3), 283–289.
16. Buttinger G., Harbeck S., Josephs R.D., Certification of mass fractions of aflatoxin B1, B2, G1 and G2 in peanut meal (BCR-263R), *IRMM Information*, 2008, Report EUR 23386 EN.

6.8.2 Travel (conferences, lectures and presentations, visits)

R.I. Wielgosz to:

- NIST, Gaithersburg (USA), 20-22 July 2008, to participate in the NIST conference on 'Accelerating Innovation in 21st century Biosciences: Identifying the Measurement, Standards and Technological Challenges';
- NIST, Gaithersburg (USA), 25-26 July 2008, to attend the meeting of the JCTLM Working Groups and the JCTLM Workshop on

‘Identifying the Needs of the IVD Industry for Higher Order Reference Materials and Measurement Procedures for Nucleic Acid Testing and Immunodiagnosics’;

- Strasbourg (France), 9-10 October 2008, to attend the International Symposium on Pharmaceutical Reference Standards organized by the EDQM;
- Berlin (Germany), 31 October 2008, as BIPM liaison to ISO TC 146 (Air Quality – Ambient Air);
- Turin (Italy), 7 November 2008, to give a presentation on ‘Activities in Metrology in Chemistry’ at the IMEKO Technical Committee 8 meeting;
- NIMT, Bangkok (Thailand), 18-21 November 2008, for meetings of the CCQM-GAWG, BAWG and OAWG;
- Bucharest (Romania), 5-6 February 2009, to attend the EURAMET METCHEM plenary session and provide an update on JCTLM activities;
- Geneva (Switzerland), 5-7 May 2009, to represent the BIPM at the WMO/Global Atmosphere Watch 2009 meeting and give a poster presentation on ‘International equivalence of reactive gas standards’;
- Helsinki (Finland), 10-12 June 2009, to give a presentation on ‘International Standards for Greenhouse Gas and Air Quality Monitoring’ at MIKES, and to act as Ph.D. examiner at the University of Helsinki for J. Walden’s thesis on ‘Metrology of Gaseous Air Pollutants’.

S. Westwood to:

- Strasbourg (France), 9-10 October 2008, to present a poster on ‘International comparisons of the assignment of mass fraction composition of pure organic compounds – a model for benchmarking capabilities for the assessment of Pharmaceutical Reference Substances?’ at the EDQM International Symposium on Pharmaceutical Reference Standards;
- NIMT, Bangkok (Thailand), 18-21 November 2008, for a CCQM-OAWG meeting;
- Amsterdam (Netherlands), 7-9 March 2009, to attend the WADA Laboratory Directors’ meeting and a meeting of the WADA Laboratory Expert Group;

- Montreal (Canada), 17-19 June 2009, to attend a meeting of the WADA Laboratory Expert Group.

R. Josephs to:

- Strasbourg (France), 9-10 October 2008, to present a poster at the EDQM International Symposium on Pharmaceutical Reference Standards;
- Strasbourg (France), 6-7 November 2008, to attend the 1st European Meeting on the Metrology of Biofuels: 'Supporting Production, Use and Regulations';
- NIMT, Bangkok (Thailand), 18-21 November 2008, for the CCQM OAWG and BAWG meetings;
- Budapest/Balatonalmádi (Hungary), 6-12 March 2009, to present a lecture on 'Evaluating Laboratory Performance Using Measurement Uncertainty' at the Joint AOCS/BIPM/ICC/IUPAC/NMKL Workshop on 'Method Performance and the Criteria Approach: Truth and Consequences' and to represent BIPM at the Inter-Agency and Codex meetings;
- Brussels (Belgium), 19-20 March 2009, to participate in the 2nd International Conference on Biofuel Standards: 'Standards and Measurements for Biofuels: Facilitating Global Trade';
- PTB, Braunschweig (Germany), 4-15 May 2009, on secondment to work on amino acid/peptide/protein analysis.

J. Viallon to:

- Dubendorf (Switzerland), 7-9 July 2008, to give a lecture on 'Performance characteristics of dynamic methods for formaldehyde standards' during the meeting of the WMO/Global Atmosphere Watch and the CCQM GAWG on Volatile Organic Compounds;
- Berlin (Germany), 28 October 2008, as BIPM liaison to ISO TC 146/SC 3 (Air Quality – Ambient Air) to discuss revisions of ISO standards related to ozone measurements;
- Bangkok (Thailand), 17-21 November 2008, for a meeting of the CCQM-GAWG;
- Rotterdam (Netherlands), 11-13 February 2009, to present a poster at the conference GAS2009;
- Geneva (Switzerland), 11-13 May 2009, to give a lecture on 'Requirements for new measurements of ozone absorption cross-

sections for the accurate determination of ozone concentration' during the WMO/Global Atmosphere Watch/Ozone Theme meeting;

- Seattle (USA), 8-12 June 2009, as BIPM liaison to ISO TC 229 (Nanotechnologies) and for a meeting of the steering committee of the BIPM workshop on nanometrology;
- Paris (France), 24 June 2009, to give a lecture on 'Performance characteristics of dynamic methods for formaldehyde standards' at the 14th International Congress of Metrology.

E. Flores to:

- Rotterdam (Netherlands), 11-13 February 2009, to give a lecture on 'Dynamic generation of NO₂ standards by permeation tubes: Performance evaluation using FTIR and UV techniques' during the conference GAS2009;
- Paris (France), 30 April 2009, to visit the LNE laboratories for the conception of a new facility for the international comparison of methane in air standards based on gas chromatography;
- Teddington (UK), 7 May 2009, to visit the NPL laboratories for the conception of a new facility for the international comparison of methane in air standards based on gas chromatography.

S. Maniguet to:

- NIST, Gaithersburg (USA), 25-26 July 2008, to attend the meeting of the JCTLM Working Groups and the JCTLM Workshop on 'Identifying the Needs of the IVD Industry for Higher Order Reference Materials and Measurement Procedures for Nucleic Acid Testing and Immunodiagnosics';
- DIN, Berlin (Germany), 9-10 December 2008, to attend the ISO TC 212/WG2 meeting.

6.9 Visitors to the Chemistry Section

- Bernhard Niederhauser (METAS), 30 June to 4 July 2008.
- James Tsilongo (NMISA), 14-18 July 2008.
- Dita Heikens (NMi-VSL), 15-19 September 2008.
- Glenn Ross (Department of Environment and Climate Change, NSW Australia), 20-24 October 2008.
- Bertil Magnusson and Sarka Langer (SP), 9-12 March 2008.
- James E. Norris (NIST), 2-5 June 2009.

6.10 Guest workers

- C. Dazhou (NIM), 27 August to 30 November 2008.
- G. Ochmann (GUM), 1 September to 30 November 2008.

7 WATT BALANCE (M. STOCK)

7.1 Watt balance (R. Chayramy, H. Fang, A. Kiss, E. de Mirandés, A. Picard, J. Sanjaime, S. Solve, M. Stock, A. Kanté*, B. Parker**)

Discussions at the CCU meeting in May 2009 underlined the importance of the future *mise en pratique* for the new definition of the kilogram and the central coordination role which the BIPM is expected to play in this. The meeting also emphasized the importance of a watt balance at the BIPM, which would be operated on a long-term basis as an international reference facility.

The main distinctive feature between the BIPM watt balance and those built at other NMIs is that all quantities will be measured simultaneously, so that separate force and velocity experiments are not required. This mode of operation would ideally be carried out in the form of a cryogenic watt balance with a superconducting coil. The present experiment works at room temperature and will allow testing of the feasibility of simultaneous force and velocity measurements. A feasibility study on the cryogenic experiment will be started in September 2009 by a research fellow.

As of mid-2008 we have the capability to measure the induced voltage and the coil velocity while the coil moves vertically through the air gap of the magnet. From these measurements a value for the magnetic induction in the centre of the air gap can be deduced, which allows us to test the repeatability of the experiment. The first results – made in air and without vibration isolation – showed a repeatability of between 1 part and 2 parts in 10^4 over 16 days and were presented at the CPEM in 2008. To improve these results, better temporal synchronization of the voltage and velocity measurements is

* Student from Institut Universitaire de Technologie d'Evry, May-June 2009.

** Student from Massachusetts Institute of Technology, June-July 2009.

needed, so that correlated noise, which is included in both signals, drops out when the ratio of the two quantities is calculated. Much work has therefore been carried out to understand the detailed functioning, and in particular the timing, of the voltmeters and the interferometer. We have discovered that the correlation between voltage and velocity was less good than expected due to the presence of oscillatory coil movements at a frequency of about 25 Hz. Since the mirror of the interferometer was fixed on the circumference of the coil, this led to a significant Abbe error in the velocity measurements. As a consequence, the position of the interferometer mirror needs to be changed. We expect that the move to the new laboratory with the heavy concrete base will also improve the results due to the lower vibration level.

With the integration of the weighing cell at the end of 2008, we now have a complete watt balance where all quantities can be measured. However, many of the components are not yet in their final form. During preliminary force measurements it was observed that the force depended on the vertical position of the coil, which should not be the case in the absence of a coil current and of ferro- and paramagnetic parts. A calculation showed that the very small diamagnetism of the copper wire and the coil former, together with the observed gradient of the magnetic field, are sufficient to explain the observations. This effect is unavoidable and must occur in all watt balances, but has not previously been discussed. Under the condition that the effect is stable between the experiments with and without the test mass, it should have no consequence.

