

Bureau international des poids et mesures

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

(1 July 2009 – 30 June 2010)

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 2010

Member States

Argentina	Kenya
Australia	Korea (Democratic 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	
Kazakhstan	

Associates of the General Conference

Albania	Cuba
Bangladesh	Ecuador
Belarus	Estonia
Bolivia (Plurinational State of)	Georgia
CARICOM	Ghana
Chinese Taipei	Hong Kong, China
Costa Rica	Jamaica

.../...

Associates of the General Conference (cont.)

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

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 (Rules of procedure for the Consultative Committees (CCs) created by the CIPM, CC working groups and CC workshops, 2009, CIPM-D-01). 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. At present, there are ten such committees:

1. The Consultative Committee for Electricity and Magnetism (CCEM), new name given in 1997 to the Consultative Committee for Electricity (CCE) set up in 1927.
2. The Consultative Committee for Photometry and Radiometry (CCPR), new name given in 1971 to the Consultative Committee for Photometry (CCP) set up in 1933 (between 1930 and 1933 the CCE dealt with matters concerning photometry).
3. The Consultative Committee for Thermometry (CCT), set up in 1937.

4. The Consultative Committee for Length (CCL), new name given in 1997 to the Consultative Committee for the Definition of the Metre (CCDM), set up in 1952.
5. The Consultative Committee for Time and Frequency (CCTF), new name given in 1997 to the Consultative Committee for the Definition of the Second (CCDS) set up in 1956.
6. The Consultative Committee for Ionizing Radiation (CCRI), new name given in 1997 to the Consultative Committee for Standards of Ionizing Radiation (CCEMRI) set up in 1958 (in 1969 this committee established four sections: Section I (X- and 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 2010

Director: Prof. A.J. Wallard

Deputy Director/Director Designate: Prof. M. Kühne

Mass: Dr R.S. Davis

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² Also Chemistry

³ Also General Services

Director's Report
on the Activity and Management
of the International Bureau
of Weights and Measures
(1 July 2009 – 30 June 2010)

1 INTRODUCTION

1.1 General introduction and overview of the year

This report covers the first year of the 2009-2012 programme of work approved by the 23rd meeting of the General Conference on Weights and Measures (CGPM, 2007). As a result of the schedules associated with meetings of the CGPM, it is also a year in which the BIPM is involved in the planning, and the preparation of the documents for, the 24th meeting of the CGPM which will take place in 2011. The scientific and international liaison work will be detailed later in the report and my main aim in this introduction is to give the reader an overview of the year and to highlight a number of achievements and issues which are important for international metrology. In the programme of work presented to the 23rd meeting of the CGPM, the scientific and other activities as well as their deliverables were set out in some detail, with justifications as to why the BIPM was best placed to undertake the work. The programme of work to start in 2013 is being prepared using the same approach, as we are highly conscious that metrology budgets world-wide are under pressure and that the BIPM must respond to the highest priority needs as set out by its main customers and stakeholders: the National Metrology Institutes (NMIs) in Member States. Delegations to the 24th meeting of the CGPM will, no doubt, debate the detail and the cost of the 2013-2016 programme, but the essential first step is to ensure that the BIPM's proposals have been thoroughly discussed and prioritized in the meetings of the CIPM's Consultative Committees. This has been done and we point out that the consultation is now even more extensive as the number of intergovernmental organizations and international bodies with which we operate has increased dramatically. This is perhaps the greatest and most powerful evidence we can offer to Governments as proof of the relevance of our work and the collaborations we have established to extend best practice metrology and the International System of Units (SI) into new areas of application. All of this costs money and demands resources. Both quantities are scarce but I am convinced that the efficiency of the BIPM and its ability to deliver its commitments are key factors in the BIPM's success and will, I hope, have a strong influence on the discussions in October 2011.

One point made at the meeting of the CGPM in 2007 was that the BIPM should have more regular contact with Governments in between meetings of

the General Conference. Although there are several formal reports to Governments, it was apparent that there was a need for a means of conveying key messages quickly and clearly. At the start of 2010, therefore, the second “short report” was issued to alert the metrology community and Government Officials to the major developments and issues of interest. I hope you find these reports, as well as the KCDB Newsletter, useful to keep you informed and provide information in addition to the formal reports and information exchanges we arrange through meetings of NMI Directors and with experts in Consultative Committees. As many of you will know, we plan to issue an invitation to Member States to attend a pre-meeting, probably in May 2011, in advance of the meeting of the CGPM in October 2011. This meeting will be held after the distribution of the documents for the General Conference and thus will provide an opportunity, in advance of the meeting of the CGPM, to hold informal discussions on the proposed programme of work for the BIPM.

One of my personal aims has been to promote the work of the BIPM widely and to encourage new Members and Associates. I am therefore very pleased to report that the Republic of Kenya, previously an Associate, became a Member State on 1 January 2010, the Republic of Ghana became an Associate on 17 September 2009, and the People’s Republic of Bangladesh became an Associate on 29 March 2010. Negotiations with a number of other States are well in hand and I am confident that there will be several more new Members and Associates before the meeting of the General Conference in 2011.

This will be my last Director’s report to the Member States as I retire at the end of December 2010. It has been a privilege to serve the world of international metrology and I am grateful for the support and friendship I have found. My task has been made easier by the response of the staff of the BIPM to a changing world; although we have had to take tough decisions on priorities in the face of financial considerations, this ensures that the BIPM’s scientific programme is sound, and firmly anchored on the needs of the NMIs and our other stakeholders. I have been particularly pleased to see an increase in the number of staff coming to work at the BIPM on secondment or short-term detachments. Their infusion of new ideas and skills complements the essential continuity provided by the permanent staff and also provides a way of enhancing the links between the BIPM and the secondees’ host laboratories. Looking back, I am keenly aware also of a significant number of changes within the BIPM itself, including updates and changes to our internal rules and practices.

There is no doubt that the international liaison work of the BIPM has increased dramatically in recent years, in the scientific departments as well as at corporate level. We have established more and more strategic partnerships and collaborations with specialist bodies and with intergovernmental organizations and international bodies. This, I believe, is an important step towards our goal of achieving world-wide uniformity of measurement, as we can bring our understanding of traceability and uncertainty to partner bodies and thus encourage the adoption of best measurement practice – and the SI – in new areas of application.

The BIPM is, I believe, well equipped for the future, both scientifically and organizationally and I wish my successor, Prof. Michael Kühne, well in meeting his challenges.

1.2 BIPM's programme of scientific and international liaison work

The main activities of the BIPM are, essentially, the following:

- Provision and improvement of unique international reference facilities which are used by NMIs in Member States so as to provide comparisons, calibrations and associated studies in a cost-effective way;
- Liaison with other bodies with similar or complementary missions and interests so as to advance the state of world metrology;
- Maintenance and updating of the primary standards which realize the SI units, so as to meet metrological requirements;
- Vigorous promotion of metrology; and
- Maintenance of the operation of the CIPM MRA to meet national and international needs for world-wide uniformity of measurement and to help reduce technical barriers to trade.

All of these activities have been the subject of great activity and development in the last year.

As will be reported in more detail later in this report, significant progress has been made with our flagship project, the watt balance, and the facilities associated with maintenance and dissemination of the unit of mass after a redefinition of the kilogram at some point in the future. The watt balance team has been strengthened by scientists drawn from across the BIPM as well as through recruitment of both permanent and short-term staff. The watt

balance is working well in its initial phases and is showing great reproducibility. Better performance will be achieved when the apparatus moves to its final purpose-built destination.

The Mass Department has been preparing for the transition from its present Director (R. Davis) to its Deputy Director (A. Picard) upon the retirement of Dr Davis on 1 November 2010. In addition, the laboratory for calibrations of 1 kg standards is being completely renovated to accommodate a new vacuum mass comparator. This will complement our existing vacuum comparator and, at the same time, replace a comparator that is now obsolete. This upgrading of laboratory space and equipment is motivated in large part by the need to continue to provide traceability to the kilogram after its future redefinition. A second major upgrade, now well under way, is the creation of a pool of 1 kg artefacts. The mass obtained by weighted average of the masses of the elements of the pool will be more robust and more stable than the mass of the present international prototype, and could be tightly linked to the most accurate realizations of the new kilogram definition.

Our Time, Frequency and Gravimetry Department continues to produce the monthly *Circular T* within a few days of receiving all the data from the contributing laboratories. Some 13 primary frequency standards now contribute to TAI and its stability is estimated to be 4 parts in 10^{16} for averaging times of one month. The GPS Precise Positioning Technique is now in use for 15 of the TAI time links. In addition to the traditional time activities, the Department's staff continue to oversee the key comparison of laser frequencies, now carried out by RMO laboratories, and the key comparison of absolute gravimeters. The latest International Comparison of Absolute Gravimeters (ICAG-2009), completed in October 2009, also included a pilot study for non-CIPM MRA participants.

In the Electricity Department, the initial commissioning, in collaboration with the NMIA (Australia), of the calculable capacitor has represented a most exciting advance this year. Achieving the stringent specifications for the mechanical structure and the electrical and optical systems has proven to be extraordinarily challenging but the receipt of the definitive electrode bars from the NMIA has enabled the final assembly to take place. The Department has also been active in the provision of on-site voltage comparisons as part of an increased programme for the NMIs.

The Ionizing Radiation Department has conducted the first two accelerator dosimetry comparisons on site using the BIPM's travelling graphite calorimeter. The new primary standard for mammography dosimetry is fully

operational and the first two comparisons have been completed. Guest scientists from four NMIs have helped launch the first three brachytherapy comparisons, and the Department remains on target with its schedule of NMI comparisons and characterizations of standards.

Seventeen BIPM ongoing radionuclide activity comparisons using the unique International Reference System (SIR) took place this year, including for the first time measurements of the radionuclide ^{64}Cu . Following a successful first comparison of the short-lived $^{99\text{m}}\text{Tc}$ radionuclide using the SIR Transfer Instrument (TI), further comparisons are being prepared. Major effort has been invested in developing the triple-to-double coincidence ratio technique (TDCR) for activity measurement to extend the SIR to pure beta emitters.

In Chemistry, the gas metrology activities continue to develop international equivalence of gas standards for air quality and climate change, in particular comparisons of ozone reference standards, nitrogen monoxide (aimed at providing the World Meteorological Organization (WMO) Global Atmosphere Watch (GAW) network with a Central Calibration Laboratory), nitrogen dioxide, and methane. The organic analysis team is, through carefully prepared pure materials intended for use as primary calibrators and a study of comparison results, able to identify previously unknown, or un-assessed, influences from structurally related or other impurities or from method-dependent analyses. The trend is towards molecules of greater molecular weights, particularly those relevant to health care, and to the extension of SI-traceable measurements including a project on insulin carried out with the collaboration of the World Health Organization (WHO) and the National Institute of Biological Standards and Control (NIBSC, UK).

Throughout 2009 the BIPM has continued to strengthen its liaisons and links with a number of intergovernmental organizations and international bodies. Our work with the WMO continues to intensify and the two bodies held a joint symposium on the broad subject of Metrology and Climate Change, and how satellite-based, ground-based and other monitoring techniques can be improved by the adoption of best-practice metrology. Led by a series of expert speakers, parallel discussion sessions helped create a great deal of commitment by our colleagues in the meteorological community to take much greater advantage of the expertise to be found in NMIs.

For the BIPM, the workshop was a major step forward because although there have been many working-level contacts in a variety of different disciplines between the metrologists and parts of the observation networks –

the Global Atmospheric Watch (GAW) and Global Earth Observation System (GEOS) networks for example – the workshop provided the opportunity to complete a long negotiation when the WMO Director General, Michel Jarraud, signed the CIPM MRA on 1st April 2010. The general conclusions were that:

- measurement results from climate monitoring and Earth energy balance by remote sensing from satellite- as well as ground-based methods and observation should, where practical, be traceable to the SI so as to help provide continuous, homogenous and quality-assured data sets over the long term;
- the meteorological community should continue to specify its measurement needs and communicate these formally to the NMIs;
- the WMO, the BIPM, the NMIs and the academic communities should work together to meet stated requirements for measurement standards with accuracies that meet the needs of climate scientists and modellers and, where relevant, legislators and regulators; and
- calibrations of instruments used by the meteorological community should be made at all stages in space missions as well as for Earth-based projects and the NMI community should be involved in planning and execution.

The WMO and the BIPM have established a common strategy to identify the need for accurate measurements and to ensure that the recommendations of the workshop are fully followed up, implemented and monitored. The result is a commitment to collaborate in order to tackle the measurement issues in one of the most important challenges facing the world at the moment. A report is being finalized and will be circulated very widely, including to governments, intergovernmental organizations, NMI Directors, the International Panel on Climate Change, and the United Nations Framework Convention on Climate Change (UNFCCC).

Under the BIPM's Memorandum of Understanding with UNIDO, we continue to collaborate on promotion of "MAS" (metrology, accreditation and standardization); one outcome of this is a UNIDO-supported programme to enhance activity within the newly formed AFRIMETS Regional Metrology Organization. Joint planning for an AFRIMETS Summer School in February 2011 is well advanced.

With the International Organization for Standardization (ISO) the BIPM is increasing its representation at meetings of committees concerned with

metrology, notably in nanoscience, and areas where traceability to the SI is an important component of written standards. The BIPM is also looking to strengthen links between these committees and the CIPM's Consultative Committees.

As a result of discussions between the Directors of the BIPM and the International Organization for Legal Metrology (OIML) a number of possibilities for closer liaison and integration were discussed between the CIML Presidential Council and the bureau of the CIPM in a bilateral meeting last March. The options included co-location at the BIPM site or merger of the two organizations. The options had earlier been discussed by the OIML Member States during their 2008 CIML meeting but did not meet with the overall support of the OIML membership. Further discussions have therefore been put on hold for the time being.

For a number of years, there has been growing activity and interest in the potential redefinition of four base units of the International System of Units (SI) as a result of advances in watt balances and the International Avogadro Collaboration, and a number of NMI-based measurements of the Boltzmann constant.

The relevant Consultative Committees continue to monitor and review the situation and there is now the basis of a firm commitment in favour of:

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

The CIPM will continue to consider whether the time is right for a redefinition and for proposals to be made to the CGPM. At present, based on discussions of the CIPM at their meeting in October 2009, it is unlikely that the CGPM will be asked in 2011 to take formal decisions on the numbers associated with the values of the fundamental constants to be used for new definitions of the base units, although by then a clear way forward should be visible. There seems to be no fundamental urgency in terms of the need for improved uncertainties for realizations of the base units, and no damage to the SI will be caused by waiting until the science is clear and agreement is

established on the practical realizations (*mises en pratique*). I also expect greater clarity on the role of the BIPM after any redefinition. The emerging consensus is that watt balances (and possibly realizations of the “silicon Avogadro”) will provide absolute realizations of the definition of the kilogram but they are not so suitable as routine ways of disseminating mass. Current thinking is that the BIPM would continue to provide NMIs of Member States with a mass calibration service based on traditional platinum-iridium prototypes as well as a new generation of metallurgically and metrologically improved artefacts, and that the BIPM should pilot a key comparison of watt balance realizations.

Promotion of metrology takes many forms. The BIPM's staff are regular speakers at specialist international and national fora and its scientific departments actively lead or take part in joint committees, commissions or initiatives to introduce the concepts of metrological traceability and uncertainty into new areas of activity. The latter is almost always a joint effort, with the BIPM bringing metrology knowledge and collaborating organizations either providing authority in the domain of application or creating the opportunities for joint work. Although noted by NMI Directors and Governments as being of a high priority for the BIPM, the BIPM's resources for this task, have always been limited and I was therefore reluctant to initiate new ventures which could not be adequately supported by the existing staff. Our resources, however, have recently been increased through the appointment of a permanent International Liaison Officer. Although this post was initially proposed in the programme of work approved by the CGPM at its 23rd meeting, in the prioritization exercise carried out with the CIPM in October 2008 and on which I reported last year, it was as yet unfilled.

World Metrology Day continues to be a major focus of promotional activity. Although the BIPM provides the annual theme and poster, the explosion of interest and use by NMIs world-wide, as well as by other metrology bodies and companies has amazed me. Three different language versions of the posters were produced and graphics files were provided for local adaptation into other languages as required. Numerous events were organized to draw attention to the practical applications of metrology.

The CIPM MRA has now been signed by the NMIs of 47 Member States and 27 Associates, as well as by three international organizations, bringing the total number of signatory and other designated institutes committed to

the CIPM MRA to 211. As is reported later, the numbers of CMCs and reports of comparisons in the KCDB continue to grow.

A major symposium to mark 10 years of the CIPM MRA was held in conjunction with the annual meeting of NMI Directors in October 2009. During a day and a half of discussion, attendees heard of the uses to which the CIPM MRA is put by a number of NMIs, intergovernmental and international organizations and by industrial companies. Case studies and other illustrations of success helped demonstrate that the CIPM MRA has improved confidence in measurements world-wide; this provides a sound basis for future approaches to regulators and legislators who rely on measurements to achieve their own missions.

After 10 years of operation, the text of the CIPM MRA is showing signs of its age. Some written standards referred to in the 1999 document have been superseded, and operational practice as approved by the CIPM and implemented through the RMOs no longer accords with the original text. A project to revise the document is therefore under way and was presented to the NMI Directors at their meeting in June 2010. Further negotiation and discussions are ongoing, with the intention of reaching agreement on an updated document by the time of the 2011 meeting of the CGPM.

1.3 Meeting of the CIPM

The CIPM held its usual meeting in October 2009 and was sorry to receive the resignation of Prof. Gao Jie who has been a member for some sixteen years.

Prof. Ernst Göbel will retire as President after the CIPM meeting in 2010, and Dr Barry Inglis was elected to succeed him.

The CIPM approved a number of policy documents, on traceability of measurements for CMCs, the Rules of Procedure for Consultative Committees and their working groups, and criteria for membership of the CCU, and approved a document developed by the JCRB on the procedure for approval of a new RMO. The approval of a new RMO is particularly important as the GULFMET network is being formalized and guidance was needed on the criteria the CIPM would use to make decisions on the acceptability of a new RMO in relation to the CIPM MRA.

The CIPM also dealt with a number of issues related to the management of the BIPM, notably amendments to its staff pension scheme. For a number of

years, the BIPM's management has been reviewing the financial basis of the current scheme in view of changing patterns of life expectancy and related actuarial issues. The CIPM approved a number of modifications to the existing scheme designed to improve its financial stability and security and also the details of a new scheme to be applied to staff recruited to the BIPM as of January 2010. The CIPM also reviewed and made a number of changes to the staff rules, salary structure and financial rules and accountancy practices.

1.4 Joint Committee for Guides in Metrology (JCGM)

The annual meeting of representatives of the eight member organizations of the Joint Committee for Guides in Metrology (JCGM) was held on 2 December 2009. Two main Resolutions were adopted; one concerning the nomination by member organizations of experts to the JCGM Working Groups, and the other on the wording of the JCGM Charter as concerns the production and publication of JCGM documents. Reports were also received on the work of the Working Group on the Expression of Uncertainty in Measurement (JCGM-WG1), the Working Group on International Vocabulary of Basic and General Terms in Metrology (JCGM-WG2) and the JCGM *ad hoc* group on measurement software.

The GUM (*Guide to the Expression of Uncertainty in Measurement*, also known as JCGM 100:2008) is now available free of charge in both English and French on the BIPM website. The JCGM-WG1 finalized its work on the *Introduction to the GUM and related documents*. This document which is extensively hyperlinked to the other JCGM documents is also known as JCGM 104:2009 and has been published on the BIPM's open website (see www.bipm.org/en/publications/guides/).

The 3rd edition of the VIM (International Vocabulary of Metrology – Basic and General Concepts and Associated Terms), the “VIM3”, has been available free of charge from the BIPM website since 2008 (see www.bipm.org/en/publications/guides/, JCGM 200:2008). The JCGM-WG2, however, has recognized that the versions of the VIM3 published by ISO/IEC and OIML were slightly different from the main JCGM/BIPM document, and that, in addition, the three texts contained a number of mistakes requiring formal corrections. During the year covered by this report, the JCGM-WG2 has drawn up the appropriate *Corrigenda*, to be attached to each of the three versions of the VIM3, in order to produce a

corrected and unique master file, which may be used for further extension of the vocabulary. The *Corrigendum* to be applied to the JCGM/BIPM document, in French and English, was published on the BIPM website in June 2010.