A mechanical system with eight piezo-transducers is being assembled to dynamically control the angular and horizontal coil alignment. The system is currently being tested before its integration into the watt balance. A mass exchanger is being constructed with the help of an engineering student.

The geometry of the winding of the large precision solenoid, which will become our reference for magnetic field alignment, has been determined to allow calculation of the deviations of the magnetic field from that of a perfect solenoid. We have found that the quality of the solenoid will indeed permit its use as an alignment reference. The next step will be to orient the solenoid horizontally by using a flat coil (spiral copper coating on optical glass) which itself will be aligned against a mercury pool by using an autocollimator. A non-magnetic support structure to place the flat coil close to the centre of the solenoid was constructed in the BIPM Workshop.

The collaboration with the Machine Tools Department of the Technical University of Aachen (RWTH/WZL) is continuing on the fabrication of the magnet. The difficulty lies in the very small tolerances of some parts and the

very precise assembly required, which will be difficult in the presence of magnetic forces up to 15 kN. The drawings for the magnet and the assembly tools are nearly finished and fabrication will start in the second half of 2009.

A new laboratory is now available, providing two concrete blocks: one for the watt balance (64 tons) and one for the gravimeter (10 tons). It is planned that some of the participants at the ICAG-2009 in October 2009 will determine the gravitational acceleration on the gravimetry site in the watt balance laboratory. During June and July 2009 a summer student will map the distribution of the gravitational acceleration in this laboratory using a relative gravimeter. We are also measuring the vibration level in the new laboratory. Preliminary results indicate that the level of vibration is low and comparable to that of our best gravimetry site. The new laboratory is equipped with a filtered electric power supply and low-noise solid-state lighting.

Work has started on the development of a dedicated Josephson voltage standard for the measurement of the induced voltage. This system will be based on an SNS-array developed at NIST. During the coming year the bias current source will be developed based on a low-noise battery-operated power supply. The measurement equipment required to operate the array has been assembled and the software for the dc biasing has been written.

7.2 Publications, lectures, travel

7.2.1 External publications

1. Picard A., Fang F., Kiss A., de Mirandés E., Stock M., Urano C., Progress on the BIPM watt balance, *IEEE Trans. Instrum. Meas.*, 2009, **58**(4), 924-929.
2. Picard A., Fang H., Kiss A., de Mirandés E., Stock M., The BIPM watt balance for the future realization of the mass unit, *Proc. 14th International Metrology Congress* (Paris; 22-25 juin 2009), Paris, 2009, CD-Rom.

7.2.2 Travel (conferences, lectures and presentations, visits)

A. Picard to:

- Sartorius, Ilmenau (Germany), 16 December 2008, to discuss modifications of the watt balance weighing cell;

- ONERA, Palaiseau (France), 9 June 2009, accompanied by E. de Mirandés, to give an invited presentation on the BIPM watt balance.

M. Stock and A. Picard to:

- RWTH/WZL, Aachen (Germany), 6 October 2008, to discuss the fabrication of the watt balance magnet.

H. Fang to:

- the International Congress of Metrology, Paris, 24 June 2009, to give a presentation on the BIPM watt balance.

E. de Mirandés, A. Picard and L. Le Mée to:

- METAS, Bern (Switzerland), 19-20 February 2009, to visit the watt balance and discuss a database for watt balance results.

H. Fang, A. Kiss, E. de Mirandés, A. Picard, M. Stock to:

- the International Congress of Metrology, Paris, 24 June 2009, to present two posters on the BIPM watt balance.

7.3 Visitors

- Mr Jean-Jacques Guillet, Mayor of Chaville and *Député des Hauts de Seine*, and Mrs C. Mass from the administration of the German Parliament, 2 July 2008.
- Members of the Committee on Science and Metrology of the French Académie des Sciences, 17 November 2008.
- Dr R. Steiner (NIST, USA), 1-5 December 2008.
- Ing. Hector Martinez (DIGENOR, Dom. Rep.) and Mr Moritz Ackermann (PTB), 2 February 2009.
- Participants at the WBTM, organized by LNE, 18 March 2009.
- Mr J. Kallmerten (RWTH, Germany), 16 June 2009, to discuss the fabrication of the watt balance magnet.
- Dr W. Schmid (PTB, Germany), Secretary of EURAMET, 26 June 2009.

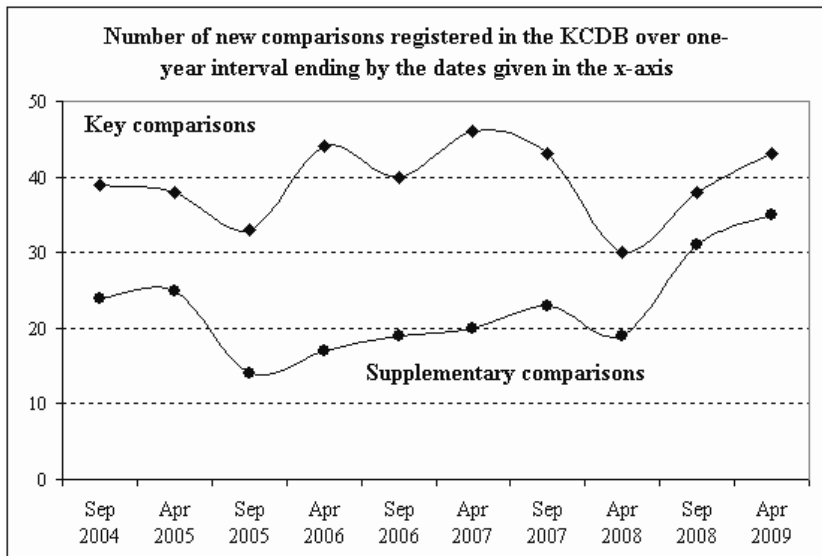
8 THE BIPM KEY COMPARISON DATABASE, KCDB (C. THOMAS)

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

8.1.1 Key and supplementary comparisons

On 14 June 2009, the BIPM key comparison database (KCDB) covered 659 key comparisons (81 from the BIPM, 327 from the CCs, and 251 from RMOs) and 212 supplementary comparisons. Two new BIPM key comparisons were recently registered in the KCDB: BIPM.RI(II)-K1.Cu-64 and BIPM.RI(I)-K6. These correspond to novel work undertaken by the BIPM Ionizing Radiation Section: SIR measurement of radionuclide Cu-64, and absorbed dose for high-energy x-ray beams from linear accelerators.

The evolution of the number of key and supplementary comparisons registered in the KCDB over one-year intervals is shown below.



One observes that 35 new supplementary comparisons have been registered over the last year. This is the highest rate ever observed, and reflects the awareness of the RMOs of the interest of declaring their internal exercises and posting the corresponding reports in the KCDB, mainly in support of their CMC claims. The number of newly registered key comparisons averages at about 40 per year.

Of the 659 key comparisons registered in the KCDB on 14 June 2009:

- 87 corresponded to exercises prior to the implementation of the CIPM MRA, and will never have results published in the KCDB (these have been 'Approved for provisional equivalence');
- 74 of the 81 ongoing BIPM key comparisons had results published in the KCDB and are regularly extended as new data become available (most of them also serve as 'master' key comparisons to which other CC and RMO key comparisons are linked); and
- another 267 CC and RMO key comparisons had their final reports approved and posted in the KCDB website, and corresponding tables of numbers and graphs entered in the database.

All together, the KCDB currently includes more than 1200 graphs of equivalence.

The results of some 97 RMO key comparisons have been published in the KCDB. Linkage is also computed for bilateral key comparisons subsequent to full-scale CC key comparisons; their results are added on the appropriate graphs of equivalence.

The final reports (or appropriate references) of about half of the supplementary comparisons registered in the KCDB are also posted in the KCDB.

Note that final reports of key and supplementary comparisons posted in the KCDB are also generally published in the *Metrologia Technical Supplement*.

A number of key comparison results are also regularly updated. These mainly concern the ongoing BIPM key comparisons in electricity (voltage, resistance, and capacitance), in chemistry (ozone measurements), 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 on the Statistics page of the KCDB website at http://kcdb.bipm.org/kcdb_statistics.asp.

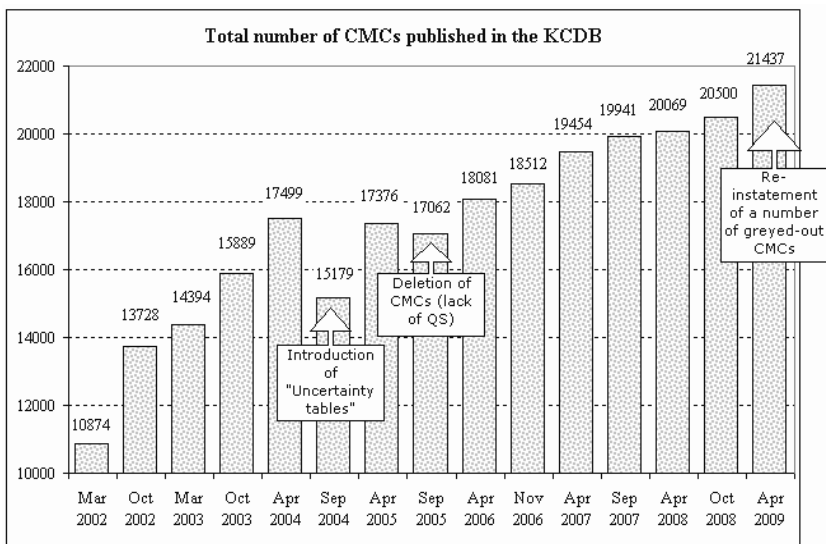
8.1.2 Calibration and Measurements Capabilities – CMCs

At mid-June 2009, about 21 200 CMCs were published in the KCDB. This represents an additional 1200 CMCs compared to May 2008. Indeed, over

the last year, 38 newly approved sets of CMCs declared by all the RMOs were published. The two most important sets, in terms of number of CMCs, were declared through the APMP in Electricity and Magnetism (set identified as APMP.EM.6.2008: 175 new CMCs and tens of revisions) and in Chemistry (set identified as APMP.QM.13.2008: 195 new CMCs and tens of revisions).

Note that the first CMCs from Costa Rica (24 CMCs in Mass Standards) and the first CMCs from Egypt (2 CMCs in Length) were published in the KCDB on 26 November 2008 and 11 February 2009, respectively.

Details on the number of CMCs currently published in the KCDB, per country and per metrology area, are available in real-time from the Statistics page of the KCDB at http://kcdb.bipm.org/kcdb_statistics.asp along with information about the temporary removal ('greying-out') and reinstatement of CMCs linked to approval of appropriate Quality Systems.



On 3 June 2009, 490 CMCs were still greyed-out from the KCDB due to the lack of an approved Quality System (QS). The KCDB Office asked the JCRB at its 20th meeting to clarify the status of those CMCs that had been greyed-out in July 2005, following the decision of the 15th JCRB, as it may be that some of them will never be re-published as they are out of date and no longer correspond to services delivered. The matter was considered by the RMOs and reports were submitted to the 22nd meeting of the JCRB. Subsequent actions were taken by the KCDB Office at the end of March 2009: definitive deletion or confirmation of the greyed-out status for

some CMCs, and reinstatement of many others. Since then the temporary removal and reinstatement of CMCs in the KCDB according to the QS status has constituted routine work, based on correspondence between the KCDB Office and the Chairs of the RMO Technical Committees on Quality Systems.

In addition to publishing newly approved sets of CMC and monitoring the temporary removal and reinstatement of CMCs linked to changes in QS status, the KCDB Office deals with numerous corrections: editorial changes, deletion of services that are no longer available, and changes of laboratory names and acronyms (for instance 'NMI-VSL' changed to 'VSL' on 1 March 2009).

Data summarizing the evolution of numbers and graphs presented in the KCDB Statistics page over the past two years are now available in the form of Excel files in the restricted-access JCRB CMCs website.

8.2 Visits to the KCDB website (C. Thomas)

New software to analyse the connections to the KCDB website was implemented in January 2009.

The number of monthly visits since then varies between 7000 and 8000, and corresponds to a total of about 60 000 pages opened each month. However, this does not include the number of visitors accessing the data using our keyword search engine.

All pages are equally visited, including the News page, the Statistics page, and the Newsletters, and PDF files of comparison reports and of CMC lists are regularly downloaded.

Visitors come from all over the world, and reach the KCDB website from:

- personal bookmarking, direct URL address typing or using links given in e-mails for about 75 % of them;
- Internet search engines (Google, Yahoo, etc.) for about 5 % of them; and
- links proposed in other websites (especially NMI websites) for the remaining 20 %.

It is very difficult to identify our visitors, apart from that part of our audience coming from NMIs; the statistics show that our site also attracts other communities, and we think that this includes regulators, accreditors, and commercial and industrial companies.

8.3 Publicity and KCDB Newsletters (S. Maniquet and C. Thomas)

We 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. In addition, issues 10 and 11 of the successful *KCDB Newsletter* were launched on 18 December 2008 and 16 June 2009 respectively.

We are also preparing a 'Frequently Asked Questions' section for the KCDB website. Nine questions have been identified, and draft answers have been prepared in the form of short answers complemented by more detailed explanations. These 'FAQs' were submitted to the JCRB, which will give its comments at the time of the 23rd JCRB meeting, scheduled to be held in September 2009.

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

C. Thomas to:

- Paris (France), on 12 September 2008, 20 October 2008, 26 November 2008, 8 January 2009, and 18 May 2009 at the LNE, and on 3 April 2009 at the OIML, for meetings of the Organizing Committee of the 14th International Congress of Metrology, and on 18 November 2008 for the meeting of the Technical and Scientific Committee of the same Congress at the Palais des Congrès in Paris;
- Teddington (United Kingdom), 2 February 2009, for a meeting of the Organizing Committee of the 14th International Congress of Metrology;
- Reading (United Kingdom), 3 February 2009, to meet Prof. Ian Mills and Prof. Malcolm Sperrin;
- Institut de France, Paris (France), 2 March 2009, for a meeting of the committee *Science et métrologie* of the Académie des Sciences;
- Paris, 22-25 June 2009, to attend the 14th International Congress of Metrology and to present an invited paper on the BIPM key comparison database.

8.5 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 is a member and acts as the Scientific Secretary of the permanent committee

Science et métrologie of the Académie des Sciences. C. Thomas was a member of the Organizing Committee and of the Technical and Scientific Committee of the International Congress of Metrology 2009 ('Metrology'2009'), held in Paris from 22-25 June 2009.

8.6 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 WGSI) and on coordination of the RMOs (CCEM RMOWG), a member of the CCM Working Group on the SI kilogram (CCM-WGSI-kg), a member of the CCRI RMO Working Group for RI CMCs, and a non-voting member of the CCT Working Group on Key Comparisons (WG7). C. Thomas is also the BIPM Liaison of the CODATA Task Group on Fundamental Constants, and BIPM Contact for the JCGM and its WG2 (VIM).

C. Thomas attended the following meetings in part or full:

- 21st JCRB meeting, 24-25 September 2008;
- 6th CCAUV and related meetings, 8-10 September 2008;
- 97th CIPM (in part), 14-16 October 2008;
- Meeting of the Steering Committee for the BIPM Workshop on 'Physiological Quantities and SI Units', 28 January 2009;
- 26th CCEM and related meetings, 11-13 March 2009;
- BIPM QS Workshop, 17 March 2009 (morning);
- 22nd JCRB meeting, 17 March 2009 (afternoon) and 18 March 2009;
- BIPM Forum on coordination of NMI international activities, 19-20 March 2009;
- 18th CCRI Section III, 1-2 April 2009;
- 15th CCQM, 22-24 April 2009;
- 19th CCRI Section I, 13-15 April 2009;
- CODATA Task Group on Fundamental Constants, 25 May 2009;
- 19th CCU, 26-28 May 2009;
- 18th CCTF, 4-5 June 2009;
- 14th CCL and related meetings, 8-11 June 2009;
- CCRI RMO WG, 12 June 2009;
- 20th CCRI Section II, 17-19 June 2009;
- 14th International Congress of Metrology, 22-25 June 2009.

C. Thomas is also responsible for the organization of seminars at the BIPM, acted as the Scientific Secretary of the BIPM Metrology Summer School 2008, and is the Scientific Secretary of the BIPM Workshop on Physiological Quantities and SI Units.

8.7 Visitors

- Dr A. Steele, NRC (Canada), 25 September 2008.

9 THE JOINT COMMITTEE OF THE REGIONAL METROLOGY ORGANIZATIONS AND THE BIPM, JCRB (L. MUSSIO)

9.1 AFRIMETS approved as expansion of SADC MET

The JCRB recommended to the CIPM the approval of AFRIMETS as an expansion of the existing RMO SADC MET. Being an expansion of an existing RMO means that AFRIMETS already has the required structures in place, including technical committees capable of reviewing CMCs, technical capabilities to participate in key comparisons, participation in CCs, and a committee for the review of quality systems. AFRIMETS is now part of the JCRB with full rights.

9.2 Evaluation of Quality Systems

With the aim of harmonizing the RMO procedures for review and approval of Quality Systems, a half-day seminar was organized at the BIPM in conjunction with the March 2009 meeting of the JCRB. The RMOs gave presentations of the status of their review systems and highlighted any significant changes since the previous seminar held in Berlin in 2006.

The seminar also included a presentation of the BIPM's Quality System as well as the way chosen by the BIPM to make public its calibration and measurement services, needed to make transparent the traceability route for those NMIs that rely on BIPM calibrations.

The RMOs provided a number of suggestions and useful comments, many of which will be implemented to further improve the Quality System.

9.3 New documents under discussion

Document CIPM MRA-D-05, 'Comparisons in the CIPM MRA', was presented to the JCRB and a discussion was held on the requirements for comparisons. A new draft has been prepared and has been circulated among the RMOs for comments.

Document CIPM MRA-P-01, 'Procedure for approval of new RMOs' was re-discussed to provide a clear definition of RMO and cover the differences in the meaning of 'member' among the different RMOs; the revised version will be submitted to the CIPM in October 2009 for final approval.

9.4 Feedback from the CC and their Working Groups

In order to obtain formal feedback from the CCs and the CC Working Groups, a questionnaire was circulated before the JCRB meeting including the following topics:

- Periodicity of CMC reviews;
- Work and issues related to the device under test (DUT);
- Reactions and actions on 'lower level' service categories;
- Reactions to the CIPM traceability statement;
- Different procedures for inter-RMO reviews of CMCs (if any);
- Additional issues or questions related to the CIPM MRA for discussion at the next JCRB meeting.

9.4.1 Periodicity of CMC reviews

The question of the periodic review of published CMCs was discussed by the JCRB.