1.5 BIPM Workshops on “Physiological Quantities and SI Units” and on “Metrology at the Nanoscale”

In addition to a growing number of workshops organized by the various Consultative Committees and Joint Committees, the BIPM has recently initiated a number of specialist workshops. These relate to current “hot topics” and are designed to bring together cross-disciplinary groups to address the challenges and, where possible, set out a plan of action to deal with them.

The BIPM Workshop on Physiological Quantities and SI Units took place on 16-17 November 2009 and attracted some 70 people from about 22 countries around the world. Most of the attendees were from NMIs, and were active in Technical Committees or Working Groups of international organizations, institutions or unions such as ISO, IEC, CIE, ICRU, IUPAC and IUPAP. The workshop was dedicated to the subject of “Health and Safety for Humans”, with presentations by twelve metrology experts covering the six fields selected by the Scientific Steering Committee. For more details see §9.4.1 and the full report on the BIPM website at www.bipm.org/en/events/physiological_quantities/.

The BIPM Workshop on Metrology at the Nanoscale brought scientists from the NMIs and industry together with experts from the regulatory and standards development community. The two-day Workshop, held on 18-19 February 2010, was attended by more than 100 participants and approached the very broad topic of nanotechnology with thematic lectures and round-table discussions in eight topical areas. Again, the programme was very lively, and the presentations were uniformly excellent, allowing the attendees to address the focal question of the meeting: “What activities are required to establish an effective international infrastructure for metrology at the nanoscale”. For more details see §9.4.2 and the report on the BIPM website at www.bipm.org/en/events/nanoscale/.

1.6 The BIPM Quality System

The BIPM continues to offer a number of measurement services, both internally and externally, in conformity with its self-declared ISO/IEC 17025 Quality System. During the year 2009-2010, 78 Certificates and 6 Study Notes were issued.

The Audit Plan for 2009 included a number of internal and external audits of the BIPM's five scientific departments, during which no major non-conformities were found.

An internal Quality Group met three times during the period to review the results of the audits and to discuss non-conformities and other points about the BIPM's Quality System. The annual Management Team Review Meeting of the Quality System, held on 1 October 2009, noted a number of action points which have since been resolved.

Mr Bruno Coelho was appointed Quality, Health and Safety Manager in September 2009.

1.7 Health and Safety

The BIPM continues to take its obligations seriously in the domain of Health and Safety and, as mentioned above, a new post of "Quality, Health and Safety Manager" was created in 2009. An internal Health and Safety Committee (HSC) met three times during the year and has noted over 50 actions. A concerted effort has been made to improve the BIPM's Health and Safety documentation, including improved procedures for the treatment of chemical waste. The HSC is also updating the BIPM's Health and Safety Manual and is developing an internal guide to good practice with respect to environmental issues. A successful radiation protection audit took place in April 2010.

1.8 Staff Commissions

A number of the BIPM's staff commissions were merged in June 2008, as a consequence of the new Staff Regulations, Rules and Instructions (RRI). This has resulted in a more coherent situation for the Commission for Conditions of Employment (CCE), which can communicate freely with the staff on matters raised in its discussions with the Director and senior

administrative staff. The Commission's workload is a heavy one, especially during a period of change in relation to the staff pension scheme and related changes in the retirement provisions. Members of the Commission are elected by the staff of the BIPM, and have to balance their time between the important task of representing staff interests and dialogue with the Director, and their technical or other work.

Over the period of this report, the CCE has

- participated in three meetings with the Director;
- issued two memoranda on the amendments to the pensions fund;
- performed a survey among staff members to identify topics for further discussion;
- proposed modifications to the RRI or to amendments to the RRI suggested by the Director. Some of them have already been approved and others have been or are being implemented.

Other Commissions deal with various aspects of staff welfare and social and other activities so as to help offer a warm working environment which helps bring staff together and especially helps new staff settle into what is often not their native country.

I am extremely grateful to staff who undertake Commission activities.

1.9 Science at the BIPM

Mass: The goals of the Mass Department are to maintain or improve current calibration facilities, while at the same time preparing for the challenges posed by the prospect of a future redefinition of the kilogram. We also are heavily involved in technical work that is prerequisite for the redefinition.

Calibrations of 1 kg mass standards, either Pt/Ir prototypes or stainless steel standards, have been carried out for more than a dozen NMIs. Auxiliary determinations of: the volume, the location of the centre of gravity and the magnetic properties of these standards, are made as needed. Since February 2010, 1 kg mass comparisons have been carried out exclusively on our Metrotec balance, which is temporarily relocated in an adjacent laboratory. This was necessary in order to renovate the calibrations laboratory (room 104), as planned in the current 4-year programme of work. Our Metrotec balance was recommissioned in its new location prior to being used for calibrations. A second calibration balance, the HK1000MC, is now obsolete

and will be replaced by a Mettler-Toledo M-One. Delivery of the new balance is expected by the end of 2010. Both the Metrotec and the new M-One balance will be installed in adjacent cabins within the renovated room 104.

We also continue to be heavily involved in the International Avogadro Coordination (IAC) project, where the BIPM takes a lead role in mass measurements of the silicon spheres used in this work. The BIPM organizes inter-laboratory mass comparisons of the spheres. This work has been complicated by the discovery of surface contamination on the spheres, as described in more detail in §2. The personnel of the Mass Department also contribute significantly to the development of the BIPM watt balance, described in detail in §7.

We are also preparing to create a highly stable “pool” of artefacts that will embody the value of the new kilogram. To this end we are assembling twelve 1 kg artefacts made of three different materials. Four cylinders of traditional Pt/Ir alloy are in the final phases of fabrication at the BIPM, and four spheres of single-crystal silicon are on order from a supplier in Japan. Construction is under way of storage facilities for maintaining these artefacts in a non-reactive gas such as nitrogen or argon, or in a well-characterized vacuum. We expect that an appropriately averaged mass of the elements of this pool will be linked experimentally to all available primary realizations of the new kilogram, and that such comparisons will be carried out periodically as needed.

Other work to support parts of the *mise en pratique* for the new kilogram is being carried out under terms of a trilateral cooperation among the BIPM, NPL (United Kingdom of Great Britain and Northern Ireland^{*}) and METAS (Switzerland).

The Consultative Committee for Mass and Related Quantities (CCM) has created a Task Group to work out methods of comparing mass standards under vacuum to mass standards maintained in air. Much of the work described above is also realized in a collaborative effort with the CCM.

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 EAL, 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

^{*} henceforth UK.

the period of this report thirteen primary frequency standards contributed to improving the accuracy of TAI, including nine caesium fountains (IT CSF1, LNE-SYRTE FO1, LNE-SYRTE FO2, LNE-SYRTE FOM, NICT CSF1, NIST-F1, NMIJ F1, PTB CSF1 and PTB-CSF2). Throughout the year a total correction of -6.1×10^{-15} has been applied to $[f(EAL) - f(TAI)]$.

Following the approval by the Consultative Committee for Time and Frequency (CCTF), in June 2009, of the use of the GPS Precise Positioning Technique (PPP) for clock comparisons for TAI, solutions based on this method (TAI PPP) have been used in the routine computation reported in *Circular T* from October 2009, with the progressive inclusion of 15 such links.

The first GLONASS common-view civil-code link, between the PTB (Germany) and the VNIIFTRI (Russian Federation), was introduced into the TAI computation in November 2009.

The Department continues to organize and run calibration campaigns of 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. A new cooperation with EURAMET provides regional support for the calibration of GNSS equipment in laboratories contributing to TAI.

Support has been provided to the various CCTF and CCL working groups, for which a number of members of staff have responsibilities. The Department provides the executive secretariat of the CCTF and the CCL, and was active in the organization and attendance of working group meetings of the CCL in June 2010.

Studies have continued for improving the algorithm used to calculate TAI and UTC.

A limited programme of research in the Department 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 (tai.bipm.org/iers/), and a new version is in preparation.

Concerning the realization of reference frames for astrogeodynamic applications, staff from the Department have participated in the construction

of a new international celestial reference frame which has been recommended by the IAU as the primary access to the international celestial reference system.

The Department continues to provide technical advice to pilot and host laboratories in different RMOs in relation to the key comparison of stabilized lasers CCL-K11.

Measurements for the ICAG-2009, which included both a Key Comparison and a Pilot Study, took place at the BIPM headquarters between July and October 2009, and the final results will soon be published.

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

The Time, Frequency and Gravimetry Department's 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 Department are members of commissions, working groups and executive bodies in many international organizations, for which in many cases they provide the chairmanship. A significant number of articles have been written within the period of this report.

Electricity: The work of the Electricity Department has focused on its comparisons 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, which has been developed in collaboration with the NMIA (Australia).

In total, nine key comparisons were carried out with NMIs in the fields of voltage, resistance and capacitance measurements. During 2009 the Electricity Department issued 62 calibration Certificates and 5 Study Notes for 14 NMIs of Member States. 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 – but not exclusively – by NMIs that do not possess their own primary standards.

In the framework of our quality system, the measurement activities in voltage, resistance and capacitance were successfully audited by external experts from the METAS, NPL and PTB, respectively. The quality of the BIPM scientific procedures as well as that of the written documentation was recognized.

The new automatic system for calibration of Zener voltage standards at 1.018 V has been validated and is now used routinely. The new transportable Josephson voltage standard for on-site comparisons has been successfully compared against the existing standard within a relative standard uncertainty of about 1×10^{-10} . Nevertheless, further work is required to improve the reliability of the system, which is a crucial pre-requisite for on-site comparisons.

Work has started on the fabrication of a dedicated Josephson voltage standard for the watt balance. The instrumentation needed to operate the array has been successfully tested together with the array. The dc bias source, which will be used to select the quantized voltages of all thirteen segments of the array, is presently under development. It will operate entirely on batteries, the charging unit for which has already been built.

A new cryostat for the quantum Hall resistance (QHR) standard has been delivered. This is a replacement for the old cryostat which had developed a cold leak. We now need to construct the electronics required for future on-site QHR comparisons. A new room-temperature current comparator bridge, which will shorten the link between the QHR and the BIPM reference capacitors, is under construction.

The BIPM and the NMIA are collaborating on the construction of 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 . This will be highly relevant for the discussions on unit redefinitions. In early 2010, the NMIA completed the fabrication of the final precision mechanical components for the calculable capacitor of the BIPM. The four electrode bars fabricated by the NMIA are well within the cylindricity specification of $0.1 \mu\text{m}$, which is crucial for achieving the target uncertainty. Dr John Fiander from the NMIA was seconded to the BIPM for ten weeks to collaborate on the construction of the instrument and to provide knowledge transfer to colleagues at the BIPM. This collaboration allowed the testing of all critical components and resulted in the need to redesign some of the key components. However, no fundamental flaws were detected and we expect that the calculable capacitor will be available for measurements by the end of 2010.

Watt balance: During the last year, considerable improvements have been made on the measurement of the voltage-velocity ratio. These are due to improved synchronization of the voltage and velocity measurements, an in-depth characterization of the voltmeter, and a reduction of the Abbe offset error of the velocity measurement.

For the first time, an extensive series of measurements of the Planck constant has been carried out following the particular measurement approach of the BIPM watt balance. Since the Type B uncertainties are still relatively large, the main purpose at this stage is to demonstrate the repeatability and reproducibility of the experiment. The relative standard deviation of the results of eleven series of measurements was found to be 5×10^{-6} . The relative combined standard uncertainty at this stage is estimated as 5×10^{-5} and the deviation from the CODATA 2006 value is comparable with the uncertainty.

The new watt balance laboratory will provide improved vibration isolation and temperature stability. While the new laboratory was empty, a 3D map of the gravitational acceleration g was established. This 3D map will be used to determine the value of g at the position of the watt balance test mass. The watt balance will be moved to the new laboratory when the future vacuum enclosure is completed. At the same time, several newly developed electromechanical systems, including a mass exchanger, a sensitivity calibration system for the weighing cell, and a device for dynamic control of coil horizontal displacements and tilts, will be integrated into the watt balance suspension.

Fabrication of the definitive magnetic circuit has started. Most of the pre-machining will be undertaken by the BIPM workshop, and this will be followed by heat treatment and precision machining by a specialist company. We plan to assemble the system in the first half of 2011.

A feasibility study on the future cryogenic watt balance started in September 2009. The first aspects being studied are the consequences of Meissner diamagnetism of the superconducting wire.

Ionizing radiation: The new values for air kerma in low- and medium-energy x-ray beams and in ^{137}Cs beams, as approved by the CCRI(I), are now being disseminated. The study of the effects of low air pressure on both graphite and plastic ionization chambers in ^{60}Co radiation is complete and has been used to assist the ININ (Mexico) with the design of their primary standard for gamma beam dosimetry. A primary standard for gamma beam dosimetry has been constructed for the ARPANSA (Australia) and a comparison is planned for 2011. The study of the I -value for graphite has been published and the ICRU is considering this new result. The consequences will be debated at the next meeting of the CCRI(I).

The graphite calorimeter for absorbed dose to water has been operated in the ^{60}Co beam with a reproducibility now approaching 1 part in 10^3 . The first accelerator dosimetry comparison, with the NRC (Canada) in June 2009, is now at the Draft B report stage. The second in this series of BIPM ongoing comparisons took place at the PTB (Germany) in March 2010 and the results are currently being analysed.

The new primary standard for mammography dosimetry is fully operational and the first two comparisons, with the NMIJ (Japan) and the NIST (USA), have been completed and the reports drafted. The national standard of the NIM (China) has also been characterized.

The Draft B report for the high-dose (up to 30 kGy) comparison is close to completion. The BIPM provides reference irradiations at the 1 kGy level in this comparison, which is conducted at 10-year intervals.

The BIPM is grateful to the guest scientists from the RISØ (Denmark), NMISA (South Africa), VSL (Netherlands) and ININ (Mexico) who enabled the first three BIPM ongoing brachytherapy comparisons to be carried out at the VSL, LNE-LNHB (France) and NPL (UK). The results are currently being analysed.

In total, fifteen dosimetry comparisons have been carried out and thirteen reports of previous comparisons have been published in the last 12 months. In addition, a report of the preliminary characterization of the free-air chamber of the NIS (Egypt) for its future use as their primary standard was published. Seventeen national secondary standards have been characterized in terms of dosimetric quantities, and support for the IAEA continues with regular irradiations of their dosimeters for the IAEA/WHO measurement service.

An internal audit of the dosimetry Quality System was held at the end of 2009. Maintaining and improving the radiation standards' facilities, including the necessary Quality System measurements, represents a significant part of the Department's work.

A total of seventeen ampoules were submitted to the BIPM ongoing activity comparisons using the International Reference System (SIR) in 2009. Ten new results have been registered in the SIR master file, including new radionuclide submissions from three NMIs for ^{64}Cu . (These sources were also used to verify the linearity of the new SIR electronics.) Five comparison reports were published, covering seven results; the remaining 22 reports are in hand. Impurity activity levels were measured using the BIPM Ge(Li)

gamma spectrometer for five ampoules submitted for comparisons; the replacement of this system by the HPGe spectrometer is pending further work. A successful internal audit of the SIR within the BIPM Quality System was carried out in late 2009.

The first comparison of the short-lived ^{99m}Tc radionuclide at the NIST using the SIR Transfer Instrument (TI) was successful and the Draft A report has been prepared following a detailed analysis of the uncertainty budget for the TI. The BIPM is grateful to the LNE-LNHB and the NPL for providing the ampoules necessary to enable the calibration of the TI against the SIR and thus provide the link for the NIST result to those of the other NMIs that have taken part in the SIR for this radionuclide.

Effort has been concentrated this year on developing the equipment for the triple-to-double coincidence ratio technique (TDCR) for activity measurement. The computational methods in use at the BIPM have been verified through a comparison with other NMIs, and the results have been published. These developments enabled the BIPM to take part in the CCRI(II) ^3H comparison using this technique and obtain a result that agreed with the comparison mean value within the uncertainties. However, to improve future results and enable this method to have potential for use as the extension of the SIR to pure beta emitters, the pre-amplifiers have been modified and a Compton source efficiency tracing (CET) method is being implemented using an external ^{241}Am source and a high-purity Ge spectrometer.

The results of the CCRI ^3H comparison are being prepared by the BIPM to form the Draft A report. A significant number of earlier CCRI(II) comparison reports are awaiting publication, the work on extending the SIR to beta emitters having again taken priority. Although, the BIPM did not take part in the recent comparison of alpha particle activity measurement piloted by the NPL, we took part, with a satisfactory result, in a CCRI(II) comparison of uncertainty evaluation piloted by the IRA-METAS (Switzerland). The formal report is awaited.

The Ionizing Radiation Department, having been made responsible for the internal calibration of standard platinum resistance thermometers at the BIPM, conducted a bilateral SPRT comparison with the LNE-INM. It also updated its Quality System and ran the first calibration campaign for the BIPM's scientific departments.

Chemistry: The Chemistry Programme has continued to make significant progress in its three areas of activity, notably: international equivalence of gas standards for air quality and climate change monitoring; international equivalence of primary organic calibrators, for health, food, forensics, pharmaceuticals, and environmental monitoring; and support for CCQM and JCTLM activities and liaison with intergovernmental organizations.

In the area of gas metrology, the BIPM continues to coordinate surface ozone reference standard comparisons (BIPM.QM-K1). Over the last year, four national laboratories participated in comparisons at the BIPM, and the BIPM installed an instrument upgrade kit for one of the participants. The BIPM's gas-phase titration (GPT) system for ozone has been redesigned and is currently under test, whilst the molybdenum converter within the NO_x chemiluminescence analyser has been replaced by a species-specific photolytic converter. The development of laser-based SRP and ozone absorption cross-section measurements has continued. The laser-based SRP now has the same noise level at 244 nm as the mercury-lamp-based SRP at 254 nm. Using relative ozone absorption cross-section values published in 2004, the two types of SRPs produce measurement results of ozone concentration that agree within the measurement noise. Accurate measurements of the optical path length inside the instrument gas cells have started, using a method based on interferometry. A facility for direct measurement of the ozone absorption cross section in the far UV has been designed and is being constructed

The nitrogen monoxide comparison facility has been upgraded and stability studies of standards undertaken, providing information to be used in the establishment of a Central Calibration Laboratory for the WMO GAW network. The CCQM-K74 key comparison for nitrogen dioxide standards has been successfully concluded and Draft A of the comparison report was circulated to participants in June 2010. The measure of gas mole fractions by FTIR spectroscopy is under study in CCQM-P110, the report of which is currently being finalized by the BIPM, and will be the basis of a workshop to be held during the meeting of the CCQM-GAWG in November 2010. The programme to establish a facility for determining the international comparability of methane in air standards at ambient level continued during 2009-2010 with the purchase of a gas chromatography (GC-FID) facility. The main parts of the new facility for the generation of formaldehyde (HCHO) in nitrogen were installed and validated during 2009-2010, in preparation for future key comparisons in this area.

The Organic Analysis Programme is continuing to coordinate CCQM comparisons for the assignment of the mass fraction content of organic compound pure substances that are intended for use as primary calibrators. The development and validation of analytical methods for the production and characterization of the CCQM-K55.b (Aldrin) comparison material has been completed. Procedures developed or investigated included: GC-MS and GC-FID methods; LC-UV methods; LC-MS/MS methods using electrospray and photoionization detection; NMR spectroscopy; Karl Fischer titration; and conditions for the assignment of the water content of the candidate material.

The CCQM-K55.b (Aldrin) key comparison material was prepared at the BIPM by purification of technical grade aldrin donated by the NMIA. A call for participation was circulated in January 2010 and eighteen NMIs or DIs registered to participate in the key comparison, with an additional seven laboratories participating in the parallel pilot study CCQM-P117.b. The comparison samples were distributed to the participating institutes in May 2010 and the comparison results will be discussed at the November 2010 meeting of the CCQM-OAWG.

The development of methods that will be used in the preparation and characterization of the study material for the CCQM-K78 (assignment of the mass fraction content of aldrin in a solution of isooctane) key comparison has started. Procedures developed or investigated to date for the CCQM-K78 candidate materials include: preparation of gravimetrically assigned solutions of aldrin in isooctane; sub-sampling of aliquots of the solution into ampoules followed by flame sealing; and GC-FID methods for assessing the homogeneity of a batch of sealed ampoules.

The BIPM has started to investigate pure material characterization methods for analytes of higher molecular weight and complexity that are of direct relevance to the CCQM. Angiotensin I and insulin were chosen as model systems, and the development and validation of analytical methods for amino acids has started. Procedures are being developed for the determination of structurally related and other impurities in commercially available pure isoleucine, leucine, phenylalanine, proline, tyrosine and valine materials.

Results for the purity key comparison CCQM-K55.a (Estradiol) were received in March 2009. Follow-up studies found the cause of the significant differences in the water content originally reported by the participants. A

Draft B report has been prepared in which a reference value for the estradiol content of the comparison sample was proposed.

The JCTLM database was updated in January 2010 to include WG1 Cycle 6 reference materials, and WG2 Cycle 4 reference measurement laboratory services approved by the Executive Committee during its annual meeting (December 2009). In May 2010, 49 reference measurement laboratory services were removed from the JCTLM database, as these laboratories had failed to meet the ISO 15195 and ISO/IEC 17025 accreditation application deadline.

The WG1 Cycle 7 call for nominations of higher order reference materials and reference measurement methods or procedures, and the WG2 Cycle 5 call for nominations of reference measurement laboratory services were announced on the JCTLM website in January 2010. An email notification was sent to about 300 potential JCTLM contributors. As of May 2010, 42 nominations for materials, 30 nominations for procedures and 4 nominations for services had been received and sent to Review Teams for evaluation. The redesign and update of the JCTLM database due to changes in JCTLM nomination forms, necessitated by the revision of ISO 15194, was undertaken by an external contractor. The new web-based version of the system was published in March 2010.

The BIPM-defined study on “Measurement Service and Comparison Needs for an International Measurement Infrastructure for the Biosciences and Biotechnology” was contracted to the LGC (UK), and a draft of the overall study report is currently being prepared by the LGC. This will be ready for stakeholder comment by October 2010, and a final version, taking into account stakeholder comments, will be ready by March 2011.

1.10 Publications, lectures and travel of the Director and Deputy Director

1.10.1 External publications

1. Wallard A.J., News from the BIPM – 2009, *Metrologia*, **47**, 103-111.
2. Kühne M., Thomas C., Report on the BIPM Workshop on Physiological Quantities and SI Units (16-17 November 2009), *Rapport BIPM-2010/05*, 5 pp

1.10.2 Travel (conferences, lectures and presentations, visits)

A.J. Wallard to:

- Kazan (Rep. of Tatarstan, Russian Federation) 21-25 September 2009, with L. Mussio, for the 23rd meeting of the JCRB;
- London (UK), 9-10 December 2009, for a Pathfinder Group meeting;
- Kuala Lumpur (Malaysia), 13 December 2009, for the 25th APMP General Assembly and Metrology symposium;
- Monterey (USA), 24-27 January 2010, for a meeting of the NCSLI Board;
- Geneva (Switzerland), 29 March 2010, to attend the Science Committee for the WMO-BIPM Workshop on Measurement Challenges for Global Observation Systems for Climate Change Monitoring: Traceability, Stability and Uncertainty;
- Geneva (Switzerland), 30 March-2 April 2010, to co-chair the WMO-BIPM Workshop on Measurement Challenges for Global Observation Systems for Climate Change Monitoring: Traceability, Stability and Uncertainty;
- London (UK), 7-8 June 2010, for a meeting with representatives of the Measurement Board of the UK Government's Department for Business, Innovation and Skills;
- Tsukuba (Japan), 9-12 June 2010, with M. Kühne, to the NMIJ/AIST;
- Daejeon (Rep. of Korea), 12-16 June 2010, to attend the CPEM 2010 and give a presentation on the CIPM MRA.

M. Kühne to:

- Vienna (Austria), 16-17 September 2009, with P.J. Allisy-Roberts, to meet the Deputy Director General of the IAEA and colleagues at the IAEA;
- Lima (Peru), 25-30 October 2009, with L. Mussio, to attend the SIM General Assembly and related meetings;
- PTB, Braunschweig (Germany), 10 December 2009, to discuss linear accelerator (linac) work;
- PTB, Berlin (Germany), 11 December 2009, to take part in a colloquium on the occasion of the retirement of Dr Buck, Head of the PTB Institute in Berlin;
- Geneva (Switzerland), 29 March 2010, to attend the DCMAS meeting;

- Geneva (Switzerland), 30 March-2 April 2010, to attend the WMO-BIPM Workshop on Measurement Challenges for Global Observation Systems for Climate Change Monitoring: Traceability, Stability and Uncertainty;
- Astana (Kazakhstan), 19-23 April 2010, for the 20th meeting of COOMET Committee (COOMET 20) and the 8th meeting of the Joint Committee for Measurement Standards (JCMS-8);
- Berlin (Germany), 10 May 2010, with Prof. Göbel, to visit the Ministry of Economy of Germany;
- Berlin (Germany), 11 May 2010, to participate in a Lagrange lecture;
- Moscow (Russian Federation), 19-20 May 2010, to make a presentation on the occasion of World Metrology Day, and to visit the Gosstandard and the VNIIMS;
- Lisbon (Portugal), 23-27 May 2010, for the EURAMET General Assembly.

1.11 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; 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. 21 (Mexico), Nos. 60 and 64 (China), No. 67 (Czech Republic) and No. 94 (Japan). This is the first calibration for No. 94, which was fabricated recently. Calibrations have been completed for prototypes No. 52 (Germany) and No. 83 (Singapore). Calibrations of prototypes for Canada and Egypt are under way, as well as those of two newly made prototypes for Pakistan and Kenya.

Certificates for two 1 kg standards in stainless steel were issued for NML-SIRIM (Malaysia). Calibrations have been finished for another six 1 kg standards: three for KazInMetr (Kazakhstan), two for MSL (New Zealand) and one for NMC, A*STAR (Singapore). In addition, six 1 kg standards are in the process of calibration for various NMIs: one for BIM (Bulgaria), two for NIS (Egypt) and three for NIMT (Thailand).

Determinations of magnetic susceptibility were made for 1 kg standards in stainless steel: three for NIS, three for KazInMetr and one for MSL. Such measurements are typically carried out and reported as additional information accompanying the initial mass calibration of the standard by the BIPM. At the request of NIS, the magnetic susceptibility of the Egyptian prototype No. 58 was determined. Since the BIPM developed the capability to determine the magnetic susceptibility of Pt-Ir alloy, we have used this measurement as an additional means to control the quality of material received from our supplier. The fabrication of No. 58 took place well before we had this capability, but the measurement result is the same.

At the request of NMC, A*STAR, the volume of their 1 kg mass standard in stainless steel has been verified by weighings made in air of differing density, where the known volume of a BIPM artefact is used as the standard.

2.1.2 Mass calibration laboratory (P. Barat and R.S. Davis)

A complete renovation of room 104, normally used for 1 kg mass calibrations on our HK1000 MC and Metrotec balances, has been under way

since February 2010. During the renovation work, the HK1000 MC balance was completely dismantled and carefully stored. Our Metrotec balance was moved to room 105 with the help of Mettler-Toledo (Greifensee, Switzerland). The balance has been recommissioned in its new location: masses of BIPM 1 kg prototypes and BIPM working standards in platinum iridium were measured before and after the relocation, and the results agreed to within 1.1 μg , with a standard uncertainty of $u_c = 2 \mu\text{g}$. This indicates that the transfer of the Metrotec balance from room 104 to room 105 was carried out successfully.

In early 2010, a call of tender was issued for provision of a mass comparator working at atmospheric pressure and under vacuum to replace the HK1000 MC balance, which is now obsolete. As a result of this call, the BIPM will acquire a M-One 6V-LL comparator from Mettler-Toledo, which is scheduled for delivery at the end of the year.

2.1.3 Air density determination (P. Barat and R. S. Davis)

A previous Director's Report (2008) reported that following the renovation of room 105 in late 2006, we had observed some discrepancies in the air density determination. The BIPM workshop therefore prepared new air-buoyancy artefacts for use in this room. By measuring the air density by means of artefacts (gravimetric method) and by comparing this result to the CIPM-2007 formula for air density determination, we have been able to track the air density difference between the two methods. We believe that the artefact result is essentially correct and that any difference is due to some contaminant in the laboratory air. During the period April-June 2010, the mean relative difference inside the Metrotec balance was 1.5×10^{-4} , which is significant. The evolution of this difference is the subject of an ongoing study. Calibrations requiring significant corrections for air buoyancy can be made with confidence in room 105 by using the buoyancy artefacts as required.

2.1.4 BIPM susceptometer (R.S. Davis)

The BIPM susceptometer has been used to calibrate a stainless steel cylinder to be used by MIKES (Finland) as a standard of volume magnetic susceptibility. The device has also been used to screen materials used in the BIPM watt balance and related equipment. Finally, we have verified that the

susceptibility of two end samples of a newly-delivered Pt/Ir ingot was as expected (see §§2.8 and 2.10.1).

2.2 Automated 100 g balance to support BIPM mass calibrations (R.S. Davis and C. Goyon-Taillade)

The purpose of this balance (AX 106) is to improve the efficiency of our mass calibrations for mass standards ranging from 100 g to 5 g. Extensive measurements were performed in order to commission this new measurement system. The typical standard deviation of series of 24 weighings is 1 µg. For the decade 10 g to 100 g, the difference in results between measurements performed in 2009 and measurements performed manually in 2006 is less than 3 µg in all cases. For the 1 g to 10 g decade, the AX 106 balance was used with the 10 g artefact as the standard to calibrate a transfer mass set (see density calibrations of this set in §2.10.2). Subsequently, routine calibrations were performed manually using our UMT 5 balance with the mass of the transfer set. The difference with the results of previous manual weighings is less than 2 µg in all cases.

The mass of two 50 g copper artefacts was determined for the BIPM watt balance project.

The VSL (Netherlands) uses a similar device and we are grateful to them for supplying their software to us. We have documented our complete validation procedure of the software, as required by our Quality System. Our new service will be audited in September 2010 as part of a scheduled peer review of mass calibration services.

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

Last year we mentioned our intention to re-evaluate uncertainty components due to the position of the masses in our Sartorius CCL 1007 mass comparator. The aim was to reduce the combined uncertainty of mass determinations. Two stainless steel mass standards, having nearly identical volumes, were used to minimize the air buoyancy correction and changes to the apparent mass differences. The positioning errors among the eight possible mass locations were within 1.9 µg with an associated standard uncertainty of less than 0.6 µg. These results are now sufficiently accurate to

take full advantage of the capability of the mass comparator. Two major projects (see §§2.4 and 2.5) and two studies (see §§2.6 and 2.7) have been undertaken this year. We have demonstrated that the Sartorius CCL 1007 mass comparator can be used to carry out mass comparisons in air or under vacuum to the highest accuracy.

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

As mentioned in the last Director's Report (2009), the BIPM is the pilot laboratory for an inter-laboratory mass comparison carried out in vacuum of the two isotopically enriched silicon 1 kg spheres known as AVO28#5 and AVO28#8. This work falls within the framework of the International Avogadro Coordination (IAC) project. The other laboratories involved in this comparison are the NMIJ/AIST (Japan) and the PTB (Germany). Both spheres were measured at the BIPM for the first time in 2008. The BIPM received these spheres again in 2009. Unfortunately, between these measurements, the surface of AVO28#5 had been accidentally contaminated at an NMI with traces of Delrin®. The sphere was therefore sent to the PTB where it was treated with chromosulfuric acid to remove traces of the contamination. No significant change in mass was observed at the BIPM after the PTB treatment. The combined standard uncertainty for the mass determination under vacuum for both spheres is the same as that obtained in 2008, i.e. 5.4 µg. The measurements in 2008 and in 2009 show that the mass difference between air and vacuum conditions is within 0.1 µg and 0.9 µg respectively for the sphere AVO28#5 and within 2.0 µg and 3.2 µg for the sphere AVO28#8. Mass determination under vacuum in 2008 and 2009 for AVO28#5 and AVO28#8 are in agreement within 3 µg and 7 µg, respectively. The agreement among the laboratories is within 10 µg and 20 µg respectively for the spheres AVO28#5 and AVO28#8. This international mass comparison is completed, but another source of surface contamination has since been identified. In this case, the surface of each sphere was contaminated by Cu and Ni during polishing. It appears that the spheres must be re-polished to remove the contamination and this will necessitate a repeat of the inter-laboratory mass comparisons.

2.5 CCM WGM-TG1: Mass comparison with sorption artefacts

(P. Barat and A. Picard)

To anticipate the *mise en pratique* for the future new definition of the kilogram, it was mentioned last year that Task Group 1 (TG1) of the CCM Working Group on Mass Standards (CCM-WGM) had carried out a comparison of stainless steel sorption artefacts in air and vacuum. Five laboratories which are members of the TG1 steering committee have carried out comparisons with a view to including additional members of TG1 in a second round. The main goal of this exercise was to evaluate the performance of sorption artefacts and to validate the protocol for the future TG1 comparison. The laboratories involved in this study were the BIPM, LNE, PTB, METAS and the NPL, which was the pilot laboratory.

This comparison is complete and shows the stability of the artefacts to be comparable with other comparisons (taking into account the manipulations involved). Comparison results in air and under vacuum agree among all participants to within their claimed uncertainties, although the water sorption coefficients (calculated from the artefacts themselves) vary among participants; this is still under investigation.

2.6 Study of mass contamination under vacuum by vacuum gauge

(P. Barat and A. Picard)

The NPL has reported an investigation of mass contamination under vacuum (J. Berry and S. Davidson, Contamination deposited on mass standards in vacuum from an inverted magnetron gauge, *Meas. Sci. Technol.*, 2008, **19**, 115102). Within the framework of the IAC project, the PTB has observed a significant contamination of their vacuum balance. Accordingly, this year the BIPM looked for similar contamination in our own vacuum balance. The vacuum gauge which we use combines an inverted magnetron and a Pirani gauge to form a single, compact unit (Boc Edwards WRG-S-NW25 D147-01-000) that operates from 10^4 Pa to 10^{-7} Pa. The mass difference under vacuum between a platinum-iridium artefact (surface area = 72 cm^2) and a silicon sphere (surface area = 275 cm^2) has been determined. During the study, the residual pressure in our CCL1007 mass comparator was of the order of 2×10^{-3} Pa. We have made three sets of measurements, with the gauge switched ON, OFF and ON, respectively. For the three sets, we have observed a gain in mass difference under vacuum of $1.3 \text{ ng day}^{-1} \text{ cm}^{-2}$ (gauge ON), $0.1 \text{ ng day}^{-1} \text{ cm}^{-2}$ (gauge OFF) and $0.7 \text{ ng day}^{-1} \text{ cm}^{-2}$ (gauge

ON), which is about twenty times smaller than the contamination observed by the NPL. Nevertheless, to avoid any source of contamination, we have installed a T-shaped connection between the vacuum gauge and the enclosure of the CCL1007 comparator. The study will be repeated using this new configuration of the vacuum gauge.

2.7 Study of gravity gradient (P. Barat and A. Picard)

CENAM (Mexico) has provided the BIPM with four specially designed 1 kg stainless steel artefacts which can be used to determine the gradient of the local acceleration due to gravity by means of mass comparisons. The height of the centre of mass of two of the artefacts, both of cylindrical form, differs by about 20 mm, and thus an apparent difference in mass of about 6 μg due to the gravitational gradient would be expected. The other two artefacts have an asymmetric, dumbbell shape, for which the centre of gravity is not aligned with the vertical axis. Therefore, by weighing the artefacts under vacuum (2 mPa) and then turning them “upside down”, it is possible to determine the local gradient of acceleration due to gravity from the mass differences and the nominal value of g . The study is ongoing.

2.8 Storage set-up for an ensemble of mass standards (P. Barat, F. Idrees, E. de Mirandes and A. Picard)

In anticipation of the redefinition of the kilogram, the BIPM is assembling a pool of artefacts. The average mass of the pool will help to ensure the stability of the BIPM mass reference, which will be used for dissemination of the mass unit. The average mass of the pool must be traceable to the future new definition of the kilogram. This will require comparisons with primary realizations of the “new” kilogram. This ensemble of about twelve artefact masses will include artefacts fabricated using Pt-Ir alloy, single-crystal silicon crystal, stainless steel and, perhaps, one additional material. An initial study is planned to monitor the mass stability as a function of the storage conditions in order to determine the best storage conditions for the future. One set of artefacts will be stored under vacuum (at about 1 mPa), two other sets under a chemically inert gas such as nitrogen or argon, and a final set in ambient air. All the artefacts will be stored on PEEKTM plastic inside electro-polished, stainless steel containers. The inert gas will flow through the storage system at about 0.1 L/min. The outlet gas will be

monitored for oxygen, water and hydrocarbons at the level of parts in 10^6 . The residual gas in the vacuum storage system will also be monitored at the same level. For the artefacts stored under ambient air, there will be no flow system or monitoring of impurities. The containers have been fabricated by the BIPM workshop and the network linking the containers to the gas sources and analysers is under construction.

2.9 Trilateral cooperation among NPL, METAS and BIPM

(S. Davidson – NPL, P. Fuchs – METAS and A. Picard)

Our current work plan, which is constrained by the budget that was approved by the General Conference on Weights and Measures at its 23rd meeting (2007), applies to the years 2009-2012. The level of funding approved by the CGPM did not enable the Mass Department to carry out its desired programme. As a reaction to these budget constraints the NPL and, later, METAS proposed a collaboration with the BIPM in order to provide human and other resources during the years 2009-2012 in support of activities in the BIPM Mass Department aimed at preparing for the *mise en pratique* of the future new definition of the kilogram. The NPL provides one research physicist working primarily at the NPL and spending about 60 % of their time per year on activities essential to the BIPM and of interest to the NPL. The contribution from METAS is carried out as required by one physicist at the level of up to 50 % of their time per year.

The cooperation addresses the following areas:

- The methodology of air-vacuum mass comparisons which can be addressed by gravimetric measurements at the BIPM, NPL and METAS working independently on surface artefacts provided by the NPL and METAS.
- Surface analysis by means of XPS on samples belonging to METAS, or provided by the BIPM or the NPL. This project will be applicable to Pt-Ir, silicon and gold alloy samples (provided by the BIPM).
- Mass comparisons, in vacuum or under an inert atmosphere, of suitable artefacts transported under conditions similar to the conditions of the desired comparisons. An external interlock is required for loading artefacts, as well as purpose-built carrying containers.
- Effectiveness of the cleaning method employed on the various materials used (Pt-Ir, silicon and, perhaps, gold alloy). The effectiveness of

cleaning can be determined by means of gravimetric measurements combined with XPS analysis. The cleaning methods to be studied include: plasma jet of hydrogen or oxygen at low pressure (developed by METAS); exposure to ozone and ultraviolet light (UVOx method, developed by the NPL); the traditional method of cleaning and washing used by the BIPM; and the method developed by the NMIA for the Avogadro project (solvent method).

The cooperation is ongoing and some results have already been obtained for:

- a) cleaning procedures,
- b) mass stability between air and vacuum of Pt-Ir, NatSi and stainless steel,
- c) mass comparisons in vacuum,
- d) containers for transfer of mass standards,
- e) storage conditions for mass standards,
- f) recontamination of Pt-Ir samples.

2.10 Volume/density (R.S. Davis, C. Goyon-Taillade and F. Idrees)

2.10.1 Volume/density of mass standards above 300 g (R.S. Davis and C. Goyon-Taillade)

This year, densities were determined for two mass standards in stainless steel belonging to NIS (Egypt). This is a standard service offered to NMIs.

To prepare the pool of artefacts needed for the new definition of the kilogram (see §2.8), acceptance tests were performed on two 300 g samples cut from the ends of the Pt/Ir ingot. This test is specified in the technical protocol agreed with our supplier, Johnson Matthey. The process of manufacturing 4 cylinders and a stack of 8 disks from this ingot is under way at the BIPM workshop. After the process is complete, these artefacts will constitute the Pt/Ir elements of the pool.