Noting that its statement about a five-year review period may have been misinterpreted, that RMO reviews of quality systems occur every five years, and that recently a system of annual reports from the NMIs was introduced in which the NMIs report any changes that may affect their CMCs, the JCRB resolved that the periodic review of published CMCs should be performed by the RMOs and recommended that the RMOs review the templates used for the annual reports to ensure that the NMIs address this issue.

The JCRB further noted that in some areas the CCs may wish to make a specific decision on the review period and review procedure applicable to their community.

9.4.2 Work and issues related to the DUT (Device Under Test)

All the CCs follow the established policy of including the DUT components in the uncertainty budgets for CMCs. In those exceptional cases where these components are not included, this should be explicitly stated in the CMCs.

9.4.3 Policy on traceability in the CIPM MRA

In the March 2008 meeting of the JCRB, a policy was approved for establishing the traceability of CMCs in the context of the CIPM MRA. This policy was modified and approved during the 2008 meeting of the CIPM. However, comments on the text have subsequently been received from some of the CCs and RMOs. Although the policy is accepted in general, the main point still under discussion is how to provide a clear statement for those quantities that do not have a clear path to the SI, such as in some areas of chemistry and materials properties. The JCRB has thus consulted with the CCs and drafted a new text that takes into consideration these problems. The new draft will be circulated among the RMOs through the JCRB representatives and it is planned to have the final text approved at the next JCRB meeting (September 2009) and presented to the CIPM in October 2009.

9.4.4 Reactions and actions on 'lower level' service categories

This issue was discussed by the JCRB and at the joint BIPM-ILAC meeting. Proposals for new 'lower level' services categories will be made by ILAC, and the CCs will decide on their inclusion in the present lists.

9.5 BIPM-ILAC joint activities

BIPM and ILAC held a bipartite meeting in March 2008. The main outputs from this meeting were:

- that an update of the references to international standards is needed, particularly in the text of the CIPM MRA;

- a proposal that the JCRB considers a change in policy, making on-site reviews mandatory;
- a proposal that the JCGM-WG2 reviews the references to ILAC P10 in the VIM;
- that ILAC will propose new service categories for those fields in which existing categories do not cover 'low level' services, with a view to forming a common list for use in the accreditation and NMI communities;
- that the definition of CMC should be updated in the CIPM MRA;
- that the participation of the BIPM in ILAC committees, particularly the AIC, should be continued.

The JCRB Executive Secretary is now participating in the AIC, for the review of the documents 'ILAC policy for traceability' and 'Guidelines for the accreditation of NMIs'.

The Deputy Director of the BIPM, Prof. Michael Kühne, has been designated liaison delegate to ILAC.

9.6 Forum on coordination of NMI international activities (P. Espina*)

At the request of a number of NMIs with activities in developing countries, the BIPM held a discussion "Forum on coordination of NMI international activities" at the BIPM headquarters on 19-20 March 2009. The objectives of the Forum's Steering Committee were to facilitate the exchange of information between the various NMI International Offices, and to identify opportunities for cooperation, collaboration and coordination among them. They also aimed to develop more efficient and effective ways of conducting programmes aimed at helping the development of metrology in emerging economies.

The March meeting concluded that there was a need to facilitate information exchange on a daily basis, and for further discussion on two topics. The first concerned cooperation between the international activities of NMIs, through sharing national strategic plans with regard to measurement systems, and reviewing international strategies and activities developed by the NMIs with respect to interactions with other NMIs and economies in the global

* On secondment from the NIST (United States) until 31 December 2009.

environment. The second area for discussion concerned national technical assistance and capacity building activities, with a view to sharing visions of NMIs as recipients, deliverers and coordinators to facilitate related RMO activities.

The members of the Forum decided that similar events could be held in the future.

9.7 JCDCMAS (M. Streak*)

The annual meeting of the JCDCMAS took place in March 2009. The BIPM took the lead in suggesting that the original expectations of the JCDCMAS were too optimistic – particularly concerning the ability of the group to coordinate work, as it turned out that all member bodies followed their internal policies. The BIPM initiated a discussion in which the options of closure or a substantial redrafting of the terms of reference were considered. The consensus was that:

- the original expectations were indeed too optimistic;
- it was, however, valuable to have informal working-level exchanges of experiences and an opportunity for each body to see the plans and policies of the others;
- that to disband the JCDCMAS could send the wrong signals to some of the current partners and/or the States which benefit from their actions.

The BIPM therefore prepared some new terms of reference for an informal group that would meet on an ad hoc basis. The proposed terms are currently being circulated at working level.

9.8 Publications, lectures, travel: JCRB

9.8.1 New CIPM MRA documents

A new document ‘Guide to the implementation of the CIPM MRA’ (CIPM MRA-G-01) was approved by the JCRB and the CIPM. This brings together all the current relevant policy documents and, now that it is web-based, it can be updated regularly. The Guide should be useful to NMIs and

* On secondment from the NMISA (South Africa) until 24 April 2009.

to technical and other committees in the RMOs. Please contact the JCRB Executive Secretary if you encounter any difficulty interpreting the Guide.

The document 'Calibration and Measurement Capabilities in the context of the CIPM MRA' (CIPM MRA-D-04) was approved by the JCRB and the CIPM. This document supersedes all the previously existing documents on CMCs and should now be applied by NMIs and RMOs.

All CIPM MRA related documents are now available at <http://www.bipm.org/en/cipm-mra/documents/>.

9.8.2 Revised CIPM MRA documents

Documents 'JCRB guidelines for the monitoring and reporting of the operation of quality systems by RMOs' (CIPM MRA-G-02) and 'Guidelines for the review of CMCs and the monitoring and reporting of the operation of quality systems by international intergovernmental organizations who are signatories of the CIPM MRA' (CIPM MRA-G-03) have been edited and reformatted to the BIPM Quality System. No changes were made to the texts of the documents.

Both documents are available at: <http://www.bipm.org/en/cipm-mra/documents/>.

9.8.3 Travel (conferences, lectures and presentations, visits)

L. Mussio to:

- CEPAL, Santiago (Chile), 26-27 August 2008, for the *Primer diálogo bianual entre organismos reguladores regionales de américa latina y el caribe*;
- Warsaw, 21-22 April 2009, for an ILAC–IAC meeting;
- 14th International Metrology Congress, Paris (France), 24 June 2009, to chair the session *Reconnaissance Internationale des Certificats d'Étalonnage*.

P. Espina to:

- Vienna (Austria), 16 September 2008, to visit UNIDO;
- Bratislava (Slovakia), 17-18 September 2008, to participate in the COOMET TC1.4 (flow and related quantities) meeting, visit the SMU laboratories, and meet with Peter Lukác, Chairman, Office of Standards, Metrology and Testing of the Slovak Republic;

- Geneva (Switzerland), 28 October 2008, to visit the WMO to discuss plans for a WMO/BIPM workshop on ‘Measurement Challenges for Global Observation Systems for Climate Change Monitoring: Traceability, Stability and Uncertainty’;
- Geneva (Switzerland), 29-31 October 2008, to participate in the ISO workshop on conformity assessment standards in support of market surveillance and to represent the BIPM at the 24th ISO-CASCO plenary meeting;
- Skopje (FYROM), 27-28 November 2008, to participate in the EURAMET Focus Group on Facilitating National Metrology Infrastructure Development;
- Astana (Kazakhstan), 1-3 December, 2008, to participate in a COOMET Awareness Seminar for General Directors of NMIs sponsored by the PTB;
- Teddington (UK), 8-9 December 2008, to participate in a Technical Cooperation Meeting between the BIPM, NPL, and PTB, and visit to the NPL laboratories;
- Copenhagen (Denmark), 10 March 2009, to participate in the EURAMET TC Flow Meeting.
- Riyadh (Saudi Arabia), 2 May 2009, to participate in talks regarding metrology in the GCC countries at the GCC Standardization Organization (GSO) and to discuss BIPM membership issues with the Saudi Arabian Standards Organization (SASO).
- Dubai (United Arab Emirates), 3-4 May 2009, to participate in a discussion with the Heads of National Standardization Bodies in the GCC and to take part in the GSO symposium: ‘The Importance of Metrology to National Economy’;
- Tunis (Tunisia), 20 May 2009, to give a talk at the Tunisian World Metrology Day event;
- Gaithersburg, Md. (USA), 15-16 June 2009, for meetings with various NIST staff;
- Boulder, Co. (USA), 18-19 June 2009, for meetings with various NIST staff.

9.9 Activities related to the work of the Metre Convention

L. Mussio participated in the following meetings:

- *Primer diálogo bianual entre organismos reguladores regionales de américa latina y el caribe*, CEPAL, 26-27 August 2008;
- 21st JCRB meeting, 24-25 September 2008;
- CCAUV RMO meeting, 8 October 2008;
- CCAUV meeting, 9-10 October 2008;
- CIPM meeting, 14-17 October 2008;
- CCRI RMO WG meeting, 20-21 November 2008;
- JCGM meeting, 5 December 2008;
- BIPM-OIML-ILAC 'tripartite' meeting, 4 March 2009;
- Bipartite ILAC-BIPM meeting, 5 March 2009;
- JCDCMAS, 6 March 2009;
- Quality Systems Workshop, 17 March 2009;
- 22nd JCRB meeting, 17-18 March 2009;
- Forum on coordination of NMI international activities, 19-20 March 2009;
- CCRI(III) meeting, 1-3 April 2009;
- CCQM KCWG meeting, 17-18 April 2009;
- CCQM meeting, 23-24 April 2009;
- CCRI(I) KCWG, 11 April 2009;
- CCRI(I) meeting, 13-15 May 2009;
- CCU meeting, 26-28 May 2009;
- CCL-CCTF Frequency Standards WG, 2 June 2009;
- CCTF meeting, 4-5 June 2009;
- CCL WGDM meeting, 8 June 2009;
- CCL meeting, 10-11 June 2009;
- CCRI RMO WG meeting, 12 June 2009;
- CCRI(II) meeting, 17-19 June 2009.