A bilateral density comparison of a Pt/Ir cylinder was carried out with the PTB (Germany) in 2009. The mass of the artefact at that time was 16 g above 1 kg (it would later undergo final mass adjustment at the BIPM to $1 \text{ kg} \pm 1 \text{ mg}$). Details of this comparison will be published in a publicly

available BIPM Report, co-authored by our colleagues at the PTB. The report is being written.

2.10.2 Volume/density of mass standards less than 100 g (R.S. Davis, C. Goyon-Taillade and F. Idrees)

Volumes were determined for one 10 g mass standard and five mass standards between 1 g and 5 g. This set was specially designed for use as a transfer standard between our AX 106 and UMT 5 balances (see §2.2). In addition, the volumes of two 50 g copper masses were determined for the BIPM watt balance project.

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

Calibrations of BIPM manometers with respect to the pressure balance maintained in the Mass Department have been carried out four times this year. Thirty-two internal certificates were issued to BIPM scientific departments (including the Mass Department). In addition to these calibrations, verifications of three instruments were performed. In September 2009, our calibration capabilities underwent a successful peer review by an expert from the PTB.

2.12 Humidity generator (C. Goyon-Taillade and F. Idrees)

We have continued the development of a humidity generator with the goal of introducing an internal calibration service for secondary instruments measuring the humidity or dew point of ambient air. The principle is a two-temperature, one-pressure generator with total recirculation. Following the identification of problems with the thermal gradient inside the saturator, a new model for the saturator was designed and fabricated by the BIPM workshop. The temperature will be monitored by means of SPRTs placed at four different positions within the saturator (in water, in air above the water, and near the inlet and outlet tubes).

2.13 Lectures, travel: Mass Department

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

R. Davis to:

- University of Reading (UK), 7 August 2009, for a meeting of a CCU group tasked with producing new draft definitions for the SI base units;
- XIX IMEKO World Congress, Lisbon (Portugal), 7-11 September 2009, with A. Picard, to chair a workshop on the redefinition of the kilogram (organized by the BIPM) and to attend a meeting of IMEKO TC3;
- INRIM, Turin (Italy), 22-23 September 2009, to attend the 4th International Workshop on Progress in Determining the Boltzmann Constant;
- INRIM, Turin (Italy), 23 September 2009, to attend the CCT WG4/TG-SI meeting as an *ex officio* member;
- Laboratoire de l'Accélérateur Linéaire (LAL), Orsay (France), 20 October 2009, to present an invited talk on the redefinition of the kilogram;
- INDECOPI, Lima, (Peru), 2-5 November 2009, to lecture at a SIM workshop on mass metrology;
- LNE and LNE-INM/Cnam, Paris, Trappes, Saint-Denis (France), 18-19 February 2010, as a member of a committee organized by the Agence d'évaluation de la recherche et de l'enseignement supérieur (AERES);
- NMC, A*STAR (Singapore), 1-4 March 2010, for peer assessment of mass services;
- EURAMET TC-Therm, Thessaloniki (Greece), 14-15 April 2010, to present news from the CCT;
- NMIJ, Tsukuba (Japan), 24 May 2010, for technical discussions;
- University of Tokyo (Japan), 25 May 2010, to visit Dr Kuroda's group;
- 10th International Metrology Symposium, Tokyo (Japan), 26 May 2010, to present an invited talk: "The next generation of mass standards";
- TEMPMEKO & ISHM Symposium, Portoroz (Slovenia), 31 May-3 June 2010;

- VNIIM, St Petersburg (Russia), 21 June 2010, with Z. Jiang, for a meeting of the CCM-WGG;
- IAG symposium “TGSMM 2010”, St Petersburg (Russian Federation), 22-25 June 2010.

A. Picard to:

- XIX IMEKO World Conference, Lisbon (Portugal), 7-11 September 2009, to attend the conference and give a talk on the watt balance progress at the workshop on the redefinition of the kilogram;
- INRIM, Turin (Italy), 22-23 September 2009, to attend the 4th International Workshop on Progress in Determining the Boltzmann Constant;
- INRIM, Turin (Italy), 23 September 2009, to attend the CCT WG4/TG-SI meeting as a guest of the chairman;
- ILL, Grenoble (France), 26-27 November 2009, to attend an IAC meeting;
- EURAMET TC-Mass, Istanbul (Turkey), 3-5 March 2010;
- EURAMET TC-Therm, Thessaloniki (Greece), 14-16 April 2010;
- KRIS, Daejeon (Rep. of Korea), 10-11 June 2010, to attend IAC project meeting.

2.14 Activities related to the work of Consultative Committees

R. Davis is Executive Secretary of the CCM and the CCT and a member of several working groups and task groups of these CCs. Both the CCM and the CCT met in early 2010.

A. Picard is coordinator for mass measurements in the International Avogadro Coordination project/CCM Working Group on the Avogadro Constant (see §2.4). He is a member of the CCM-WGSI-kg and the steering committee of CCM-WGM-TG1, both of which are charged with aspects of the *mise en pratique* for a future redefinition of the kilogram.

2.15 Visitors to the Mass Department

- Mr Luis Manuel Peña (CENAM), 3-10 July, to deliver prototype No. 21 for calibration and to work on aspects of mass metrology, and 23 July 2009, to collect No. 21 following its calibration.

- Dr Mitsuru Tanaka (President of the CCM), 4 September 2009, to plan the CCM meeting in March 2010.
- Dr W. Sabuga (PTB), 17 September 2009, to carry out a peer assessment of our internal calibration service for atmospheric pressure.
- Dr Naoki Kuramoto (NMIJ/AIST), 1-2 October 2009, for a technical visit and to collect the silicon spheres for the IAC project.
- Mr J. Soullard, MBraun France, Orsay (France), 16 November 2009, to start the construction of the glove box; and 27 May 2010 and 30 June 2010, to make some tests.
- Dr P. Richard, Vice-Director of METAS, 11 January 2010, to coordinate the CCM working group meetings and workshop to take place in March 2010.
- Dr L. Nielsen (DFM), Chair of CCM WGM TG2, 11-12 January 2010, to coordinate the CCM workshop and TG meetings in March 2010.
- Messrs D. Heydenbluth and M. Schreiber, Sartorius AG, 5 February 2010, to make adjustments to the Automatically Unloadable Container (AUC).
- Mr M. Kliebenschädel, Mettler-Toledo, Greifensee (Switzerland), 16-19 February 2010, to move the Metrotec balance from room 104 to room 105.
- Mr Hazim Abdallah (NIS), 17-20 May 2010, to deliver mass standards for calibration and for technical discussions.

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

3.1 International Atomic Time (TAI) and Coordinated Universal Time (UTC) (E.F. Arias, A. Harmegnies, 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 2009*, volume 4, complemented by computer-readable files on

the BIPM website, provides the definitive results for 2009. Starting with this volume the Annual Report is available only in electronic form; it is published on the BIPM website at www.bipm.org/en/publications/time_activities.html

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 continues in the Department with the aim of improving the long-term stability of EAL and the accuracy of TAI.

After having studied the clock frequency prediction, and concluded that the H-masers could be responsible only for about 20 % of the drift of EAL, a comparative analysis of algorithms in different time scales has started and is ongoing.

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. On average during 2009, about 15 % of the participating clocks were 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, is about 4 parts in 10^{16} for averaging times of one month. 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 2009, individual measurements of the TAI frequency have been provided by thirteen primary frequency standards, including nine caesium fountains (IT CSF1, LNE-SYRTE FO1, LNE-SYRTE FO2, LNE-SYRTE FOM, NICT CSF1, NIST F1, NMIJ F1, PTB CSF1 and PTB CSF2). Reports on the operation of the primary frequency standards are regularly published on the BIPM website and collated in the *BIPM Annual Report on Time Activities*.

As of July 2004, a monthly steering correction of at most 7 parts in 10^{16} is applied as deemed necessary. Since July 2009, 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 -6.1×10^{-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(BIPM09), valid until December 2009, which has an estimated accuracy of about 5 parts in 10^{16} . Moreover, since January 2010, we provide each month an extension of TT(BIPM09) based on the most recent TAI computation. Such an extension is useful for pulsar analysis pending the yearly updates of TT(BIPM). Studies aimed at improving the computation of TT(BIPM) are ongoing, in order to keep it in line with improvements in the primary frequency standards.

3.2.4 Local representations of UTC in national laboratories as broadcast by the GNSS

Following a recommendation by the CCTF (2009), preparatory work has started in the Department with a view to publishing the relationship between UTC(USNO) and UTC(SU) (as broadcast by GPS and GLONASS) and UTC as disseminated in the BIPM's *Circular T*.

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 Department actively participate in the work of the CCL/CCTF Frequency Standards Working Group, and the CCTF Primary 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. The latest changes to the list, containing frequency values and uncertainties for transitions in Rb, Hg⁺, Yb⁺, Sr⁺ and Sr, were recommended by the CCTF in June 2009, and no further updates have been produced during the period covered by this report. Staff from the BIPM Time, Frequency and Gravimetry Department continue to participate in the rapidly evolving field of optical frequency standards, addressing 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 69 participating time laboratories equipped with GNSS receivers and/or operating TWSTFT stations.

Significant improvements have been made within the Department on the time links used for the calculation of TAI; data from three independent techniques are included in the process of comparison of laboratories' clocks based on tracking GPS and GLONASS satellites, and on two-way satellite time and frequency transfer through geostationary telecommunications satellites (TWSTFT).

The GPS all-in-view method is widely used and takes advantage of the increasing quality of the International GNSS Service (IGS) products. Clock comparisons are possible using C/A code measurements from GPS single-frequency receivers, or dual-frequency, multi-channel GPS geodetic-type receivers (P3). The older GPS single-channel single-frequency receivers

* Retired on 31 August 2009.

currently represent only 3 % 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 becoming equipped.

The GPS phase and code data provided by time laboratories is processed each month using the Precise Point Positioning (PPP) technique. Following approval by the CCTF at its meeting in June 2009, such PPP links have been introduced in the calculation of TAI since September 2009. Currently, 30 laboratories participate regularly, about 15 of which are used as TAI links. Comparisons of the PPP links with others obtained by TWSTFT and P3 are published monthly on the Time, Frequency and Gravimetry Department's ftp server.

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

The first GLONASS common-view civil-code link between PTB and VNIIFTRI was introduced into TAI computation in November 2009, providing results consistent with the GPS multi-channel single-frequency links.

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

All GNSS links are corrected for satellite positions using IGS and ESA post-processed, precise satellite ephemerides, and those links using single-frequency receivers are corrected for ionospheric delays using IGS maps of the total electron content of the ionosphere.

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 Time, Frequency and Gravimetry Department is a member.

The method developed to perform the absolute calibration of the Ashtech Z12-T hardware delays allows the BIPM to use this receiver for differential calibrations of similar receivers world-wide, and calibration campaigns began in January 2001. Calibration results have also been issued for other receivers: the Septentrio PolARx2 since 2006 and the Dicom GTR50 and Javad JPS E-GGD since 2009. Other types of receivers are being investigated in collaboration with laboratories equipped with them. Since 2009, the BIPM travelling receiver for differential calibrations is a GTR50. 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. Results of the differential calibration exercises are made available on a dedicated web page (www.bipm.org/jsp/en/TimeCalibrations.jsp), where past calibration results are also provided.

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. The BIPM has computed its own solutions for such time links since October 2007, using the GPSPPP software from Natural Resources Canada, and these links have been introduced into the TAI regular computation since September 2009.

Work on GLONASS P3 and GLONASS PPP time links started in June 2010.

3.4.3 Two-way time transfer

Two meetings of the TWSTFT participating stations have been held since July 2009, and the CCTF WG on TWSTFT met at the AOS (Poznań, Poland) in October 2009. 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 GNSS single-frequency, dual-frequency and TW observations are published monthly on the Time, Frequency and Gravimetry Department's ftp server (<ftp://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 2009 to June 2010, GPS and GLONASS time equipment for single- and dual-frequency reception has been calibrated. The BIPM is also supporting TWSTFT calibration trips, supported by a GPS receiver from our time laboratory.

Work on the absolute calibration of GNSS receivers was started by a Ph.D. student through a collaboration co-financed with the CNES and also involving the LNE-SYRTE. In 2009 work started at the CNES to carry out absolute calibration of GNSS antennas. In addition, the PhD 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.

Cooperation started with EURAMET for having regional support to the GNSS equipment calibration in contributing laboratories. This action follows Recommendation CCTF 2 (2009) and opens the possibilities of further interaction with other RMOs.

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

Results of the key comparison in time, CCTF-K001.UTC, involving the time laboratories participating in the CIPM MRA, were regularly published in the KCDB after publication of the monthly *Circular T* until June 2009. Since then, a link to the most recent issue of *Circular T* has been proposed from the KCDB.

Guidelines for the characterization of the frequency traceability of local realizations $UTC(k)$ to the SI second are under preparation in the Time, Frequency and Gravimetry Department, as requested by the CCTF in June 2009.

As decided by the 98th CIPM meeting in 2009, the BIPM continues to support the CCL-K11 key comparison in terms of participation in measurement campaigns as well as in giving general advice. In particular, the BIPM took part in the campaign held at the NMIJ/AIST in April 2010 in which 8 participants successfully participated. Together with a similar campaign at the NRC in September 2009 and measurements in BEV and MIKES, the total number of participating NMIs is now 17. This demonstrates that after the initial start-up period the CCL-K11 is running effectively and produces valuable data to support CMC claims.

3.6 **Pulsars** (G. Petit)

The work with the Observatoire Midi-Pyrénées (OMP, Toulouse, France) on a pulsar survey has stopped. Collaboration continues with 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 Time, Frequency and Gravimetry Department 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* (tai.bipm.org/iers/). Updates to the *Conventions* (2003) have been posted on the website 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* is expected to be available before end-2010.

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 Time, Frequency and Gravimetry Department, BIPM comb activities are limited to the maintenance of the BIPM frequency combs for internal applications.

3.9 Calibration and measurement service (L. Robertsson and L. Tisserand)

The Time, Frequency and Gravimetry Department 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.

Twenty lasers were measured for ICAG-2009. As planned, for the first time in this international comparison, studies of the beam characteristics in the

* Retired on 31 August 2009.

interferometers of the participating gravimeters were made, in order to account for small corrections related to diffraction effects.

Checks of the frequency of the rubidium clocks in the gravimeters were made during the measurement campaign.

3.10 Iodine cells (R. Felder*, J. Labot† and L. Robertsson)

As decided by the CIPM, the service of filling and testing iodine cells was stopped on 31 July 2009, after having delivered all the cells to national laboratories and various institutes.

3.11 Gravimeter FG5-108 (L. Vitushkin‡)

After having modified the laser head of the compact Nd:YVO₄/KTP/I₂ laser at 532 nm and the optical fibre system for light delivery to the interferometer of the FG5-108, the gravimeter has been tested with good results. However, after having replaced the motor of the dropping chamber and the dropping controller, tests after re-adjustments showed that the gravimeter was still malfunctioning. After many trials and discussions with the developers of the instrument it has been decided to stop the measurements.

3.12 8th International Comparison of Absolute Gravimeters, ICAG-2009 (L. Vitushkin, Z. Jiang, L. Robertsson and L. Tisserand)

In contrast to earlier comparisons of absolute gravimeters, the ICAG-2009 was split into two parts which ran consecutively, one as a key comparison, CCM.G-K1, and a second as a pilot study, with 12 and 10 participants respectively. This was the first time a key comparison for absolute gravimetry was arranged. Both comparisons were running under essentially the same protocol even though some relaxed conditions were accepted for the pilot study. A 5 station scheme with 3 measurements for each instrument was used. A preliminary evaluation of all the results has now been made and a Draft A report has been edited.

* Retired on 31 August 2009.

† Retired on 30 June 2009.

‡ Retired on 30 November 2009.

In connection with the ICAG-2009, measurements of both the laser frequency and the frequency of the Rubidium frequency standards of the gravimeters were carried out. A BIPM reference laser, calibrated with an optical frequency comb system prior to the ICAG-2009, were used as a reference in the beat frequency measurements. In the case of the Rubidium standards, a reference signal, calibrated relative to UTC, was used and a phase meter giving frequency as well as stability measurements was carried out.

In addition, measurement of the beam parameters for the laser beams used for the interferometric determination of the position of the free falling test mass was made. This is important for making a good estimate of the error due to the Gouy phase shift.

Measurements at two sites in the room that will house the watt balance have been made with some participating gravimeters. These measurements are not included in the official report, but will serve to monitor the stability of the gravity field in the room.

3.13 Publications, lecture, travel: Time, Frequency and Gravimetry Department

3.13.1 External publications

1. Arias E.F., Current and future realizations of coordinate time scales, *Proc. IAU Symp.* **261**, Cambridge University Press, 2010, 16-21.
2. Arias E.F., Panfilo G., Impact of new frequency standards on the international timescales, *Proc. IAU*, Vol **5**, 2010, 223-224.
3. Harmegnies A., Panfilo G., Arias E.F., Detection of outliers in TWSTFT data used in TAI, *Proc. 41st PTTI Systems and Applications Meeting*, 2010, 421-432.
4. Harmegnies A., Panfilo G., Arias E.F., BIPM time activities update, *Proc. 41st PTTI Systems and Applications Meeting*, 2010, 183-188.
5. Jiang Z., Arias E.F., Lewandowski W., Petit G., Toward unified TWSTFT and GNSS delay characterization for UTC time transfer?, *Proc. EFTF 2010*, 2010, CD-ROM.
6. Jiang Z., Lewandowski W., Konaté H., TWSTFT Data Treatment for UTC time transfer, *Proc. 41st PTTI Systems and Applications Meeting*, 2010, 409-420.

7. Jiang Z., Petit G., Combination of TWSTFT and GNSS for accurate UTC time transfer, *Metrologia*, 2009, **46**, 305-314.
8. Jiang Z., Becker M., Francis O., *et al*, Relative Gravity Measurement Campaign during the 7th International Comparison of Absolute Gravimeters, *Metrologia*, 2009, **46**, 214-226.
9. Jiang Z., Fully use of the redundancy in TWSTFT and GNSS time and frequency transfer, *Proc. EFTF2009*, 1194-1197.
10. Jiang Z., Lewandowski W., Konaté H., TWSTFT data treatment for UTC time transfer, *Proc. 41st PTTI Systems and Applications Meeting, 2010*, 409-420.
11. Jiang Z., Piester D., Liang K., Restoring a TWSTFT Calibration with a GPS Bridge - a standard procedure for UTC time transfer, *Proc. EFTF 2010*, 2010, CD-ROM.
12. Jiang Z., Interpolation of TW time transfer from measured points onto standard MJD for UTC generation, *Proc. EFTF 2010*, 2010, CD-ROM.
13. Lewandowski W., Jiang, Z., Use of GLONASS at the BIPM, *Proc. 41st PTTI Systems and Applications Meeting*, 2010, 5-14.
14. Lewandowski W., Jiang Z., Use of GLONASS at the BIPM, *Proc. PTTI2009*, 2010, 5-13.
15. Liu Y., Jiang Z., Precise time transfer activities in Singapore, *Proc. EFTF-IFCS 2009*, 2010, 634-638.
16. Ma C., Arias E.F., Bianco G., Boboltz D., Bolotin S., Charlot P., Engelhardt G., Fey A., Gaume R., Gontier A.-M., Heinkelmann R., Jacobs C., Kurdubov S., Lember S., Malkin Z., Nothnagel A., Petrov L., Skurikhina E., Sokolova J., Souchay J., Sovers O., Tesmer V., Titov O., Wang G., Zharov V., The Second Realization of the International Celestial Reference Frame by Very Long Baseline Interferometry, *IERS Technical Note N°35*, 2009.
17. Panfilo G., Arias E.F., Algorithms for International Atomic Time, *UFFC special issue on the 2009 Joint Meeting of the EFTF and IEEE FCS*, 2010, 140-150.
18. Panfilo G., Arias E.F., Studies and possible improvements on EAL algorithm, *Proc. EFTF-IFCS 2009*, 2010, 110-115.
19. Petit G., Relativity in the IERS Conventions, *Proc IAU Symposium 261*, Cambridge University Press, 2010, 16-21.

20. Petit G., Current use of GNSS time transfer in TAI and future strategies, Proc. 2nd Int. Colloq. on scientific and fundamental aspects of Galileo, 2009, CD-Rom.
21. Petit G., Luzum B., Report of the IERS Conventions Center, *IAU Transactions XXIIIB*, 2010.
22. Petit G., Atomic time scales TAI and TT(BIPM): present performances and prospects, *Proc. IAU*, Vol 5, 2010, 220-221.
23. Souchay J., Andrei A., Barache C., Bouquillon S., Suchet D., Baudin M., Gontier A.-M, Lambert S., Le Poncin Lafitte C., Taris F., Arias E.F., The construction of the Large Quasar Astrometric Catalogue, *A&A* 494, 2, 2009, 799-815.
24. Zhang H., Li H., Lewandowski W., Jiang Z., TWSTFT activities at NTSC, *Proc. EFTF-IFCS 2009*, 2010, 1206-1208.

3.13.2 BIPM publications

25. *BIPM Annual Report on Time Activities for 2009*, 2010, 4, 104 pp., available only at www.bipm.org/en/publications/time_activities.html
26. *Circular T* (monthly), 7 pp.
27. Lewandowski W., Tisserand L., Relative characterization of GPS time equipment delays at the OP, AOS, GUM, LT, TP, BEV, OMH, NIMB, NMC, and ZMDM, *Rapport BIPM-2010/02*, 27 pp.
28. Lewandowski W., Tisserand L., Relative characterizat on of GPS time equipment delays at the OP, PTB, AOS, USNO and IT, *Rapport BIPM-2010/03*, 16 pp.
29. Lewandowski W., Tisserand L., Relative characterization of GNSS receiver delays for GPS and GLONASS C/A codes in the L1 frequency band at the OP, SU, PTB and AOS, *Rapport BIPM-2010/04*, 40 pp.

3.13.3 Travel (conferences, lectures and presentations, visits)

E.F. Arias to:

- Rio de Janeiro (Brazil), 2-7 August 2009, to attend the 27th General Assembly of the IAU, Joint Discussion 6 on Time, to give an oral presentation and for business meetings of Commission 18, 31, 52;
- Buenos Aires (Argentina), 30 August-12 September 2009, to give an oral presentation at the Scientific Assembly of the IAG, for a meeting

of the GGOS Steering Committee, and for a meeting of the IGS Governing Board;

- St Petersburg (Russian Federation), 14-18 September 2009, to attend the 4th meeting of the ICG and for a meeting of the WG D and its Task Forces on Time and Geodetic References;
- Vienna (Austria), 15 February 2010, for a preparatory meeting of the 5th ICG;
- Thessaloniki (Greece), 15-17 March 2010, for a meeting of the Time and Frequency Technical Committee of EURAMET;
- Paris (France), 15 June 2010, to give a presentation at the Workshop on Quasars and unresolved galaxies with Gaia;
- Newcastle (UK), 28 June to 1 July 2010, to give an invited presentation at the IGS Workshop and for a meeting of the WG D and its Task Forces on Time and Geodetic References.

A. Harmegnies to:

- Albuquerque, New Mexico (USA), 14-22 November 2009, for the PTTI Tutorial, to give oral and poster presentation at the 41st PTTI Systems and Applications Meeting, and to attend a meeting of the TWSTFT participating stations;
- Orsay (France), 22-25 June 2009, for training on FORTRAN;
- Brussels (Belgium), 27-30 July 2009, to work on GNSS time transfer for TAI.

Z. Jiang to:

- St Petersburg (Russian Federation), 20-25 June 2010, for the IAG Symposium on Terrestrial Gravimetry, and for a meeting of the CCM-WGG.

W. Lewandowski to:

- Warsaw (Poland), 28-30 September 2009, 13 October 2009, 25-26 May 2010, and 23-24 June 2010, to the Space Research Centre (SRC) and the Central Office of Measures (GUM);
- Brussels (Belgium), 8 July 2009, to the European Commission to discuss the Galileo time scale;
- Lintong and Beijing (China), 10-15 August 2009, to discuss definitions of time scales at the NTSC and NIM;

- Geneva (Switzerland), 7-11 September 2009, for meetings of the ITU Working Party 7A and Study Group on the Future of UTC Leap Second;
- St Petersburg (Russian Federation), 13-18 September 2009, to attend the 4th meeting of the UN International Committee for GNSS (ICG);
- Savannah, Georgia (USA), 19-25 September 2009, to attend the 49th meeting of the Civil GPS Service Interface Committee (CGSIC) and chair its Timing Sub-Committee, and to attend the ION GNSS conference;
- Poznań (Poland), 10-22 October 2009, for the 17th meeting of the CCTF Working Group on TWSTFT;
- London, Westminster (UK), 25-28 October 2009, to attend the Interparliamentary Conference on Space;
- Albuquerque, New Mexico, (USA), 14-22 November 2009, for the 41st PTTI Systems and Applications Meeting and a meeting of the TWSTFT participating stations;
- Noordwijk (the Netherlands), 19-25 April 2009, for the EFTF Symposium and for a meeting of the TWSTFT participating stations.

G. Petit to:

- Queretaro (Mexico), 20-22 July 2009, to visit CENAM and give an invited lecture;
- Rio de Janeiro (Brazil), 2-7 August 2009, to attend the 27th General Assembly of the IAU, give two presentations, and attend a business meeting of Commission 52;
- Padua (Italy), 13-16 October 2010, for a meeting of the GNSS Science Advisory Committee and to attend the 2nd International Colloquium on scientific and fundamental aspects of Galileo , with a presentation;
- Saint-Mandé (France), 25 October 2009, for a meeting of the Commission Geopositionnement of the French CNIG;
- Paris, 24 March 2010, for a meeting of the GNSS Science Advisory Committee;
- Noordwijk (Netherlands), 12-16 April 2010, to attend the EFTF, at which he gave an two oral presentations and received the 2010 EFTF Award;
- Daejeon (Rep. of Korea), 13-18 June 2010, to give a presentation at the CPEM 2010, and to visit the KRISS time laboratory.

L. Robertsson to:

- Kuala Lumpur (Malaysia), 12-16 December 2009, to give a lecture on a workshop on comb-related metrology and attend the APMP TCL meeting;
- Tokyo (Japan), 15-25 April 2010, as adviser for a CCL-K11 comparison campaign;
- Singapore (Singapore), 7-12 June 2010, for meetings of the CCL WGs;
- Daejeon (Rep. of Korea), 13-19 June 2010, to attend the CPEM 2010.

L. Tisserand to:

- Boulder (USA), 9-13 November 2009, for the NIST Time and frequency Seminar.

L. Vitushkin to:

- St Petersburg (Russian Federation), 9-13 November 2009, for discussions on comparisons of gravimeters.

3.14 Activities related to external organizations

E.F. Arias is a member of the IAU and participates in its working group 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 also represents the BIPM in the GGOS Steering Committee, a scientific service of the IAG. 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 is also a member of a consultative Group on the Reform of 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, and the UN International Committee on GNSS (ICG).

G. Petit is co-director of the Conventions Centre of the IERS. He is 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 Science 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'.

3.15 Activities related to the work of Consultative Committees

E.F. Arias is Executive Secretary of the CCTF and shared until 31 August 2009 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 was the Executive Secretary of the CCL and Joint Secretary of the CCL/CCTF Frequency Standard WG until the 31 August 2009.

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. Robertsson is, since the 1 January 2010, Executive Secretary of the CCL and a member of the CCL WG on strategic planning and of the Discussion group DG-11 (Lasers). He is the BIPM representative on the Working Group on Gravimetry of the CCM.

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

3.16 Visitors to the Time, Frequency and Gravimetry Department

- Drs Ernst Boyarsky and Larisa Afanasieva (O. Yu. Schmidt Institute for the Physics of the Earth, Moscow, Russian Federation), 18 September to 5 October 2009, to participate as observers in ICAG-2009.
- Dr O. Francis (University of Luxembourg, Luxembourg), 18 March 2010, for a BIPM seminar, and for the installation of a relative gravimeter for determining Earth tides on the site.
- Dr S. Junqueira (ONRJ, Brazil), 8 July 2010, to discuss frequency comb applications to time and frequency metrology.
- A group of 20 delegates to the ELSA Conference “Gaia, at the frontiers of astrometry”, 9 June 2010, for a visit to the Department.

3.17 Guest workers

- Dr F. Lahaye (Natural Resources Canada), 22-25 September 2009, for a cooperation on GPS PPP.
- Miss A. Proia (Ph.D. student), 25 January to 20 February 2010, to work on her PhD on absolute calibration of GNSS receivers.
- Dr Leonid Vitushkin (VNIIM, Russian Federation), 19-23 April 2010, for the preparation of the results of ICAG-2009.
- Dr Paweł Lejba (Space Research Centre - AOS, Borowiec, Poland), 15-30 June 2010.

4 ELECTRICITY (M. STOCK)

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

The validation process for the new automatic system for the calibration of electronic Zener voltage standards at 1.018 V, which started last year, has been completed following a statistical analysis based on the calculation of the power spectral density. Two programmable arrays, one of them taking the role of a Zener voltage standard, were set to the same theoretical voltage within a few nanovolts and were compared to each other 2048 times over 3 consecutive days with the new automated Zener calibration facility. The

1/f noise floor expected for those measurements has been found to be one order of magnitude higher than expected. A thorough analysis of the measurement setup revealed that an optical communication isolator was responsible for this significant increase of the noise level. The device has been removed from the setup with the aim of significantly reducing the noise.

New measurements have been carried out to compare the new transportable conventional Josephson voltage standard (JVS), operated at 10 V, to the present Josephson primary standard. This is the second in a series of a major programme of internal comparisons to validate the quality of the new transportable standard. The latest results show good agreement, $(U_{\text{new}} - U_{\text{reference}}) / U_{\text{reference}} = -7.4 \times 10^{-11}$, with a total relative standard uncertainty of 1.4×10^{-10} .

However, the new transportable JVS has not yet reached a sufficient level of reliability to be used in the BIPM on-site Josephson comparison programme. Effectively, under certain circumstances the propagation of the RF signal along the waveguide is still perturbed. A direct consequence is an intermittent loss of the Shapiro steps. The problem has been investigated and seems to be directly related to the intrinsic properties of the waveguide. Further investigations are in progress.

The technical work on the development of a dedicated Josephson voltage standard for the BIPM watt balance has started. The instrumentation needed to operate the array has been assembled in a measurement bay and has been successfully tested together with the array. Software has been written to investigate the dependence of the Shapiro step widths of each of the 13 array cells on the RF frequency and power. From the analysis of the results, the optimum operating parameters - bias currents, frequencies and power of the RF signal - and their margins will be determined.

A dedicated DC bias source has been designed and is currently under development. This source will be powered with batteries in order to reduce the impact of electromagnetic interference between the electrical supply of the watt balance experiment and that of the instrumentation required to operate the array. The source allows independent biasing of the 13 cells of the array. The final objective is to programme the array to generate a quantum voltage which closely follows the voltage produced across the coil of the balance at any time, in order to remain within the limits of the selected range of the analogue amplifier. The amplifier recovery from an overload

would contribute to a considerable reduction in the acquisition time of the voltage difference when the coil moves at a constant velocity.

An external audit of the voltage calibration service within the framework of the BIPM Quality System was completed successfully in November 2009.

4.2 Electrical resistance and impedance

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

The new QHE cryostat purchased last year was delivered and was found to comply with the specifications. This allowed the old QHE cryostat to be sent for repairs. The origin of the ‘cold leak’, detected one year ago, was found by the manufacturer and was repaired. We now have two reliable cryostats, one staying at the BIPM as the primary standard and the other one for the future on-site comparisons of quantum Hall standards.

As a result of the heavy calibration workload, combined with the long-term absence of one technician, the construction of the electronics needed for such comparisons is still under way. The situation should improve from August 2010 when a new technician is scheduled to start work.

A new resistance bridge dedicated to measuring a pair of 51.6 k Ω resistors (which form part of the BIPM quadrature bridge) directly against the quantized Hall resistance is under construction. It will shorten the measurement chain linking the QHR and the BIPM reference capacitors, with the aim of reducing the overall uncertainties, which is also of importance for the planned determination of the von Klitzing constant with the calculable capacitor. The main features of this bridge are the room temperature current comparator, based on previous BIPM developments, and the use of a single current source, instead of the more usual double current source. This allows simpler electronics and more stable operation. The bridge design was presented at the CPEM conference.

The work related to resistance calibrations was successfully audited by an external expert in November 2009.

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

The capacitance reference at 10 pF has been maintained by two transfers to the quantum Hall resistance over the reporting period. The working standards have then been used to disseminate the farad via calibrations and comparisons as listed in §§4.4 and 4.5. No major development work has been undertaken on the capacitance bridges, as work has been concentrated on the calculable capacitor. The capacitance calibration service was successfully audited by an external expert in November 2009.

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

Construction of the calculable capacitor instrument at the BIPM commenced in earnest in 2010. The original timeline of the project was to deliver a new measured value of the von Klitzing constant, R_K , in time for the 2010 CODATA fundamental constants adjustment. Although this is no longer possible, a result can be expected in 2011, which will be highly relevant for the continuing discussions on unit redefinitions.

John Fiander from the NMIA worked at the BIPM for 10 weeks (in April-June 2010) to enable the construction of the instrument. There was a change in plan from the original schedule, in that the BIPM instrument was assembled before the NMIA's own version. This meant that this period was not simply one of construction, but of development and debugging of the design. The fundamental design has proven to be sound, but inevitably some details have had to be changed in the light of experience with the real instrument. The experience of working together on the problems found during construction has no doubt provided a much deeper transfer of knowledge about the design to the BIPM staff than would have been achieved by building the second 'copy'. The BIPM workshop gave continuous support to the project over this period, responding rapidly to requests for modifications and new parts.

At the time of writing (June 2010), the project is in a state of rapid change and development, but the present status can be summarized as follows:

* Time, Frequency and Gravimetry Department.

† BIPM workshop.

- The remaining precision components (lead screw and main electrode bars) have been delivered from the NMIA to the BIPM, and have been successfully installed in the instrument. The set of 4 electrodes are well within the original cylindricity specification of $0.1\ \mu\text{m}$, and will contribute only around 1 part in 10^9 to the overall uncertainty budget.
- The capacitor has been fully built up to test all the critical components, alignment procedures and the functioning of the interferometer. Some key components will now be redesigned in the light of this experience (for example the spring mounts at the top of the main electrodes).
- No fundamental flaws have been found that will prevent the instrument reaching its target uncertainty of less than 1 part in 10^8 . The alignment procedure for the main electrodes has been demonstrated to the required precision, and the interferometer has worked well (showing a mechanically very stable cavity between the movable mirrors).
- Some further experimentation will be necessary to finalize the redesigned components, and the optical system needs further development, but we can expect the instrument to be essentially complete by the end of 2010.
- 2011 will then see the concentrated work of measurement, testing of influence quantities and estimation of uncertainty components required to arrive at a value of R_K .

The measurement chain for linking the calculable capacitor to the quantum Hall resistance is the same as that used for regular maintenance of capacitance, and is thus in good working order. One extra bridge is required for the first step from the calculable capacitor to 1 pF, and this was tested recently using fixed 0.2 pF and 0.6 pF standards. The tests were limited by the stability of these standards, but served to show that there are no major problems with the bridge. A full evaluation of the bridge can only be done with the calculable capacitor itself, and this will form part of the measurements planned for early 2011. The new resistance bridge mentioned in §4.2.1 should also be ready by this time, and will form part of the final measurement chain.

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

Two on-site comparisons of Josephson voltage standards with the SMD (Belgium) and the EIM (Greece) have been successfully completed in

November 2009 and March 2010, respectively. The results of the comparison with SMD have been published and are very satisfactory:

$$\text{At } 10 \text{ V: } (U_{\text{SMD}} - U_{\text{BIPM}}) = -0.4 \text{ nV} \quad u = 1.3 \text{ nV}$$

The results of the BIPM-EIM comparison are not yet available.

The result of a comparison with the NIST, carried out in March 2009, has also been published during the reporting period:

$$\text{At } 10 \text{ V: } (U_{\text{NIST}} - U_{\text{BIPM}}) = -0.8 \text{ nV} \quad u = 1.0 \text{ nV}$$

The studies undertaken in the framework of this comparison resulted in a joint NIST-BIPM paper presented at the CPEM conference.

Two bilateral voltage comparisons using Zener voltage standards as transfer standards were carried out at the level of 1.018 V and 10 V with INTI (Argentina) and with the NSAI (Ireland) between August and October 2009 and in May 2010, respectively.

$$\text{At } 1.018 \text{ V: } (U_{\text{INTI}} - U_{\text{BIPM}}) = -0.01 \text{ } \mu\text{V} \quad u = 0.03 \text{ } \mu\text{V}$$

$$\text{At } 10 \text{ V: } (U_{\text{INTI}} - U_{\text{BIPM}}) = -0.24 \text{ } \mu\text{V} \quad u = 0.38 \text{ } \mu\text{V}$$

The results for NSAI are not yet available.

In the framework of the resistance comparisons at 1 Ω and 10 k Ω , BIPM.EM-K13.a and BIPM.EM-K13.b, the reports on the bilateral comparisons of resistance standards with the NMIA (Australia) and NIMT (Thailand) were finalized.

$$(R_{\text{NIMT}} - R_{\text{BIPM}}) / (10 \text{ k}\Omega) = +0.66 \times 10^{-6} \quad u = 0.11 \times 10^{-6}$$

$$(R_{\text{NMIA}} - R_{\text{BIPM}}) / (1 \text{ } \Omega) = -0.13 \times 10^{-6} \quad u = 0.11 \times 10^{-6}$$

The report on the comparison of 1 Ω and 10 k Ω resistors with the GUM (Poland) is in the Draft B stage.

Capacitance comparisons at 10 pF (BIPM.EM-K14.a) and 100 pF (BIPM.EM-K14.b) with the CMI (Czech Republic) were completed during this period, and measurements have started for a comparison with NPLI (India).

4.5 Calibrations

During the period from 1 July 2009 to 30 June 2010, the Electricity Department calibrated:

- 1 Ω resistors for the BIM (Bulgaria), NML-SIRIM (Malaysia), NIS (Egypt), INMETRO (Brazil), DMDM (Serbia) and NIMT (Thailand); 100 Ω resistors for the BIM (Bulgaria), NMC, A*STAR (Singapore), DMDM (Serbia), SMD (Belgium), NIMT (Thailand) and KRISS (Rep. of Korea); 10 k Ω resistors for the BIM (Bulgaria), NIS (Egypt), INMETRO (Brazil), DMDM (Serbia), SMD (Belgium), NIMT (Thailand) and KRISS (Korea);
- 1 pF, 10 pF or 100 pF capacitors for the PTB (Germany), CMI (Czech Republic), NIMT (Thailand), NMISA (South Africa) and SMU (Slovakia);
- two Zener diode voltage standards at 1.018 V and 10 V for the NIS (Egypt), and one Zener diode voltage standard at 1.018 V and 10 V for the BIPM Ionizing Radiation Department.

During the year 2009 the Department provided 62 Calibration Certificates and 5 Study Notes for 14 NMIs of Member States.

4.6 Publications, lectures, travel: Electricity Department

4.6.1 External publications

1. Wood B., Solve S., A review of Josephson comparison results, *Metrologia*, 2009, **46**(6), R13-R20.
2. Giblin S., Willenberg G.-D., Fletcher N., Frequency dependence of gas dielectric-capacitors used in sub-nA reference current generators, *CPEM Digest*, 2010, 318 pp.
3. Fletcher N., Goebel R., A current comparator bridge for the direct measurement of 51.6 k Ω against the quantized Hall resistance, *CPEM Digest*, 2010, 575 pp.
4. Solve S., Chayramy R., The BIPM compact Josephson voltage standard, *CPEM Digest*, 2010, 155 pp.
5. Tang Y., Solve S., Witt T.J., Impact of $1/f$ noise on Josephson voltage standard comparison, *CPEM Digest*, 2010, 175 pp.
6. Goebel R., Fletcher N., Stock M., Pritchard B., Xie R., Coogan P., and Johnson L., Bilateral Comparison of 1 Ω standards (ongoing BIPM key comparison BIPM.EM-K13.a) between the NMIA (Australia) and the BIPM, *Metrologia*, 2009, **46**, *Tech. Suppl.*, 01011.