M. Streak participated in the following meetings:

- BIPM-OIML-ILAC 'tripartite' meeting, 4 March 2009;
- Bipartite ILAC-BIPM meeting, 5 March 2009;
- JCDCMAS, 6 March 2009;
- Quality Systems Workshop, 17 March 2009;
- 22nd JCRB meeting, 17-18 March 2009;

- Forum on coordination of NMI international activities, 19-20 March 2009.

P. Espina participated in the following meetings:

- 21st JCRB, 25 September 2008;
- 97th CIPM, 14-16 October 2008;
- BIPM-OIML meeting, 16 December 2008;
- Meeting of the steering committee for the BIPM Workshop on physiological quantities and SI units, 28 January 2009;
- Annual BIPM-ILAC-OIML meeting, 4 March 2009;
- Annual BIPM-OIML meeting, 4 March 2009;
- Annual BIPM-ILAC meeting, 5 March 2009;
- Annual JCDCMAS, 6 March 2009;
- 22nd JCRB, 17-18 March 2009;
- Forum on coordination of NMI international activities, 19-20 March 2009;
- Meeting of the steering committee for the WMO-BIPM Workshop on measurement challenges for global observation systems for climate change monitoring: traceability, stability and uncertainty, 22 June 2009.

9.10 Visitors

- Tunisian Delegation: Mme M. Chambon (LNE, France), Mme Souaz Bouazis (Tunis), M Cherif Bekiri (Tunis), 27 March 2009 ;
- British Delegation: Ms Aphrodite Korou (Head of Standardisation Policy, Innovation Delivery), Ms Rose Newton (Team Leader for EU and international standards and standardisation policy), Mr Mark Sinclair (Regional Manager - Europe West, UK Science & Innovation Network, UK Embassy in France), Ms Alison MacEwen (Science and Innovation Officer, UK Embassy in France) 23 June 2009;
- Dr Wolfgang Schmid, (Secretary of EURAMET, PTB, DE), 26 June 2009.

10 PUBLICATIONS OF THE BIPM AND INFORMATION TECHNOLOGY (J.H. WILLIAMS* AND J.R. MILES)

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

Since July 2008 the following reports have been published:

- International Committee for Weights and Measures, 96th meeting (2007), 2008, **75**, 206 pp.
- Director's Report on the Activity and Management of the BIPM (2008), 2009, **9**, 306 pp.
- Consultative Committee for Length, 13th meeting (2007), 2009, 46 pp.
- Consultative Committee for Mass, 11th meeting (2008), 2008, 36 pp.
- Consultative Committee for Amount of Substance – Metrology in Chemistry, 14th meeting (2008), 2008, 46 pp.
- Consultative Committee for Ionizing Radiation, 20th meeting (2007), 2009, 86 pp.
- Consultative Committee for Thermometry, 24th meeting (2008), 2008, 26 pp.

Following a decision of the CIPM in October 2003, reports of meetings of the Consultative Committees no longer appear in print, but are published in their original language on the BIPM website.

The last year has also seen the publication on the BIPM website of the *Guide to the Expression of Uncertainty of Measurement* (now referred to as JCGM 100:2008, GUM 1995 with minor corrections), volume 4 of *Monographie BIPM-5* (Table of radionuclides) and the report of the CIPM *ad hoc* Working Group on Materials Metrology: '*Evolving Need for Metrology in Material Property Measurements*'.

All scientific publications are listed in the appropriate sections of the report.

* until 20 November 2008.

10.2 *Metrologia* (J.R. Miles, D. Saillard** and J.H. 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 Impact Factor of *Metrologia* has continued to increase, and stands at 1.780 for 2008. The Impact Factor (IF) is defined as being the number of citations in the current year to papers published in the previous two years, divided by the number of papers published in the previous two years. Recent figures for *Metrologia* are shown below:

Year	2003	2004	2005	2006	2007	2008
IF	0.983	1.314	1.479	1.657	1.667	1.780

Metrologia has the highest impact factor of all the related journals, which is important in maintaining and boosting subscription levels as well as in maintaining high-quality submissions. The outgoing Editor, as well as the authors and referees of *Metrologia*, are to be congratulated on these results.

The technical details of the production of *Metrologia* between the BIPM and IOPP continue 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.

In addition to appearing in the printed journal, all articles are available in the online version of *Metrologia* and are accessible free of charge for one month after publication (www.iop.org/EJ/journal/Met).

In order to increase the visibility of *Metrologia* in the many laboratories dealing with metrology but separate from the signatory NMIs, a number of other designated institutes are being offered a trial period of free electronic access to the journal. The laboratories involved in the current campaign are those dealing with chemical and ionizing radiation metrology. Interested laboratories are invited to contact the IOPP at metrologia@iop.org.

Following the retirement of the part-time secretary of the Editor, the secretarial functions of the manuscript handling and review process were

** until 29 August 2008.

* until 20 November 2008.

transferred to IOPP in September 2008. This transfer process was completed with no disruption to the production of the journal, and authors can now submit their manuscripts through the IOPP's internet-based manuscript submission system.

Special issues of *Metrologia* devoted to subjects of timely interest continue to be organized by invited specialist editors in cooperation with the Editor at the BIPM. Three special issues of *Metrologia* were published during the period of this report: issues 45(6) on Timescale Algorithms, 46(2) on Radiation Dosimetry, and 46(4) on NEWRAD 2008.

The *Technical Supplement to Metrologia* is also doing well, with 89 Abstracts published during the period of this Report.

10.3 The BIPM website (J.R. Miles)

As the BIPM's primary means of communication, its website contains a wealth of information and attracts interest from a diverse audience. Many areas of the website are destined for specific user groups (including the Joint and Consultative Committees and their Working Groups); some sections provide information of particular importance to industries, accreditors and regulators; and others are of interest to the larger scientific community, to schools, journalists and even historians. The BIPM metrology portal <http://search.bipm.org/> is widely used, and the SI Brochure continues to be downloaded from the website at around 4000 times per month.

Following the above-mentioned retirement of the part-time Secretary as well as the departure of the previous Editor, the BIPM Publications Section has been severely understaffed during the period of this report. This staffing shortage has impacted hardest on the BIPM website, and for much of the period covered by this report updates have been restricted to essential maintenance rather than the addition of new facilities. Dr Miles acknowledges with thanks the help offered by a short-term and part-time Assistant, Miss A. Bêche.

Amongst the improvements to the website made during the period of this report, access to the CIPM MRA documents has been facilitated through the creation of a new section under 'CIPM MRA': see <http://www.bipm.org/en/cipm-mra/documents/>.

Attention is also drawn to the new section devoted to BIPM events, including the Summer School in 2008 and the forthcoming Workshops on Physiological Quantities and SI Units, and on Metrology at the Nanoscale.

The section describing the BIPM's international liaison activities has also been enlarged.

As part of a collaborative project to promote the benefits of metrology to society, a new website was launched to celebrate World Metrology Day (WMD) 2009: see <http://www.worldmetrologyday.org>. This was set up by Dr Espina on behalf of the BIPM and its partners in the WMD 2009 Team: NCSLI, NIST, NMIJ AIST, NMISA, NPL, OIML, and the PTB.

10.4 Information Technology (L. Le Mée)

During the period of this report, the IT group has continued to improve the BIPM's information and communications systems, notably through increasing the robustness of its internet connection, protecting remote connections by means of virtual private networks, increasing the bandwidth of the BIPM's internal networks, and by installing a start-up system 'from cold' in case of hardware failure of a server.

Security has been reinforced by the installation of a new antivirus protection system on the BIPM's PCs, and installation of the latest version of the firewall.

The IT group has put in place an open-source software system to manage the PCs throughout the site. This allows tracking of the software and hardware on each PC, thanks to a software agent installed locally and a server that centralizes all the information collected.

The BIPM's IT group has also developed a number of intranet and internet applications including a complete recording system to monitor and manage information concerning exchanges between the BIPM and its partners.

Finally, the IT group has been involved in the purchase, installation, administration and maintenance of about 30 servers and 200 office- or laboratory-based PCs, as well as a dozen network printers.

10.5 Travel (conferences and visits): Publications and Information Technology Sections

J.R. Miles to:

- IOPP (Bristol, UK), 18 February 2009, for the annual *Metrologia* Partners' Meeting;
- International Congress of Metrology (Paris), 24 June 2009.

L. Le Mée to:

- METAS, Bern (Switzerland), 19-20 February 2009, to discuss development of a database for watt balance results.

11 MEETINGS AND LECTURES AT THE BIPM

11.1 Meetings

The following meetings were held at the BIPM:

- The BIPM Metrology Summer School took place from 30 June to 11 July 2008.
- The CCRI(II) Key Comparison Working Group met on 15 September 2008 and the CCRI(II) Uncertainties Working Group on 16 September 2008, followed by a CCRI(II) Comparison Uncertainties Workshop on 17 and 18 September 2008.
- The JCRB held its 21st meeting on 24-25 September 2008 and its 22nd meeting on 16-17 March 2009.
- The CCAUV met on 9-10 October 2008; this was preceded by a meeting of its RMO CMC Working Group on 8 October.
- The Joint Committee for Guides in Metrology (JCGM) Working Group 1 (GUM) met on 12-14 November 2008 and on 7-10 April 2009.
- The ICAG Steering Committee met on 21 November 2008.
- The CCM Working Group on the Avogadro constant met on 26 November 2008, preceded by an IAC workshop on 24-25 November.
- A CCQM Pharmacopoeia Workshop on Measurement Traceability for Pharma and Bio-pharma Measurements was held on 4-5 December 2008.
- The JCGM met on 5 December 2008.
- The JCTLM Executive met on 11 December 2008, followed by a meeting of JCTLM Stakeholders and Members on 12 December.
- A meeting of the BIPM/ILAC/OIML Working Group was held on 4-5 March 2009.
- The JCDCMAS met on 6 March 2009.

- The CCEM met on 12-13 March 2009; this was preceded by meetings of its working groups from 9-11 March.
- A watt balance technical meeting (WBTM) was held on 18 March 2009.
- The CCQM met on 23-24 April 2009; this was preceded by meetings of its working groups from 17-22 April.
- A meeting of the CODATA TGFC was held on 25 May 2009.
- The CCU met on 26-28 May 2009.
- The CCRI met on 19 June 2009; this was preceded by meetings of the CCRI(I) on 13-15 May, the CCRI(II) on 17-19 June and the CCRI(III) on 1-3 April, and by meetings of various working groups: the TIWG(II) on 26 March 2009, KCWG(II) met on 7 May 2009, KCWG(I) and ADWG(I) on 11 May 2009, BSWG(I) workshop on 12 May, KCWG(II) and UCWG(II) on 15 June, and ESWG(II) and BqWG(II) on 16 June.

11.2 Presentations at the BIPM

On 17 November 2008, the BIPM hosted a celebration of the 25th anniversary of the definition of the metre, an event organized by the Committee *Science et Métrologie* of the Académie des Sciences de Paris. The meeting was chaired by the Presidents of the Committee, Prof. Jean Kovalevsky and Prof. Christian Bordé, and gathered some 60 scientists from LNE, LNE-SYRTE, LNE-INM/CNAM, CNRS, LKB and the BIPM.

Following four lectures presented by:

- Christian Bordé and Marc Himbert: '*Le mètre aujourd'hui : fondements historiques, scientifiques et technologiques*',
- Gérard Petit: '*GPS, VLBI, SLR : que mesure la géodésie spatiale ?*',
- Jean Kovalevsky: '*La mesure des distances en astronomie*', and
- Pierre Lemonde: '*Horloges optiques et peignes femto-secondes : vers une redéfinition de la seconde ?*',

a general discussion was held around the theme '*De la redéfinition du mètre à la redéfinition de la seconde : une stratégie scientifique à élaborer*'.

The following lecture was also given at the BIPM:

- L. Palafox (PTB): '*1 V and 10 V SNS Programmable Voltage Standards for 70 GHz*', 3 December 2008.

12 CERTIFICATES AND STUDY NOTES

In the period from 1 July 2008 to 30 June 2009, 66 Certificates and 7 Study Notes were issued.

For a list of certificates and Notes see pages 148-153.

13 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, human resources, legal and other services.

Over the last year it arranged more than 120 customs operations for the import and export of standards for calibrations and comparisons, it worked on arrangements for 14 recruitments, and launched a number of calls for tenders for the purchase of scientific equipment and services.

During the past year, the Finance, Administration and General Services Section finalized a number of actions after the *Regulations, Rules, and Instructions applicable to staff members* came into force on 2 May 2008, including the completion of administrative changes and arrangements as well as contractual arrangements for the provision of travel services.

After an external review of the BIPM Pension Scheme was carried out to compare it with those of other intergovernmental organizations, to review the recent evolutions of schemes in other international organizations in terms of both benefits and contributions, and to make recommendations with the aim of clarifying and completing the BIPM Pension Scheme, the Finance, Administration and General Services Section has worked on proposed amendments to the Regulations of the Pension Fund.

The Section has also worked on new Financial Regulations and started to prepare new accounting rules and policies with the aim of increasing the effectiveness and efficiency of the financial management, reinforcing accountability and transparency, and ensuring the most effective use of resources in the achievement of the priorities of the programme of work.

13.1 Accounts

Details of the accounts for 2008 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*”.

13.2 Staff

13.2.1 Appointments

- Mrs Frederique de Hargues, born 11 July 1960 in Bouscat (France), French nationality, previously personal assistant in a French private company, was engaged as *secrétaire* from 15 July 2008.
- Ms Aurélie Harmegnies, born 26 August 1984 in Libourne (France), French nationality, qualified from the École Nationale Supérieure d'Ingénieurs de Caen (France), previously intern in a French private company, was engaged as *assistant* in the Time, Frequency and Gravimetry Section from 3 November 2008.
- Mrs Laïla Dell'Oro, born 12 September 1978 in Nantua (France), French nationality, previously assistant in a French private company, was engaged as *secrétaire* in the Finance and Administration Section from 19 November 2008.
- Mr Faraz Idrees, born 5 August 1987 in Rawalpindi (Pakistan), French nationality, qualified from the Institut Universitaire de Technologie d'Orsay (France), was engaged as *technicien* working half time in the Mass and half time in the Chemistry Sections from 23 February 2009.
- Ms Tiphaine Choteau, born 17 September 1987 in Lille (France), French nationality, previously technician in a French private company, was engaged as *technicien* in the Chemistry Section from 1 April 2009.
- Prof. Michael Kühne, born 26 March 1949 in Celle (Germany), German nationality, previously member of the Presidential Board of the PTB, Braunschweig (Germany), was appointed *sous-directeur – directeur désigné* of the BIPM from 1 April 2009 according to the decision of the CIPM during its 96th session in November 2007.
- Ms Sigrid Arlen, born 16 January 1977 in Villeneuve-St-Georges (France), French nationality, previously Legal Officer at the International Labour Office in Geneva (Switzerland), was appointed *conseiller juridique - administrateur* in the Finance and Administration Section from 27 April 2009.

13.2.2 Promotions and change of grade

- Mrs Brigitte Perent, *administrateur*, head of the Finance and Administration Section, was promoted *administrateur principal* from 1 January 2009.
- Mr Alain Picard, *physicien principal* in the Mass Section, was promoted *physicien chercheur principal* from 1 January 2009 and Deputy Head of the Mass Section from 1 April 2009.
- Dr Guy Ratel, *physicien principal* in the Ionizing Radiation Section, was promoted *physicien chercheur principal* from 1 January 2009.
- Mr Rémi Cèbe, *assistant* in the Finance and Administration Section, was promoted *conseiller juridique - administrateur* from 1 January 2009.
- Mr Laurent Le Mée, *ingénieur informaticien* in the Publications and Information Technology Section, was promoted *informaticien principal* from 1 January 2009.
- Mr Carlos Dias Nunes, *jardinier* was promoted *jardinier principal* from 1 January 2009.
- Mrs Maria J. Fernandes, *agent d'entretien* was promoted *agent d'entretien principal* from 1 January 2009.
- Dr Janet Miles, previously *webmaster* and *Assistant Editor* of the BIPM's publications, was appointed *responsable des publications* from 1 March 2009.

13.2.3 Changes of title

The following changes of title as of 1 January 2009 resulted from changes in the list of posts of the ranking table included in the *Regulations, Rules and Instructions applicable to staff members* which came into force on 2 May 2008:

- Mr Enrique Dominguez, previously *gardien*, now *agent de sécurité principal* from 1 January 2009.
- Mr Cesar Neves Dos Santos, previously *gardien*, now *agent de sécurité principal* from 1 January 2009.
- Mrs Angela Dominguez, previously *gardien*, now *agent de sécurité* from 1 January 2009.
- Mrs Isabel Neves Dos Santos, previously *gardien*, now *agent de sécurité* from 1 January 2009.

13.2.4 Changes of post and transfer

- Mrs Angela Dominguez, previously *agent de sécurité*, now *agent principal d'entretien* from 4 May 2009.
- Mrs Isabel Neves Dos Santos, previously *agent de sécurité*, now *hôtesse d'accueil* from 4 May 2009.

13.2.5 Research fellow

- Dr Michael Petersen, born 6 July 1977 in Copenhagen (Denmark), French nationality, previously Ph.D. student at the LNE-SYRTE in Paris (France), was appointed as Research Fellow in the Chemistry Section from 2 March 2009.

13.2.6 Death

- Dr Rainer Köhler, *physicien principal*, Quality and Health and Safety Manager and in charge of the liaison with ISO and ILAC since 1 November 1987, died on 25 October 2008.

13.2.7 Departures

- Mrs Danielle Saillard, *secrétaire principale* in the Finance and Administration Section, left the BIPM on 31 August 2008 after 15 years of service.
- Mrs Juliette Varenne, *secrétaire*, left the BIPM on 31 August 2008 after 6 years of service.
- Dr Jeffrey H. Williams, head of the BIPM Publications and Information Technology Section since 1 December 2003, left the BIPM on 20 November 2008.
- Mr Rémi Cèbe, *conseiller juridique – administrateur* since 21 June 2006 in the Finance and Administration Section, left the BIPM on 22 March 2009.

13.3 Buildings

13.3.1 Grand Pavillon

- Refurbishment of an office on the ground floor.
- Painting of the staircase between the ground floor and the basement.