7. Goebel R., Kurupakorn C., Fletcher N., Stock M., Report on bilateral comparison of 10 k Ω standards (ongoing BIPM key comparison BIPM.EM-K13.b) between the NIMT-Thailand and the BIPM, *Metrologia*, 2010, **47**, *Tech. Suppl.*, 01005.
8. Solve S., Chayramy R., Stock M., Nicolas J., van Theemsche A., Comparison of the Josephson voltage standards of the SMD and the BIPM (part of the ongoing BIPM key comparison BIPM.EM-K10.b), *Metrologia*, 2010, **47**, *Tech. Suppl.*, 01004.
9. Tonina A., Iuzzolino R., Bierzychudek M., Real M., Solve S., Chayramy R., Stock M., Bilateral comparison of 1.018 V and 10 V standards between the INTI (Argentina) and the BIPM, August to October 2009 (part of the ongoing BIPM key comparison BIPM.EM-K11.a and b), *Metrologia*, 2010, **47**, *Tech. Suppl.*, 01002.

4.6.2 Travel (conferences, lectures and presentations, visits)

M. Stock to:

- VSL, Delft (Netherlands), 29-30 November 2009, to attend the EURAMET TCEM meeting;
- Kuala Lumpur (Malaysia), 14-15 December 2009, to attend the APMP TCEM meeting and to give a presentation on the work of the Electricity Department;
- WMO, Geneva (Switzerland), 30 March-1 April 2010, to attend the WMO/BIPM Workshop on Measurement Challenges for Global Observation Systems for Climate Change Monitoring: Traceability, Stability and Uncertainty.

S. Solve and R. Chayramy to:

- SMD, Brussels (Belgium), 19-24 November 2009, to carry out an on-site BIPM Josephson voltage standard comparison;
- EIM, Thessaloniki (Greece), 2-11 March 2010, to carry out an on-site BIPM Josephson voltage standard comparison.

S. Solve:

- ESM, Douai (France), 29 April 2010, to give a presentation on the role of the BIPM and its activities in dc voltage metrology.

N. Fletcher and R. Goebel to:

- NPL (UK), 23 September 2009, for technical discussions about cryogenic current comparators;
- Cryogenic Ltd (UK), 3 December 2009, for test of a new quantum Hall cryostat.

N. Fletcher, R. Goebel, S. Solve and M. Stock to:

- Daejeon (Rep. of Korea), 13-16 June 2010, to attend the CPEM conference and satellite meetings as detailed below. N. Fletcher presented a paper “A current comparator bridge for the direct measurement of 51.6 k Ω against the quantized Hall resistance” and chaired a presentation session at the CPEM conference; S. Solve and M. Stock both chaired poster sessions, and S. Solve presented a poster entitled “The new BIPM Compact Josephson Voltage Standard”;
- M. Stock and S. Solve attended the CCEM-WGkg meeting on 12 June 2010, and M. Stock gave a presentation on the status of the BIPM watt balance;
- N. Fletcher and R. Goebel attended the EURAMET dc and quantum metrology experts meeting on 12 June 2010;
- M. Stock attended the CCEM GT-RF meeting on 13 June 2010;
- S. Solve attended the meeting of ac/dc difference metrology experts on 13 June 2010.

4.7 Activities related to external organizations

M. Stock is a member of the CPEM Executive Committee. N. Fletcher, S. Solve and M. Stock were members of the Programme Committee of the CPEM 2010.

4.8 Activities related to the work of Consultative Committees

M. Stock is the Executive Secretary of the CCEM and the CCPR and a member of several of their working groups. The 20th CCPR meeting was held on 17-18 September 2009. The CCEM working groups met during the CPEM conference, 13-18 June 2010.

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 Department

- Dr L. Locascio (NIST, USA), 11 July 2009, to visit the Electricity Department.
- Mrs E. Barsacq (French Foreign and European Affairs Ministry), 20 August 2009, to visit the Electricity Department.
- Dr J. Schurr (PTB), 3 November 2009, for an external audit of the capacitance service.
- Dr B. Jeanneret (METAS), 4 November 2009, for an external audit of the voltage service.
- Mrs. C. Lorduy (Ministry of Commerce, Industry and Tourism, Columbia), 9 November 2009, to visit the Electricity Department.
- Dr S. Giblin (NPL), 19 November 2009, for an external audit of the resistance service.
- Dr M. Helmy Abd El-Raouf (NIS, Egypt), 23-24 February 2010, to visit the Electricity Department and collect resistance standards.
- Dr R. Behr (PTB, Germany), 17 March 2010, for discussions on programmable JAVS and on acJVS.
- Mr J. Fiander (NMIA, Australia), 26 March to 4 June 2010, to work on the calculable capacitor project.

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

Work has continued on the development of cavity ionization chambers in different materials (graphite and C552, a conducting air-equivalent plastic) and of different wall thickness, for a number of projects. Common to each of these chambers is the precise machining of the component parts and the use of the 3D coordinate-measuring machine (CMM) to determine the air-cavity volume for each chamber. A new method was developed to take into account

* On an IAEA fellowship from the ININ (Mexico) from 10 April 2010 until 12 July 2010.

flexion of the thinnest walls (graphite and plastic discs 50 mm in diameter and only 0.7 mm in thickness) under the light pressure exerted by the CMM.

A chamber in C552 was used in conjunction with a pressure vessel specifically constructed to test the effect of low air pressure on the chamber response in ^{60}Co radiation. As anticipated, the response (normalized to a reference air pressure in the usual way) varies less with air pressure than the nominally-identical graphite-walled chamber tested last year. These results have implications not only for air-kerma measurements at altitude, notably at the ININ (Mexico), but might indicate an error in all ^{60}Co air-kerma determinations using graphite-walled chambers of up to 5 parts in 10^3 depending on the chamber design.

A short paper describing a re-evaluation of the wall and axial non-uniformity corrections for the BIPM ^{137}Cs air-kerma standard, approved by the CCRI(I) at its meeting in 2009, was published in *Metrologia*.

A graphite-walled chamber was supplied to the ARPANSA and a second is under construction for the ININ, for use in each laboratory as a primary air-kerma standard. In both cases the laboratory is responsible for their own air-volume determinations.

The BIPM calorimeter, for the measurement of absorbed dose to water, has been used at regular intervals in the BIPM reference ^{60}Co beam during the year. This is primarily to demonstrate its reproducibility and in the longer term to replace the existing ionometric absorbed-dose standard for ^{60}Co . Working with dose rates typically 5 to 10 times smaller than in accelerator beams, operating the system overnight has enabled a reduction in the statistical uncertainties. The calorimeter has been installed on about ten separate occasions since March 2009, resulting in a statistical standard uncertainty approaching 1 part in 10^3 in the determination of the reference absorbed-dose rate. The calibration method for the calorimeter thermistors is under review to ensure their long-term stability using a newly constructed watertight container. The calorimeter laboratory was rearranged to provide space for the travelling equipment.

Monte Carlo calculations for the absorbed-dose conversion from graphite to water have progressed well. Complex geometry files for the four physical geometries were written for use with the most recent version of the geometry code (PENGEO). Using accelerator beam information (phase-space files) supplied by the NRC and the PTB, calculations were made of the four required parameters, for each of three accelerators beams at each laboratory. A new server was installed and has resulted in a factor of two increase in

calculation speed. Even with this improvement, each accelerator beam requires around ten days of continuous calculation to achieve a statistical standard uncertainty of 0.06 % on the dose conversion factor for that beam. Additionally, a large number of calculations were made to study systematic effects, particularly related to the electron stopping power of graphite. Following this analysis, the combined standard uncertainty of the calculated dose conversion is estimated to be below 3 parts in 10^3 . A draft paper for *Metrologia* is in preparation.

The two 50 kV radiation qualities set up on the medium-energy x-ray generator last year were used to compare the low- and medium-energy standards. The newly constructed free-air chamber for mammography was used as the transfer instrument. The results indicate a difference of 2 to 3 parts in 10^3 between the standards which, although close to the combined standard uncertainty of the standards, is larger than expected when correlation is taken into account. Further measurements are required to confirm this result.

The project to develop an absorbed-dose standard for medium-energy x-rays has progressed with the construction of a thin-walled graphite cavity standard. This has been used in ^{60}Co , with added front and rear walls, to demonstrate that the cavity volume can be accurately measured for such a chamber. Initial measurements in x-rays have confirmed the need for an air-equivalent plastic chamber at the lower energies (the graphite chamber might be constrained to 250 kV and above). Testing of the plastic chamber, whose parts are now constructed, will determine whether the target standard uncertainty of 1 part in 10^2 can be achieved. This will include measurements at low air pressures.

Improvements to the x-ray systems last year, notably the calibration of the voltage dividers and a correction for the parasitic current passing through the cooling system, have resulted in increased stability. The standard deviation of repeat air-kerma determinations over the past year is typically 2 parts in 10^4 .

Following the paper on diaphragm corrections published last year in *Physics in Medicine and Biology*^{*}, a short paper was published in *Metrologia* describing the change to the air-kerma determinations in x-rays resulting from adoption of the new correction factors as well as the correction for scatter from the medium-energy diaphragm support reported last year. A

^{*} 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.

BIPM report was issued describing the preliminary characterization at the BIPM of the cylindrical free-air chamber of the NIS (Egypt) and recommending the procedures to be followed at the NIS to enable the chamber to be used as a primary standard.

A paper was published in *Metrologia* describing the analysis made last year of published measurements and calculations that have an impact on the I -value for graphite, with the conclusion that a value of 82.5 eV (with standard uncertainty 1.5 eV) best fits the observations. This result implies a change of up to 1 part in 10^2 to cavity standards world-wide. This issue is currently being addressed by the ICRU Report Committee on Key Data, with BIPM membership.

The development of the mammography facility was completed in October 2009. The discrepancy existing between the new and existing standards for this energy range was reduced to less than 1 part in 10^3 after adjustment of the collector and guard plate co-planarity to better than 5 μm and by adding a graphite coating to both plates. After installation of the new x-ray tube with a molybdenum target, the beam orientation, shape and size were studied using radiographic films. Horizontal and vertical beam profiles were measured using a thimble-type ionization chamber. Both studies were used to determine the beam centre and to design a collimator system to produce a field with diameter of 100 mm at the reference distance of 600 mm from the tube centre. The new standard, placed on a new calibration bench, was aligned mechanically to measure the beam axis at this reference distance. Four radiation qualities in the range from 25 kV to 35 kV were established as the set of reference beams for mammography comparisons and calibrations. A study of four ionization chambers commonly used in mammography was carried out by comparing their response in the new beams and in the simulated mammography beams established previously on the tungsten-anode tube. A BIPM report was published describing the establishment of these reference radiation qualities for mammography.

Primary measurements and reference chamber calibrations have continued in all of the reference x-ray 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 gamma radiation were carried out, in the ^{60}Co beam with the VNIIM (Russian Federation) and the ARPANSA, and in the ^{137}Cs beam with the VNIIM. The reports have been drafted. Six air-kerma comparisons were carried out in x-ray beams, with the NIST, LNE-LNHB and the GUM (Poland) at low energies, with the GUM at medium energies and with the NMIJ and the NIST in the mammography beams. The NMIJ report is pending publication.

Two comparisons in terms of absorbed dose to water in the ^{60}Co gamma-ray beam were carried out with the NMIJ and the ARPANSA. The report for the ARPANSA has been drafted.

Thirteen reports of previous comparisons were published in the *Metrologia Technical Supplement* for the NIM, BEV (Austria), VSL, NRC, NPL, ENEA (Italy), VNIIFTRI (Russian Federation), LNE-LNHB, ITN (Portugal) and the MKEH (Hungary).

The first key comparison of absorbed dose to water in accelerator beams, BIPM.RI(I)-K6, was carried out at the NRC in June 2009. Although technically challenging, the operation went well and a Draft B comparison report will be published shortly. The second comparison in the series was carried out at the PTB in March 2010 and the results are currently being analysed. Both exercises illustrated the importance of stable beam monitoring and the need for radial uniformity measurements. Transportable systems are now in place to allow independent BIPM measurements of these important parameters. The comparison protocol was revised in September 2009 and again in May 2010, partially based on the experiences gained at the NRC and the PTB. The next two comparisons, at the NIST and the METAS (Switzerland) have been initiated.

The draft report of the high-dose comparison, piloted by the BIPM and using the NIST and NPL alanine dosimeters, is under discussion. The dose-rate effect observed in previous work was observed more clearly in the present comparison. While this effect has the potential to introduce dosimetric errors of up to 4 %, there is at present no consensus on how to present the data. A simplified comparison report combined with a future, more detailed scientific paper is proposed as the best way forward.

The four transfer chambers available for high-energy absorbed-dose comparisons continue to be measured periodically in the ^{60}Co beam. One transfer chamber is calibrated periodically in terms of air kerma in the ^{60}Co beam and in the 250 kV x-ray quality, for use together with a well-type

ionization chamber in the BIPM comparison of brachytherapy dosimetry for ^{192}Ir sources.

Following the meeting of the CCRI(I) in 2009, three further secondments were made available to the BIPM for the work towards brachytherapy comparisons. Firstly, Dr Claus Anderson* automated the measurement system for the well-type ionization chamber and this was then tested at the LNE-LNHB. Then Ms Zakithi Msimang† worked on the determination of the optimum position (sweet-spot) for the $^{166\text{m}}\text{Ho}$ reference source at low dose-rates, produced working instructions and a comparison protocol, and made stability measurements for the reference. During her stay, the equipment was taken for a trial comparison at the NPL. Then, following a consultation with Dr A. Aalbers, the whole system using the two transfer methods was taken to the VSL in November 2009 for the first key comparison, and Dr Anderson also participated in this work. Part of the transfer system was then taken to the LNE-LNHB in 2010 for them to calibrate the well-type chamber as part of the key comparison. Finally, Dr José Alvarez‡ was able to rejoin the BIPM as an IAEA sponsored Research Fellow. He was successful in securing the Cs-137 source for reference measurements at high dose-rate, identifying the sweet-spot for this source, re-establishing the chamber stability measurements, analysing all previous data and conducting a key comparison at the NPL. He also drafted the three first comparison reports. However, the second type of brachytherapy comparison, for the measurement of I-125 brachytherapy seed sources has not yet been launched. This will need further support from the NMIs or a significant change to the protocol. The Brachytherapy Standards working group of the CCRI(I) is being consulted.

5.1.3 Characterizations of national standards for dosimetry

Six series of characterizations of national standards were made in the low-energy, medium-energy and mammography x-ray beams, for the NMISA, NIM and the STUK (Finland), and a further eleven in the BIPM gamma-ray beams in terms of air kerma, ambient dose equivalent and absorbed dose to water, as requested by the NMISA, STUK, NIM and the NRPA (Norway). The BIPM report on the measuring conditions used for these characterizations was updated.

* from the RISØ (Denmark), August 2009.

† from the NMISA (South Africa), from September to October 2009.

‡ from the ININ (Mexico) from 12 April to 9 July 2010.

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 and G. Ratel)

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

During 2009, the BIPM received 17 ampoules filled with 11 different radionuclides from 11 laboratories, the ČMI-IIR (Czech Republic), IFIN-HH (Romania), IRA-METAS (Switzerland), IRMM (European Commission), LNE-LNHB, MKEH, NMIJ, NPL, PTB, RC (Poland) and the VNIIM (Russian Federation).

All the submissions had been made to generate equivalence values in the key comparisons. One short-lived radionuclide, ^{64}Cu has been standardized for the first time by three different laboratories, namely the ČMI-IIR, the NPL and the PTB. The results agree with each other and with the value predicted by the SIRIC programme. Counting the ten newly registered measurements for 2009, i.e. ^{64}Cu (PTB), ^{85}Sr (RC), ^{131}I (NMIJ), ^{133}Ba (IRA-METAS), ^{134}Cs (IRA-METAS), ^{137}Cs (IFIN-HH), ^{152}Eu (LNE-LNHB and VNIIM), ^{241}Am (MKEH and RC) and a previous submission of ^{75}Se by the LNE-LNHB registered this year, the cumulative number of ampoules measured since the beginning of the SIR, in 1976, is now 931, corresponding to a total of 692 independent results for 64 different radionuclides.

The final SIR values for the two ampoules of ^{177}Lu sent by the IRMM and the NPL are awaiting the conclusions of the analysis of the international comparison of a solution of ^{177}Lu , which is underway.

The result for the submission of ^{134}Cs by the NPL is still pending their result.

Update reports of five comparisons were published in the *Metrologia Technical Supplements* i.e. for ^{51}Cr , ^{57}Co , ^{64}Cu , ^{133}Ba and $^{166\text{m}}\text{Ho}$.

There are currently three results from 2006 and four from 2007 that are awaiting publication in the KCDB. Of those submitted after 2007, 75 % 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

* Part-time (60 % then 80 % from September 2009).

recommendation of the CCRI(II), 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 BIPM coordinated and participated in an exercise for the KCWG(II) on the calculation of the KCRVs. Typical SIR data were distributed to the KCWG(II) and three different methods to evaluate the KCRVs were proposed by the participants (the arithmetic mean with new rules to identify outliers, the largest consistent subset and the partially weighted mean). The results were presented and discussed at the KCWG meeting. The third method proposed looked the most promising and is being investigated further.

All the SIR measurements are now carried out with the new data acquisition system based on up-to-date electronics. The measurement of the linearity of the new electronics has been repeated using three additional ^{64}Cu sources and the data analysis is in progress. A new FORTRAN compiler was purchased and the SIRIC software (developed in collaboration with the NPL) recompiled with the updated NAG* libraries. This will enable the BIPM to maintain the software and test some modifications before distribution to the NMIs interested in using the same programme for their ionization chambers.

A successful internal audit of the SIR within the BIPM Quality System was carried out in the second half of 2009.

5.2.2 Gamma spectrometry

Routine measurements of potential impurities in short-lived radionuclides are made using the Ge(Li) spectrometer. No impurity was detected in the ^{64}Cu solutions submitted to the SIR by the NPL and the LNE-LNHB, or in the ^{67}Ga solutions submitted to the SIR by the PTB and the NIST.

Work is well in hand to calibrate the high-purity germanium spectrometer (HPGe). The efficiency measurements at the 6 different source positions are in progress.

* Numerical Algorithms Group, Oxford, UK.

5.2.3 Extension of the SIR to short-lived radionuclides

The preliminary results of the first ^{99m}Tc comparison using the SIR Transfer Instrument (BIPM.RI(II)-K4.Tc-99m) which took place at the NIST show agreement with the KCRV within one standard uncertainty. This successful result is encouraging and several NMIs have requested permission to participate in this ongoing comparison. The uncertainty budget for the transfer instrument is being finalized. Monte-Carlo simulations using the package PENELOPE2008 have enabled an evaluation of the uncertainty components related to the radioactive solution volume and density and to the glass ampoule characteristics. The simulations also confirmed the relative effect of 2×10^{-3} measured at the NIST due to the presence of ten drops of solution on the inner walls of the ampoule. The protocol of the comparison has been changed on the basis of the Monte-Carlo simulations and following the experience gained at the NIST. The Draft A report of this first comparison has been prepared.

5.2.4 Extension of the SIR to pure beta emitters

Both the commercial Beckman-spectrometer, using the CIEMAT-NIST method, and the in-house developed TDCR-spectrometer are proposed in parallel for the extension of the SIR to pure beta emitters. Effort has been concentrated over the last 12 months on the TDCR-spectrometer. To implement the Compton tracer method developed by P. Cassette at the LNE-LNHB, a source of ^{241}Am of activity 37 MBq has been purchased. The inner-detector housing has been altered by the workshop to allow easy positioning of the ^{241}Am source. A circular, 5 mm thick, curved lead shutter which can be located between the source and the scintillator has been designed to absorb the 60 keV γ -radiation when the external ^{241}Am source is not used. A high-purity Ge-spectrometer has been installed to face the centre of the lower TDCR-spectrometer wall, whose thickness has been reduced to 0.1 mm at this location. The detection chamber has also been surrounded by additional lead shielding to reduce the background radiation level.

The electronics of the three pre-amplifiers have been redesigned to improve the signal to noise ratio as the initial fast (ns) mV signals had proved too small for proper discrimination. Each of the pre-amplifiers is composed of three fast stages, the amplification of which has been chosen to avoid large and highly-perturbing oscillations in the amplified outputs. The total amplification of these new preamplifiers is such that the output signals are

now of some hundreds of mV. The BIPM-software has been altered to take rigorously into account the asymmetry of the photomultipliers. Presently, the ionization quenching is being evaluated independently using the Bethe formalism including effects related to compounds and mixtures, as scintillants are seldom pure substances. Once this software is validated it will be included in the TDCR analysis programme to allow the use of scintillants of various chemical compositions.

5.2.5 CCRI activity comparison of ^{85}Kr

Seven participants in this international comparison completed their reporting forms. Three different techniques, i.e. γ -spectrometry (4 laboratories), $4\pi(\text{PC})$ internal gas counting (3 laboratories) and standardization by a 4π - γ calibrated ionization chamber (1 laboratory) were used. Six of the results are consistent and the SIR measurements previously made of the ampoules will enable a direct link of this comparison to the SIR. The Draft A report is in preparation. As the NIST was unable to participate because of a detector failure, and the value obtained by the LNE-LNHB is not as accurate as expected, it is not likely that this comparison will identify the cause of the present discrepancy in the SIR results observed for this radionuclide.

5.2.6 CCRI activity comparisons of ^3H

Having postponed the deadline of the activity comparison of a solution of tritiated water, all the results were received by the BIPM by the end of November 2009. Similar aliquots of about 5 g of tritiated water, taken from a large amount of initial solution, had been prepared by the LNE-LNHB and poured into ampoules which were then flame-sealed. As ^3H cannot be detected in ionization chambers, no measurements with the SIR were foreseen. The LNE-LNHB forwarded the ampoules to the 19 potential participants and 15 sets of results, including those of the BIPM have been submitted. Eight different techniques were used, mainly those based on liquid-scintillation detection, i.e. the CIEMAT/NIST method with ^{54}Mn as a tracer, several variants of the TDCR method and also a counting method relying on the use of a standard of ^3H . Two further methods, one of which is based on a differential proportional counter and the other on the use of two NaI(Tl)-detectors and ^{54}Mn as a tracer, were used. When one outlier result is omitted, the other fourteen results lie within +2% and

– 4 % and are in agreement within the uncertainties evaluated for a coverage factor $k = 1$ with the arithmetic mean of the comparison. The Draft A report is in preparation.

5.2.7 Measurements of ^3H

The BIPM took part in the CCRI(II)-K2.H-3 comparison using its BIPM-developed TDCR-spectrometer for the first time. The analysis of the ^3H activity comparison results showed that the BIPM result was 4 % lower than the mean value of the comparison. To characterize the origin of this difference, although within the uncertainties, some further investigations have been made. Using the proximity of the LNE-LNHB with the BIPM, a cross check between these two laboratories was made using an exchange of sources. There seems to be no problem with the sources prepared by the BIPM but the BIPM measurements with the TDCR-spectrometer showed the same bias as during the comparison. Further investigation identified a problem in the signal level and the three fast pre-amplifiers have been modified to eliminate this problem, as described in §5.2.4. Some minor changes have also been made to the signal processing software. Validation tests have been successful but the experimental data is still being analysed.

5.2.8 CCRI Comparison of uncertainty evaluation

The BIPM participated in the CCRI comparison of uncertainty evaluation in coincidence measurements that was piloted by the IRA with the assistance of the NPL who provided the data. Each participant received the same set of coincidence measurement data with all the relevant information necessary to evaluate the uncertainties. The preliminary comparison results were presented at the UCWG(II) which showed that the BIPM participation was successful. The report of the comparison is awaited.

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

The Ionizing Radiation Department now maintains the BIPM thermometry standards to enable BIPM calibrations of SPRTs for in-house use at the

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

uncertainty levels required particularly for calorimetry, electricity and mass standards. An in-house calibration test-run was made towards the end of 2009 and in parallel, a bi-lateral indirect comparison, limited in temperature, using SPRTs as transfer instruments was carried out between the BIPM and the LNE-INM. The draft B report of this CCT-K3.1 comparison has been circulated to the CCT for their approval. The QS procedure and laboratory instructions were revised and an internal audit took place at the end of 2009. The results of the comparison and the audit demonstrated that the thermometer calibration work for the BIPM departments can be carried out within the 300 μK uncertainty requested. We are indebted to S. Solve for his knowledge transfer.

Following the comparison, the first calibration campaign since 2006 took place in early 2010, in which sixteen SPRTs belonging to the Mass, Electricity and RI departments were calibrated. The campaign also covered an internal comparison of water triple point cells as part of the quality system.

5.4 Publications, lectures, travel: Ionizing Radiation Department

5.4.1 External publications

1. Allisy-Roberts P.J., Kessler C., Burns D.T., Berlyand V., Berlyand A., Comparison of the standards for absorbed dose to water of the VNIIFTRI, Russia and the BIPM in ^{60}Co γ -rays, *Metrologia*, 2010, 47, *Tech. Suppl.*, 06003.
2. Allisy-Roberts P.J., Kessler C., Burns D.T., Delaunay F., Donois M., Comparison of the standards for air kerma of the LNE-LNHB and the BIPM for ^{137}Cs gamma radiation, *Metrologia*, 2009, 46, *Tech. Suppl.*, 06011.
3. Allisy-Roberts P.J., Kessler C., Burns D.T., Zhongqing T., Jiacheng H., Xiaoyuan Y., Kun W., Comparison of the standards for air kerma of the NIM and the BIPM for ^{60}Co gamma radiation, *Metrologia*, 2009, 46, *Tech. Suppl.*, 06013.
4. Burns D.T., A re-evaluation of the I -value for graphite based on an analysis of recent work on W , $s_{c,a}$ and cavity perturbation corrections, *Metrologia*, 2009, 46, 585–590.

5. Burns D.T., Kessler C., Allisy P.J., Re-evaluation of the BIPM international standard for air kerma in x-rays, *Metrologia*, 2009, 46, L21–L23.
6. Kessler C., Allisy-Roberts P., Burns D.T., Cardoso J., Oliveira C., Comparison of the standards for air kerma of the ITN (Portugal) and the BIPM for ^{137}Cs γ -rays, *Metrologia*, 2009, 46, *Tech. Suppl.*, 06012.
7. Kessler C., Allisy P.J., Burns D.T., Duane S., Manning J., Nutbrown R., Comparison of the standards for air kerma of the NPL and the BIPM for ^{60}Co γ -rays, *Metrologia*, 2010, 47, *Tech. Suppl.*, 06004.
8. Kessler C., Allisy-Roberts P.J., Burns D.T., Guerra A.S., Laitano R.F., Pimpinella M., Comparison of the standards for absorbed dose to water of the ENEA-INMRI (Italy) and the BIPM for ^{60}Co γ -rays, *Metrologia*, 2010, 47, *Tech. Suppl.*, 06002.
9. Kessler C., Allisy-Roberts P.J., Csete I., Machula G., Comparison of the standards for air kerma of the MKEH and the BIPM for ^{137}Cs gamma radiation *Metrologia*, 2010, 47, *Tech. Suppl.*, 06013.
10. Kessler C., Allisy-Roberts P.J., McCaffrey J.P., Ross C.K., Comparison of the standards for air kerma of the NRC and the BIPM for ^{60}Co gamma radiation, *Metrologia*, 2010, 47, *Tech. Suppl.*, 06005.
11. Kessler C., Allisy-Roberts P.J., de Prez L.A., van Dijk E., Comparison of the standards for air kerma of the VSL and the BIPM for ^{60}Co gamma radiation, *Metrologia*, 2010, 47, *Tech. Suppl.*, 06015.
12. Kessler C., Allisy-Roberts P.J., Steurer A., Tiefenboeck W., Gabris F., Comparison of the standards for air kerma of the BEV and the BIPM for ^{60}Co gamma radiation, *Metrologia*, 2010, 47, *Tech. Suppl.*, 06006.
13. Kessler C., Allisy-Roberts P.J., Steurer A., Tiefenboeck W., Gabris F., Comparison of the standards for air kerma of the BEV and the BIPM for ^{137}Cs gamma radiation, *Metrologia*, 2010, 47, *Tech. Suppl.*, 06007.
14. Kessler C., Burns D.T., Allisy-Roberts P.J., Re-evaluation of the BIPM standard for air kerma in ^{137}Cs gamma radiation, *Metrologia*, 2009, 46, L24–L25.
15. Kessler C., Burns D.T., Allisy-Roberts P.J., McCaffrey J.P., McEwen M.R., Ross C.K., Comparison of the standards for absorbed dose to water of the NRC and the BIPM for ^{60}Co gamma radiation, *Metrologia*, 2010, 47, *Tech. Suppl.*, 06016.

16. Michotte C., Nonis M., Experimental comparison of different dead-time correction techniques in single-channel counting experiments, *Nucl. Instr. and Meth.*, 2009, A(608), 163-168.
17. Michotte C., Courte S., Ratel G., Sahagia M., Wätjen A.C., Fitzgerald R., Maringer F.-J., Update of the ongoing comparison BIPM.RI(II)-K1.Co-60 including activity measurements of the radionuclide ^{60}Co for the IFIN-HH (Romania), NIST (USA) and the BEV (Austria), *Metrologia*, 2010, 47, *Tech. Suppl.*, 06010.
18. Michotte C., Courte S., Ratel G., Sochorová J., Update of the comparison BIPM.RI(II)-K1.Co-56 of activity measurements of the radionuclide ^{56}Co to include the result of the CMI-IIR, *Metrologia*, 2010, 47, *Tech. Suppl.*, 06011.
19. Michotte C., Ratel G., Courte S., Garcia-Toraño E., Kossert K., Nähle O., van Wyngaardt W.M., Simpson B.R.S., Update report of the BIPM comparison BIPM.RI(II)-K1.Na-22 of activity measurements of the radionuclide ^{22}Na to include the CIEMAT, PTB and the NMISA, *Metrologia*, 2010, 47, *Tech. Suppl.*, 06001.
20. Zimmerman B.E., Altizoglou T., Rodrigues D., Broda R., Cassette P., Mo L., Ratel G., Simpson B., van Wyngaardt W., Wätjen C., Comparison of triple-to-double coincidence ratio (TDCR) efficiency calculations and uncertainty assessments for ^{99}Tc *Appl. Radiat. Isot.*, 2010, 68, 1477-1481.

5.4.2 BIPM reports

21. Allisy-Roberts P.J., Burns D.T., Kessler C., Measuring conditions used for the calibration of national ionometric standards at the BIPM, *Rapport BIPM-2009/04*, 20 pp.
22. Burns D.T., Kessler C., Roger P., El-Sersy A.R., Preliminary characterization of the NIS free-air chamber standard at the BIPM, *Rapport BIPM-2009/02*, 12 pp.
23. Kessler C., Roger P., Burns D.T., Establishment of reference radiation qualities for mammography, *Rapport BIPM-2010/01*, 10 pp.

5.4.3 Travel (conferences, lectures and presentations, visits)

P.J. Allisy-Roberts to:

- London (UK), 2 July 2009, 21 January 2010 and 31 March 2010, for meetings of the editorial board of *Journal of Radiological Protection*; 6 August 2009, to attend a meeting of Working Groups Chairs for the UK National Measurement Office (NMO); 22 June 2010, to chair a meeting for Radiation Protection Advisers;
- Teddington (UK), 4 September 2009, 7 January 2010 and 4-5 February 2010, to chair meetings of the Acoustic and Ionizing Radiation Working Group of the UK NMS; 29 September 2009, with Z. Msimang (NMISA), to the NPL for a brachytherapy trial comparison; 8-11 June 2010, with J. Alvarez (IAEA/ININ), to conduct a brachytherapy dosimetry comparison at the NPL;
- Vienna (Austria), 15-19 March 2010, to chair the IAEA Standing Scientific Committee; 12-14 May 2010, to attend a meeting of the Dosimetry Symposium Scientific Committee;
- LNE (France), 13 November 2009, to attend the Comité Scientifique for ionizing radiation;
- LNE-LNHB (France), 12 March 2010, for a brachytherapy dosimetry comparison; 1 April 2010, to attend the Comité Scientifique for ionizing radiation;
- VSL (Netherlands), 24-27 November 2009, with C. Andersen (RISØ), for the first high-dose-rate brachytherapy comparison;
- Versailles (France), 2-4 December 2009, with S. Picard, to attend a conference on radiotherapy accidents;
- Ljubljana (Slovenia), 21-23 May 2010, to attend an Officers' meeting of the European Federation of Organisations for Medical Physics and make a presentation about the BIPM accelerator dosimetry programme.

D.T. Burns to:

- Dresden (Germany), 11-15 September 2009, to attend a meeting of the Main Commission of the ICRU;
- Paris (France), 15-16 October 2009, to attend a meeting of the EURAMET Contact Persons for Ionizing Radiation;
- Braunschweig (Germany), 8-12 March 2010, for a comparison of absorbed-dose standards in the PTB linear accelerator beams.

S. Picard to:

- Saint-Denis (France), 28 September 2009, with M. Nonis, in connection with the CCT-K3.1 comparison in thermometry with LNE-INM/CNAM;
- Braunschweig (Germany), 26 November 2009, to discuss the future key comparison of accelerator beams with Dr R.-P. Kapsch (PTB);
- Braunschweig (Germany), 8-26 March 2010, with P. Roger, for a comparison of absorbed dose standards in the PTB linear accelerator beams.

G. Ratel to:

- Bratislava (Slovakia), 7-11 September 2009, to attend the 17th ICRM Conference and then the ICRM Executive Board. G. Ratel also refereed 9 articles to be published in the proceedings of the conference;
- Roissy (France), 30 November 2009 and 1 December 2009, with S. Courte, to attend an APAVE course to obtain the aptitude certificate for the transport of dangerous goods;
- Cape Town (South Africa), 15–17 April 2010, to take part in the assessment of the NMISA as a technical assessor in radioactivity measurements;
- Tsukuba (Japan), 19-20 May 2010, to attend the ICRM Executive Board meeting.

C. Michotte to:

- Bratislava (Slovakia), 8–10 September 2009, to attend the International Conference on Radionuclide Metrology and its applications and make an oral communication on the first comparison of activity measurements of ^{99m}Tc using the SIR transfer instrument at the NIST;
- Cape Town (South Africa), 10–13 November 2009, to attend a JCGM/WG1 meeting as the BIPM contact person and Rapporteur.

5.5 Activities related to external organizations

P.J. Allisy-Roberts retired from the Working Group for the UK NMS programme for ionizing radiation and acoustics, having served since 1991 and been appointed Chairman in 1998. She is presently Chairman of the UK Ionising Radiation Health and Safety Forum and is the BIPM representative on the IAEA SSDL Scientific Committee which she currently chairs. She is

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 and a member of two ICRU Report Committees, on Key Data for Dosimetry and on Operational Quantities for Radiation Protection. He is the BIPM contact person for the EURAMET-TC for ionizing radiation.

G. Ratel is the BIPM representative on the International Committee for Radionuclide Metrology (ICRM) and is the President of the ICRM Nominating Committee.

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 seven Working Group meetings during the last 12 months in addition to a special CCRI meeting to discuss strategy, the latter in May 2010. She is also Executive Secretary of the CCAUV.

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 May 2010 and were also attended by C. Kessler and S. Picard. D.T. Burns is also member of an *ad-hoc* group evaluating the effect of excess charge on the value for W_{air} .

C. Michotte is the coordinator of the CCRI(II) Working Group on the SIR Transfer Instrument and a member of the KCWG(II) which met in April 2010. She is also the contact person at the BIPM and *rapporteur* for the JCGM/WG1 that met in November 2009 and May 2010.

G. Ratel is a member of the CCRI(II) working group on the extension of the SIR to beta emitters, which met on 7 September 2009, the KCWG(II) which met on 9 September 2009 and 27 April 2010, the UCWG(II), which met on 28 April 2010, and the BqWG(II).

5.7 Visitors to the Ionizing Radiation Department

- Dr Duncan Butler (ARPANSA), 4 December 2009.
- Dr Ganesan Ramanathan (ARPANSA), 30 April 2010.

5.8 Guest workers

- Dr Klaus Andersen (RISØ), 10 August to 4 September 2009.
- Mrs Zakithi Msimang (NMISA), 1-30 September 2009.
- Dr Anna Villevalde (VNIIM), 16-20 November 2009.
- Dr Takahiro Tanaka, Dr Tadahiro Kurosawa (NMIJ), 23-27 November 2009.
- Dr Yuichiro Morishita (NMIJ), 30 November to 4 December 2009.
- Mr Sibusiso Jozela (NMISA), 18-29 January 2010.
- Dr Jinjie Wu (NIM), 18-29 January 2010.
- Dr Wang Kun (NIM), 19-26 February 2010.
- Dr Adrian Knyziak (GUM), 26 April to 7 May 2010.
- Dr David Webb (ARPANSA), 25 May to 4 June 2010.
- Dr Jose Alvarez (ININ), IAEA Research Fellow, 12 April to 9 July 2010.

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

Two laboratories, the NIST (United States of America^{*}) in June 2009 and the CHMI (Czech Republic) in September 2009, brought or sent their ozone national standard to the BIPM for a direct comparison with the BIPM-SRP27 reference standard as part of the second cycle of the key comparison BIPM.QM-K1 which started in May 2009. Publication of reports of the second cycle comparisons have been postponed to allow publication of all reports of comparisons performed in the first cycle (2007-2008).

After the 23rd meeting of the CCQM Gas Analysis Working Group in April 2010, two pending reports (report of the comparison with NMISA performed

^{*} henceforth USA.

in July 2008 and with NPLI performed in February 2009) of the first cycle have been reviewed and published in *Metrologia Technical Supplement* in May 2009. The draft B report of the comparison with VSL, performed in September 2008, is the last report still under review by the CCQM GAWG.

In December 2009, a comparison using the BIPM.QM-K1 protocol was performed with the Agência Portuguesa do Ambiente (Portugal), which has not yet been nominated as a Designated Institute in the CIPM MRA. The report of this comparison will be published as a BIPM report.

In February 2010, a “NIST SRP upgrade kit” was successfully installed in one of the SRPs maintained by the LNE (SRP21). The installation was performed within the BIPM laboratories and a report was sent to the LNE.

6.1.2 Comparisons using the gas-phase titration facility

Trace oxygen measurements were performed on the system. Following these measurements the BIPM's gas phase titration (GPT) system was redesigned, removing the majority of the FEP tubing. The reaction vessel, originally made of 6.35 mm FEP tubing, has been replaced by 11 m of 11 mm borosilicate glass tubing. This new design is currently under test. The molybdenum converter within the NO_x chemiluminescence analyser has been replaced by a photolytic converter constructed at the BIPM. The photolytic converter is specific to nitrogen dioxide and is unaffected by ozone but has a lower conversion factor. The conversion efficiency of the photolytic convertor has been measured at 26 % but is expected to be more reproducible and species specific than the original molybdenum converter.

6.1.3 NO gas standard comparison facility

The TEI 42C chemiluminescence analyser has been successfully replaced by an Eco Physics CLD70E analyser within the BIPM's comparison facility. Stability studies have been performed on primary standards owned by the BIPM for about the last 6 years. The stability of such standards has been assessed and the information used in discussions for the establishment of a Central Calibration Laboratory for the WMO GAW network. The internal procedure on the value assignment of secondary gas standards for internal use is under revision.

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

The CCQM-K74 comparison has been successfully concluded and Draft A of the comparison report was circulated to participants in June 2010. The CCQM-K74 comparison was designed to evaluate the level of comparability of the laboratories' measurement capabilities for nitrogen dioxide (NO₂) at a nominal mole fraction of 10 µmol/mol. The proposed reference value for the comparison is based on the values assigned with the BIPM's dynamic generation facility with appropriate corrections for the presence of nitric acid quantified by FTIR spectroscopy. The quantification of gas mole fractions by FTIR spectroscopy is under study in CCQM-P110, the report of which is currently being finalized by the BIPM, and will be the basis of a workshop to be held during the CCQM GAWG meeting in November 2010.