- Painting of the kitchen and laundry room of the Director's apartment.
- Partial replacement of heating tubes of the boiler.

13.3.2 Petit Pavillon

- Partial renovation of the interior decoration.
- Maintenance of the roof.
- Reprogramming of the fire detection system.

13.3.3 Observatoire

- Refurbishment of rooms 4, 13 and 116.
- Partial replacement of air-conditioning equipment in rooms 1, 2, 3, 9 and 10.
- Maintenance of the roof.
- Refurbishment of room 2 including removal of the manobarometer.

13.3.4 Ionizing Radiation building

- Refurbishment of rooms R8 and R17 on the first floor.
- Refurbishment of the sanitary facilities on the ground and first floor.
- Installation of four open-space offices in the hall on the first floor.

13.3.5 Lasers

- Replacement of the door of the infirmary.
- Refurbishment of a room in the basement to install equipment for the Chemistry Section.

13.3.6 Nouveau Pavillon

- Replacement of light fittings in six offices on the ground floor.

13.3.7 Outbuildings and park

- Partial replacement of the fence.

13.4 Travel: Finance, Administration and General Services Section

- B. Perent and R. Cèbe attended the 6th Workshop on Pensions in International Organizations, organized by the Pensions Section of the Coordinated Organizations and the UN Joint Staff Pension Fund, hosted by the Organisation for Economic Co-operation and Development (OECD), 6-7 October 2008.
- B. Perent and S. Arlen attended a meeting at the International Labour Office in Geneva (Switzerland), 5 May 2009.
- B. Perent and S. Arlen attended a seminar on Supranational Administration organized by the International Academy of Administration Sciences in Geneva (Switzerland), 14-15 May 2009.
- B. Perent attended a seminar on Work Incapacity in Brussels (Belgium), 11-12 June 2009.

14 SECRETARIAT (F. JULY)

There continues to be a heavy workload on the Secretariat, with a large number of meetings held at the BIPM, and with fewer staff in the Section since the beginning of 2008. In collaboration with the Administration Section, the Secretariat ensures the smooth running of the numerous meetings held at the BIPM and the mailings of the associated BIPM publications. The meetings at the BIPM are essentially those of the Consultative Committees and their Working Groups. Some of these meetings, particularly those of the CCQM, are large and involve parallel sessions across the BIPM site, and even some sessions in locations off-site.

Amongst its other responsibilities, the BIPM Secretariat maintains records of the BIPM's wide range of international contacts. This database is revised and integrated with the other BIPM databases.

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

15 WORKSHOP AND SITE MAINTENANCE (J. SANJAIME)

The BIPM Workshop carries out high-precision mechanical work for the scientific Sections of the BIPM and has a well-deserved reputation for excellence in precision engineering. The main tasks of the Workshop this year have been linked to the development of the BIPM's watt balance and the fabrication of various components required by the Electricity Section to pursue the construction of a calculable capacitor in collaboration with the NMIA (Australia).

In addition, the BIPM Workshop is the unique source of Pt-Ir prototypes of the kilogram, which are made exclusively for the Member States of the BIPM. Fabrication of these prototypes makes use of the specialized equipment and unique experience of the Workshop staff.

The Workshop also provides assistance to visiting scientists as needed, when standards are brought to the BIPM for calibration or to take part in a comparison. Finally, the Workshop staff are involved with a large number of matters related to site and laboratory maintenance.

LIST OF ACRONYMS AND INITIALISMS USED IN THE PRESENT VOLUME

ADWG(I)	CCRI(I) Accelerator Dosimetry Working Group
AFRIMETS	Inter-Africa Metrology System
AIC	ILAC Accreditation Issues Committee
AIUB	Astronomisches Institut, Universität Bern, Bern (Switzerland)
ALC	Automatic Loadable Container
APMP	Asia/Pacific Metrology Programme
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency, Sydney and Melbourne (Australia)
A*STAR	Agency for Science, Technology and Research (Singapore)
BARC	Bhabha Atomic Research Centre, Trombay (India)
BEV	Bundesamt für Eich- und Vermessungswesen, Vienna (Austria)
BIPM	International Bureau of Weights and Measures/ <i>Bureau International des Poids et Mesures</i>
BMC*	Best Measurement Capability (see CMC)
BNC	Bayonet Neill-Concelman (connector)
BqWG(II)	CCRI(II) Working Group on the realization of the becquerel
BSWG(I)	CCRI(I) Brachytherapy Standards Working Group
CAD	Charged Aerosol Detection
CC	Consultative Committee of the CIPM
CCAUV	Consultative Committee for Acoustics, Ultrasound and Vibration/ <i>Comité Consultatif de l'Acoustique, des Ultrasons et des Vibrations</i>
CCEM	Consultative Committee for Electricity and Magnetism/ <i>Comité Consultatif d'Électricité et Magnétisme</i>
CCL	Consultative Committee for Length/ <i>Comité Consultatif des Longueurs</i>
CCM	Consultative Committee for Mass and Related Quantities/ <i>Comité Consultatif pour la Masse et les Grandeurs Apparentées</i>
CCM-WGM	CCM Working Group on Mass Standards

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

CCM-WGSI-kg	CCM Working Group on Changes to the SI kilogram
CCMAS	Codex Committee on Methods of Analysis and Sampling
CCPR	Consultative Committee for Photometry and Radiometry/ <i>Comité Consultatif de Photométrie et Radiométrie</i>
CCQM	Consultative Committee for Amount of Substance: Metrology in Chemistry/ <i>Comité Consultatif pour la Quantité de Matière : Métrologie en Chimie</i>
CCRI	Consultative Committee for Ionizing Radiation/ <i>Comité Consultatif des Rayonnements Ionisants</i>
CCRI(I)	CCRI Section I: x- and gamma rays, charged particles
CCRI(II)	CCRI Section II: Measurement of radionuclides
CCRI(III)	CCRI Section III: Neutron measurements
CCT	Consultative Committee for Thermometry/ <i>Comité Consultatif de Thermométrie</i>
CCTF	Consultative Committee for Time and Frequency/ <i>Comité Consultatif du Temps et des Fréquences</i>
CCU	Consultative Committee for Units/ <i>Comité Consultatif des Unités</i>
CEM	Centro Español de Metrología, Madrid (Spain)
CENAM	Centro Nacional de Metrología, Querétaro (Mexico)
CGGTTS	CCTF Group on GNSS Time-Transfer Standards
CGPM	General Conference on Weights and Measures/ <i>Conférence Générale des Poids et Mesures</i>
CGSIC	Civil Global Positioning System Service Interface Committee
CIMMEC	International Congress on Mechanical Metrology
CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, Madrid (Spain)
CIPM	International Committee for Weights and Measures/ <i>Comité International des Poids et Mesures</i>
CMC	Calibration and Measurement Capability
CMI	Czech Metrological Institute/ <i>Český Metrologický Institut</i> , Prague (Czech Rep.)
CNAM	Conservatoire National des Arts et Métiers, Paris (France)
CNES	Centre National d'Études Spatiales, Toulouse (France)
CNRS	Centre National de la Recherche Scientifique, Paris (France)
CODATA	Committee on Data for Science and Technology
	Codex Alimentarius: Commission under the Joint FAO/WHO Food Standards Programme

CONICET	Argentine Council of Research
COOMET	Cooperation in Metrology among the Central European Countries
CPEM	Conference on Precision Electromagnetic Measurements
CRDS	Cavity Ring-Down Spectroscopy/Spectrometer
CRRD	CNEA Regional Reference Centre for Dosimetry (Argentina)
DFM	Danish Fundamental Metrology, Lyngby (Denmark)
DIGENOR	Dirección General de Normas y Sistemas de Calidad, Santo Domingo (Dominican Republic)
DIN	German Institute for Standardization/ <i>Deutsches Institut für Normung</i> , Berlin (Germany)
EAL	Free Atomic Time Scale/ <i>Échelle Atomique Libre</i>
EDQM	European Directorate for the Quality of Medicines and HealthCare
EFTF	European Frequency and Time Forum
ESA	European Space Agency
EURAMET	(the former EUROMET) European Association of National Metrology Institutes
FAO	Food and Agriculture Organization of the United Nations
FCS	Frequency Control Symposium
FIG	International Federation of Surveyors/ <i>Fédération Internationale des Géomètres</i>
FMI	Finnish Meteorological Institute, Helsinki (Finland)
FTIR	Fourier Transform Infrared (FTIR spectroscopy)
FYROM	The Former Yugoslav Republic of Macedonia
GAWG	CCQM Working Group on Gas Analysis
GC-FID	Gas Chromatography/Flame Ionization Detector
GC-MS	Gas Chromatography/Mass Spectrometry
GCC	Gulf Cooperation Council
GGOS	Global Geodetic Observing System
GLONASS	Global Navigation Satellite System
GNSS	Global Navigation Satellite System(s)
GPS	Global Positioning System
GSO	Gulf Standardization Organization
GUM	Central Office of Measures/ <i>Glówny Urząd Miar</i> , Warsaw (Poland)
GUM	Guide to the Expression of Uncertainty in Measurement
HPLC	High-Performance Liquid Chromatography

HPLC-UV	High-Performance Liquid Chromatography with UV Detector
HSC	Health and Safety Commission
IAC	International Avogadro Coordination
IAEA	International Atomic Energy Agency
IAG	International Association of Geodesy
IAU	International Astronomical Union
ICAG	International Comparison of Absolute Gravimeters
ICARO	International Conference on Advances in Radiation Oncology
ICG	International Committee for GNSS
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 (USA)
IERS	International Earth Rotation and Reference Systems Service
IFCC	International Federation of Clinical Chemistry and Laboratory Medicine
IFIN-HH	“Horia Halubei” National Institute of Research and Development for Physics and Nuclear Engineering, Bucharest (Romania)
IGN	Instituto Geográfico Nacional, Madrid (Spain)
IGS	International GNSS Service
ILAC	International Laboratory Accreditation Cooperation
ILO	International Labour Organization
IMEKO	International Measurement Confederation
INER	Institute of Nuclear Energy Research, Taipei (Chinese Taipei)
ININ	Instituto Nacional de Investigaciones Nucleares, Mexico (Mexico)
INM	National Institute of Metrology, Bucharest (Romania)
INMETRO	Instituto Nacional de Metrologia, Normalização e Qualidade Industrial, Rio de Janeiro (Brazil)
INRiM	Istituto Nazionale di Ricerca Metrologica, Turin (Italy)
IOPP	Institute of Physics Publishing, Bristol (UK)
IPQ	Instituto Português de Qualidade, Caparica (Portugal)

IRMM	Institute for Reference Materials and Measurements, European Commission, Geel (Belgium)
ISCH	Institute of Health Carlos III, Madrid (Spain)
ISO	International Organization for Standardization
ISO REMCO	ISO Committee on Reference Materials
IT	Information Technology
ITN	Instituto Tecnológico e Nuclear, Savacém (Portugal)
ITU	International Telecommunication Union
ITU-R	ITU Radiocommunication Sector
IUGG	International Union of Geodesy and Geophysics
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
JRC	Joint Research Centre
KCDB	BIPM Key Comparison Database
KCRV	Key Comparison Reference Value
KCWG	Key Comparisons Working Group
KRISS	Korea Research Institute of Standards and Science, Daejeon (Rep. of Korea)
KTP	Potassium titanyl phosphate
LAPP	Laboratoire d'Annecy-le-Vieux de Physique des Particules, Annecy-le-Vieux (France)
LATU	Laboratorio Tecnológico del Uruguay, Montevideo (Uruguay)
LC-MS	Liquid Chromatography-Mass Spectrometry
LC-UV/MS	Liquid Chromatography coupled to Ultraviolet Detection and Mass Spectrometry
LGC	LGC (formerly Laboratory of the Government Chemist), Teddington (UK)
LKB	Laboratoire Kastler Brossel, Paris (France)
LNE	Laboratoire National de Métrologie et d'Essais, Paris (France)
LNE-INM	LNE Institut National de Métrologie, Paris (France)

LNE-LNHB	LNE Laboratoire National Henri Becquerel, Gif-sur-Yvette (France)
LNE-CETIAT	LNE Centre Technique des Industries Aéronautiques et Thermique, Villeurbanne (France)
LNE-SYRTE	LNE Systèmes de Référence Temps Espace, Paris (France)
LNMRI	Laboratório Nacional de Metrologia das Radiações Ionizantes, Rio de Janeiro (Brazil)
LNMRI-IRD	LNMRI Instituto de Radioproteção e Dosimetria, Rio de Janeiro (Brazil)
LS	Liquid Scintillation
METAS	Federal Office of Metrology, Bern-Wabern (Switzerland)
METCHEM	EURAMET Technical Committee on Chemistry
MIKES	Centre for Metrology and Accreditation/ <i>Mittatekniikan Keskus</i> , Helsinki (Finland)
MKEH	Hungarian Trade Licensing Office, Budapest (Hungary)
MoU	Memorandum of Understanding
MRA	Mutual Recognition Arrangement
MS	Mass Spectrometry
MSL	Measurement Standards Laboratory of New Zealand, Lower Hutt (New Zealand)
NCSLI	NCSL International, Boulder, Co. (USA)
NEWMET	North-East and West Africa Metrology Programme (region of AFRIMETS)
NICT	National Institute of Information and Communications Technology, Tokyo (Japan)
NIM	National Institute of Metrology, Beijing (China)
NIS	National Institute for Standards, Cairo (Egypt)
NIST	National Institute of Standards and Technology, Gaithersburg, Md. (USA)
NMC, A*STAR	National Metrology Centre, Agency for Science Technology and Research (Singapore)
NMi-VSL*	Nederlands Meetinstituut, Van Swinden Laboratorium (see VSL)
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 and Cape Town (South Africa)
NML	National Metrology Laboratory, Dublin (Ireland)
NML-SIRIM	National Metrology Laboratory, SIRIM Berhad (Malaysia)
NMR	Nuclear Magnetic Resonance
NMS	National Measurement System (UK)
NPL	National Physical Laboratory, Teddington (UK)
NPSL	National Physical and Standards Laboratory, Islamabad (Pakistan)
NRC	National Research Council of Canada, Ottawa (Canada)
NRC-INMS	NRC Institute for National Measurement Standards, Ottawa (Canada)
OAWG	CCQM Working Group on Organic Analysis
OIML	International Organization of Legal Metrology/ <i>Organisation Internationale de Métrologie Légale</i>
OMP	Observatoire Midi-Pyrénées, Toulouse (France)
ONERA	Office National d'Études et Recherches Aérospatiales, Palaiseau (France)
OP	Paris Observatory/ <i>Observatoire de Paris</i> , Paris (France)
ORB	Observatoire Royal de Belgique, Brussels (Belgium)
PFS	Primary Frequency Standard
PPP	Precise Point Positioning
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig and Berlin (Germany)
PTTI	Precise Time & Time Interval Applications and Planning Meeting
QHE	Quantum Hall Effect
QHR	Quantum Hall Resistance
QS	Quality System
REUNIAM	Redefinition of the SI base unit ampere (iMERA project)
RMO	Regional Metrology Organization
RMOWG	CCRI Working Group on IR CMCs
RWTH/WZL	Machine Tools Department, Technical University of Aachen/ <i>Werkzeugmaschinenlabor, Rheinisch-Westfälische Technische Hochschule</i> , Aachen (Germany)
SADCMET	Southern African Development Community Cooperation in Measurement Traceability (region of AFRIMETS)
SASO	Saudi Arabian Standards Organization, Riyadh (Saudi Arabia)

SI	International System of Units/ <i>Système International d'Unités</i>
SIM	Inter-American Metrology System/ <i>Sistema Interamericano de Metrología</i>
SIR	International Reference System for gamma-ray emitting radionuclides/ <i>Système International de Référence pour les mesures d'activité d'émetteurs de rayonnement gamma</i>
SMU	Slovak Institute of Metrology/ <i>Slovenský Metrologický Ústav, Bratislava (Slovakia)</i>
SNS	Superconductor-normal metal-superconductor
SP	Technical Research Institute of Sweden, Borås (Sweden)
SRC	Space Research Centre, Warsaw (Poland)
SRP	Standard Reference Photometer
SSDL	Secondary Standards Dosimetry Laboratories
SUNAMCO	IUPAP-C.2 Commission on Symbols, Units, Nomenclature, Atomic Masses and Fundamental Constants
TC	Technical Committee
TAI	International Atomic Time/ <i>Temps Atomique International</i>
TAIPPP	International Atomic Time Precise Point Positioning
TDCR	Triple-to-Double Coincidence Ratio Technique
TFG	Time, Frequency and Gravimetry
TG	Task Group
TG-SI	CCT Task Group on the SI
TI	Transfer Instrument
TIWG(II)	CCRI(II) Transfer Instrument Working Group
TT	Terrestrial Time
T2L2	Time Transfer by Laser Link
TW	Two-Way
TWSTFT	Two-Way Satellite Time and Frequency Transfer
UBA	Federal Environmental Agency/ <i>Umweltbundesamt, Dessau-Roßlau (Germany)</i>
UCWG(II)	CCRI(II) Uncertainties Working Group
UFFC	IEEE Ultrasonics, Ferroelectrics, and Frequency Control Society, see IEEE
UK	United Kingdom of Great Britain and Northern Ireland
UNIDO	United Nations Industrial Development Organization
U.S.	United States of America
USA	United States of America
USB	Universal Serial Bus

USNO	U.S. Naval Observatory, Washington DC (USA)
USP	U.S. Pharmacopeia, Rockville Md. (USA)
UTC	Coordinated Universal Time
UV	Ultraviolet
VAMAS	Versailles Project on Advanced Materials and Standards
VIM	International Vocabulary of Metrology, Basic and General Concepts and Associated Terms (3rd edition)
VLBI	Very Long Baseline Interferometry
VNIIM	D.I. Mendeleev Institute for Metrology, Rostekhnregulirovaniye of Russia, St Petersburg (Russian Fed.)
VNIFTRI	Institute for Physical-Technical and Radiotechnical Measurements, Rostekhnregulirovaniye of Russia (Russian Fed.)
VOC	Volatile Organic Compound
VSL	VSL (formerly NMI-VSL), Delft (Netherlands)
VTSS	Vacuum Transfer System
WADA	World Anti-Doping Agency
WBTM	Watt Balance Technical Meeting
WG	Working Group
WGDM	CCL Working Group on Dimensional Metrology
WGFF	CCM Working Group on Fluid Flow
WGG	CCM Working Group on Gravimetry
WGSP	Working Group on Strategic Planning
WHO	World Health Organization
WMD	World Metrology Day
WMO	World Meteorological Organization
XPS	X-ray Photoelectron Spectroscopy