6.1.5 Key comparison on methane standards

The programme to establish a facility for determining the international comparability of methane in air standards at ambient level continued in 2009-2010 with the purchase of a gas chromatography (GC-FID) facility. This facility, in addition to the Cavity ring-down spectroscopy (CRDS) facility purchased in 2008-2009, will allow the consistency of methane in air standards under repeatability conditions to be determined, an approach which will allow analytical measurement uncertainties to be minimized. Measurements are expected to start by the end of 2010.

6.1.6 Formaldehyde

The main parts of the new facility for the generation of formaldehyde (HCHO) in nitrogen were installed and validated during 2009-2010. A Cavity Ring-Down Spectrometer (CRDS) for the measurement of formaldehyde in nitrogen at mole fractions in the range 100 nmol/mol to 20 µmol/mol has been tested against mixtures generated by dilution from a cylinder of 10 µmol/mol of formaldehyde. Acceptance tests including criteria on the linearity, short term repeatability and reproducibility have been successfully fulfilled. A system consisting of a permeation chamber attached to a magnetic suspension balance for the dynamic generation of formaldehyde in nitrogen mixtures has been tested for stability of the mass measurement as well as possible losses of formaldehyde within the chamber.

To reach the acceptance criteria, the original system had to be improved, mainly in terms of insulation between the hot part (80 °C) and the balance. Measurements of possible losses of formaldehyde have been performed using an external source, also based on permeation, and have demonstrated the suitability of the system. Finally, the first tests of formaldehyde generation with a permeation tube of paraformaldehyde maintained at 100 °C have started and the stabilization period has been studied. An autosampler allowing future comparisons with up to 15 gas standards in cylinders has been constructed and installed. The FTIR spectrometer has been linked to the system in order to start the analysis of possible impurities in the formaldehyde/nitrogen mixtures.

6.1.7 Development of a laser-based SRP and ozone absorption cross-section measurements

Improvements in isolating the laser-based SRP from its environment have led to an improvement in the power stabilization of the laser such that its power can now achieve a stability (Allan deviation) better than 10^{-5} between 1 and 200 seconds. By additionally decreasing polarization-related issues the laser-based SRP now has the same noise level at 244 nm as the Mercury-lamp based SRP at 254 nm. Using relative ozone absorption cross-section values published in 2004, the two types of SRPs produce measurement results of ozone concentration that agree within the measurement noise. Accurate measurements of the optical path length inside the instrument gas cells using a method based on interferometry have started.

In parallel, the facility for direct measurement of the ozone absorption cross section in the far UV has been designed. Vacuum pumps, vacuum chamber parts, pressure gauges, measurement cell and a mass spectrum analyser (for impurity analysis) have been purchased. The design of the pure ozone generator has also been completed and all parts are being ordered.

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

The Organic Analysis Programme is continuing to coordinate CCQM comparisons for the assignment of the mass fraction of organic compound pure substances that are intended for use as primary calibrators. As part of their overall planning for future key comparisons, 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 should be compulsory for all NMIs which provide services under the CIPM MRA or currently have CMC claims in the Key comparison database in the area of organic analysis.

Agreement was also reached within the CCQM OAWG for the BIPM Organic Analysis Programme to include the coordination of comparisons for the assignment of the mass fraction content of organic substances in solution. In 2011 the BIPM will coordinate key comparison CCQM-K78 for the assignment of the mass fraction content of aldrin in a solution of isooctane. In addition, the BIPM's Organic Analysis Programme for the investigation of pure material characterization methods for the value assignment of analytes of higher molecular weight and complexity, such as peptides/proteins, is currently studying the following: pure amino acids, angiotensin I and insulin. The facilities at the BIPM have been adapted so that they can also be used for the handling, preparation, characterization and storage of peptide/protein materials for use in future CCQM purity assessment comparisons.

6.2.1 Method development

The development and validation of analytical methods for use in the production and characterization of the CCQM-K55.b (aldrin) comparison material was completed. The major impurities in the material were found to be structurally related impurities and residual organic solvent.

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

- GC-MS and GC-FID methods for the identification and quantification by external calibration of aldrin and related compounds;
- Protocols based on GC-FID analysis for testing the stability and homogeneity of the related substance impurity content of this material;
- LC-UV methods for independently confirming the identity assignments and quantifications of the related substance impurity content of the CCQM-K55.b study material;
- Investigation of LC-MS/MS methods using electrospray and photoionization detection for the analysis of aldrin. These methods

were not pursued because of difficulties in obtaining suitable mass spectroscopic decomposition profiles;

- Analysis of NMR spectroscopic data obtained by an external collaborator to confirm the assigned impurity profile of the CCQM-K55.b material and to obtain by qNMR an independent assessment of its mass fraction aldrin content;
- Optimization of a GC-MS method for determination of residual VOCs in the CCQM-K55.b candidate material and its application in assessing the stability and homogeneity of the VOC content of the material;
- Development of Karl Fischer titration conditions for the assignment of the water content of the candidate material;
- Application of thermogravimetric analysis to provide confirmatory data for the estimate of VOC and water content obtained by other techniques;
- Trace metal analysis to confirm the absence of significant levels of metals;
- Elemental microanalysis of percentage carbon and hydrogen content to provide supporting data for the BIPM characterization of the candidate material.

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-K78 (aldrin in solution) comparison has started.

Procedures developed or investigated to date for the CCQM-K78 candidate materials include:

- Preparation of gravimetrically assigned solutions of aldrin in isooctane;
- Sub-sampling of aliquots of the solution into ampoules followed by flame sealing;
- GC-FID methods for assessing the homogeneity of a batch of sealed ampoules.

6.2.3 Peptide calibrator studies

The BIPM has started to investigate pure material characterization methods for analytes of higher molecular weight and complexity that are of direct relevance to the CCQM. Angiotensin I and insulin were chosen as model systems after consultation with the NIST and the NIBSC. Both substances play an important role in the field of clinical chemistry, laboratory medicine, pharmaceutical analysis and sports drug testing. Study strategies have been developed for both substances and were presented in the course of the annual CCQM meetings at the BIPM. Procurement of pure amino acids, angiotensin I, insulin and the specific laboratory equipment required (e.g. hydrolysis instrumentation, rotary vacuum evaporator, mass spectrometry system) has been initiated and/or completed.

The development and validation of analytical methods for amino acids was started for their use in the characterization of both angiotensin I and insulin. Identification and quantification of major impurities present in a set of selected amino acids is of utmost relevance for peptide/protein value assignment based on amino acid analysis.

Procedures under development or investigation for the determination of structurally related and other impurities in commercially available pure isoleucine, leucine, phenylalanine, proline, tyrosine and valine materials have included:

- LC-UV-CAD methods for the identification and quantification of related compounds by external calibration of the selected amino acids;
- LC-MS/MS methods using hydrophilic interaction chromatography and electrospray ionization for the qualitative identification and quantification of the selected amino acids and related compounds. The procedures will be used for both the characterization of the selected amino acid materials and for the amino acid analysis of hydrolyzed peptides/proteins;
- Karl Fischer titration methods for the determination of the water content of the selected amino acid materials;
- GC-MS method for determination of volatile organic impurities of the selected amino acid materials;
- Thermo gravimetric analysis as a supporting method for the estimation of the total volatiles and water content.

In addition, the recruitment process for a Research Fellow working in the field of larger molecule purity analysis has started.

6.2.4 Coordination of CCQM comparisons for purity assessment

The Final Summary Report for the CCQM-P20.f (Digoxin) comparison has been accepted and will be published in 2010 as a *Metrologia Technical Supplement*.

6.2.5 Purity comparison CCQM-K55.a (estradiol)

Results for the purity comparison CCQM-K55.a (estradiol) were received in March 2009 and an initial summary was circulated to all participants prior to initial discussion in detail at the CCQM Organic Analysis Working Group meeting in April 2009. Follow-up studies resolved the cause of the significant differences in the water content originally reported by the participants in the comparison and these were discussed at the November 2009 meeting.

It was agreed that the main reason for the original lack of agreement arose when water content was measured by Karl Fischer using heated oven-transfer to release water from the estradiol sample. If the transfer temperature was below the melting point of estradiol (176 °C) water was only partially released which resulted in an underestimation of the water content of the comparison sample.

As requested at the April 2009 CCQM OAWG, the BIPM prepared a draft A report for the November 2009 meeting and a reference value for the estradiol content of the comparison sample was proposed, based on a mass balance approach similar to that used for the CCQM-P20.f comparison. Based on these discussions a draft B key comparison report was discussed at the April 2010 CCQM OAWG and agreement was reached in principle to the proposed KCRV and associated uncertainty.

6.2.6 Purity comparison CCQM-K55.b (aldrin)

The CCQM-K55.b (Aldrin) comparison material has been prepared at the BIPM by purification of technical grade aldrin donated by the NMIA. The bulk material was sub-divided into units of 500 mg. The impurity profile of

the material was assigned and the suitability of the homogeneity and stability of the batch for the purposes of the study was demonstrated. A call for participation was circulated in January 2010 and eighteen NMIs or DIs registered to participate in the key comparison, with an additional seven laboratories participating in the parallel pilot study CCQM-P117.b. The comparison samples were distributed to the participating institutes in May 2010 and the comparison results will be discussed at the November 2010 CCQM OAWG meeting.

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. S. Maniguet is coordinating the development of the JCTLM Database.

The annual JCTLM Working Group 1 and 2 joint meeting was held in conjunction with the American Association for Clinical Chemistry (AACC) meetings in Chicago in July 2009, and was followed by a workshop on 'Measurement Standards Needs for Next Generation Healthcare' organized under the auspices of the JCTLM/CCQM/NIST. JCTLM activities were also presented during a session on 'Metrology and its Application to the Clinical Laboratory' during the AACC meeting.

The eighth meeting of the Executive Committee of the JCTLM was held at the BIPM on 3-4 December 2009, and Prof. M. Müller (IFCC) was appointed as the new Chairman of the JCTLM for a term of two years, renewable for an additional period of two years. The BIPM was re-appointed as Secretariat of the JCTLM for three consecutive two year periods.

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 drugs, enzymes or electrolytes. The timetable for the review of the outstanding WG1 Cycle 3 nominations for reference materials and reference measurement procedures for electrolytes was agreed. The document listing the scope of activity for each review team was approved and made available on the JCTLM website. The recommendation made by the review team for nucleic acids to publish the three outstanding WG1 Cycle 3 nominations for reference materials under a new list category "List III" which covers reference materials with nominal properties was approved.

The JCTLM Database was updated in January 2010 to include WG1 Cycle 6 reference materials and WG2 Cycle 4 reference measurement laboratory services approved by the Executive Committee during its annual meeting. In May 2010 there were 49 reference measurement laboratory services removed from the JCTLM Database, as these laboratories had failed to meet the ISO 15195 and ISO/IEC 17025 accreditation application deadline.

As of June 2010 the JCTLM database contains:

- 227 available certified reference materials that cover 12 categories of analytes. Among these reference materials, 33 are currently listed in List II (List II includes reference materials value-assigned using internationally agreed-upon protocols), and 3 are listed in List III (List III covers reference materials having nominal properties);
- 146 reference measurement methods or procedures that represent about 75 different analytes for eight categories of analytes;
- 86 reference measurement services that can be delivered by 10 reference laboratories from 6 countries covering six categories of analytes.

The WG1 Cycle 7 call for nominations of higher order reference materials and reference measurement methods or procedures, and the WG2 Cycle 5 call for nominations of reference measurement laboratory services, were announced on the JCTLM website in January 2010, and an email notification was sent to about 300 potential JCTLM contributors. As of May 2010, 42 nominations for materials, 30 nominations for procedures and 4 nominations for services, were received and sent to Review Teams for evaluation.

The redesign and update of the JCTLM database, due to changes in JCTLM nomination forms necessitated by the revision of ISO 15194, was undertaken by an external contractor. The new web based version of the system was published in March 2010.

WG1 procedures and nomination forms have been revised for consistency with the standards ISO 15194:2009 and ISO 15193:2009, VIM 3 and addition of the List III criteria for nominal properties, and were published on the JCTLM website in January 2010.

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 published on the JCTLM web pages in December 2009.

6.4 Activities related to metrology in bioanalysis

The contract to deliver a BIPM defined study on Study of Measurement Service and Comparison Needs for an International Measurement Infrastructure for the Biosciences and Biotechnology: Input for the BIPM Work Programme, was awarded to LGC. So far, the project is on schedule. The Project Plan Draft (P1-D1) was delivered in October 2009. A Report on Roadmaps and Strategies (P2-D1) was delivered in March 2010. Draft Interview Forms were completed in October 2009. Reports from visits and interviews with key Bio-industry organizations and measurement organizations were submitted to the BIPM in March 2010. A report of the CCQM BAWG Activities & Plans was submitted to the BIPM in June 2010 together with a report on the analysis of study results. A draft of the Overall Study Report is currently in preparation by the LGC. This will be ready for stakeholder comment by October 2010, and a final version, taking into account stakeholder comments will be ready by March 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 16th meeting at the BIPM (15-16 April 2010), and was preceded by meetings of its working groups. A CCQM workshop on Forensics was held at the BIPM on 12 April 2010.

S. Westwood is a member of the CCQM Organic Analysis Working Group and of the CCQM Organic Analysis Working Group Taskforce on Core Key Competencies.

R. Josephs is a member of the CCQM Bioanalysis and Organic Analysis Working Groups.

J. Viallon is a member of the CCQM Gas Analysis Working Group.

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

S. Maniguet is a member of the CCQM Organic Analysis Working Group and Key Comparison Working Group.

6.6 CCQM comparisons coordinated by the BIPM

The BIPM is the coordinating laboratory for following CCQM comparisons:

- BIPM.QM-K1 – Ozone, ambient level (on-going)
- CCQM-K74 – Nitrogen dioxide value assignment (10 $\mu\text{mol/mol}$)
- CCQM-K55.a – 17 β -Estradiol, purity analysis
- CCQM-K55.b – Aldrin, purity analysis
- CCQM-P110 – Nitrogen dioxide (10 $\mu\text{mol/mol}$) FTIR spectroscopic study
- CCQM-K78 – Aldrin calibration solution

6.7 Activities related to external organizations

R.I. Wielgosz is a BIPM representative to the IUPAC ICTNS, 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, and is a member of the editorial board of *Accreditation and Quality Assurance*. He was the co-chair of the steering Committee of the WMO-BIPM Workshop on Measurement Challenges for Global Observation Systems for Climate Change Monitoring: Traceability, Stability and Uncertainty, and Chair of the Plenary Session of the workshop as well as the breakout session on Greenhouse Gases.

S. Westwood is the BIPM and CCQM liaison to the ISO-REMCO, and is a member of the World Anti-Doping Agency (WADA) Laboratory Committee.

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 member of the related electronic working groups on measurement uncertainties.

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

6.8 Publications, lectures, travel: Chemistry Department

6.8.1 External Publications

1. Viallon J., Botha A., Wielgosz R.I., and Moussay P., Final report on the on-going key comparison BIPM.QM-K1: Ozone at ambient level, comparison with NMISA, 2008, *Metrologia*, 2010, **47**, *Tech. Suppl.*, 08014.
2. Viallon J., Moussay P., Wielgosz R.I., Arya B.C., Mishra S.K., Kumar A., Shukla D.K., Norris J.E., and Guenther F.R., Final report on the on-going key comparison BIPM.QM-K1: Ozone at ambient level, comparison with NPLI, 2009, *Metrologia*, 2010, **47**, *Tech. Suppl.*, 08015.
3. Flores E., Viallon J., Moussay P., Idrees F. and Wielgosz R.I., BIPM Chemistry Department: International Comparison of FTIR measurements traceable to HITRAN and Gravimetrically prepared Gas Standards. Proceedings of the 2009 AGU Fall Meeting, 14-18 December, San Francisco, California. Poster session Greenhouse Gas Measurements Using Active Optical Remote Sensing A41C-0126.
4. Westwood S., Josephs R.D., 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., Ruangritinon N., Wood S., Duewer D., Schantz M., Bedner M., Hancock D., Esker J., An international comparison of mass fraction purity assignment of theophylline: CCQM Pilot Study CCQM-P20.e (Theophylline), *Metrologia*, 2009, **46**, *Tech. Suppl.*, 08019.
5. Josephs R.D., Daireaux A., Westwood S., Wielgosz R.I., Simultaneous determination of various cardiac glycosides by liquid chromatography – hybrid mass spectrometry for the purity assessment of the therapeutic monitored drug digoxin, *J. Chromatogr. A*, 2010, **1217**, 4535-4543 (Supplementary data doi:10.1016/j.chroma.2010.04.060).

6.8.2 BIPM Publications

6. Viallon J., Moussay P., Wielgosz R.I., Ross G., Comparison of Ozone Reference Standards of the DECC NSW and the BIPM, October 2008, *Rapport BIPM-2009/03*, 19 pp.

7. Steele A.G., Viallon J., Hatto P., Janssen T.J.B.M., Knight A., Locascio L., Miles J.R., Morazzani V., Prins S., Unger W., Report on the BIPM Workshop on Metrology at the Nanoscale (18-19 February 2010), *Rapport BIPM-2010/06*, 22 pp.

6.8.3 Travel and lectures

R.I. Wielgosz to:

- AACC, Chicago (USA), 18-19 July 2009, to attend the JCTLM Working Groups Meeting and JCTLM/CCQM/NIST Workshop;
- NIST, Gaithersburg (USA), 28-29 July 2009, to participate in NIST CSTL offsite meeting;
- Hohenpeissenberg (Germany), 8-9 October 2009, to participate and give a presentation at the NOxy WMO-GAW Workshop;
- Rio de Janeiro (Brazil), 3-6 November 2009, CCQM plenary session and working groups;
- National Institute for Biological Standards and Control (NIBSC), London (UK) 24 November 2009;
- INRIM, Turin (Italy), 4-5 February 2010, to participate in the EURAMET METCHEM meetings;
- Royal Society, London (UK), 22-23 February 2010, to participate in 'Greenhouse gases in the Earth system: setting the agenda to 2030';
- Geneva (Switzerland), 30 March-1 April 2010, to Chair Plenary Sessions and Breakout Sessions during the WMO-BIPM Workshop on Measurement Challenges for Global Observation Systems for Climate Change Monitoring: Traceability, Stability and Uncertainty.

S. Westwood to:

- Teddington (UK), 3-6 July 2009, to represent the BIPM and the CCQM at the 32nd annual ISO Reference Materials Committee (ISO-REMCO) meeting;
- Montreal (Canada), 13-15 September 2009, for a meeting of the WADA Laboratory Committee;
- INMETRO, Rio de Janeiro (Brazil), 3-5 November 2009, for a CCQM-OAWG meeting;

- Vienna (Austria), 5-8 March 2010, to attend the WADA Laboratory Director's meeting and a meeting of the WADA Laboratory Committee;
- Montreal (Canada), 6-9 June 2010, for a meeting of the WADA Laboratory Committee.

R. Josephs to:

- International Dairy Federation (IDF), Berlin (Germany), 23 September 2009, to attend the IDF World Dairy Summit 2009, Analysis & Sampling Session;
- INMETRO, Rio de Janeiro (Brazil), 3-6 November 2009, for the CCQM-OAWG/BAWG meetings;
- National Institute for Biological Standards and Control (NIBSC), London (UK), 24 November 2009, to give a presentation on SI Traceable Peptide Quantification;
- Agilent, Waldbronn (Germany), 15 January 2010, for LC-MS instrument demonstration;
- Thermo, Courtaboeuf (France), 17 January 2010, for LC-MS instrument demonstration;
- CCMAS, IAM and Workshop, Budapest (Hungary), 5-10 March 2010, to represent the BIPM at the Inter-Agency Meeting, Codex Alimentarius CCMAS meetings and at the Joint AOCS/ BIPM/ ICC/ IUPAC/ NMKL Workshop on Codex Methods of Analysis: What, When, Why, How to Use?

J. Viallon to:

- Tel Aviv (Israel), 18-22 October 2009, as BIPM liaison to ISO TC 229 (Nanotechnologies) plenary and working group meetings;
- Rio de Janeiro (Brazil), 3-6 November 2009, CCQM plenary session and working groups;
- PTB (Braunschweig, Germany), 19-20 November 2009, to attend the Co-Nanomet European Workshop on Nanometrology;
- Geneva (Switzerland), 30 March-1 April 2010, to give a lecture on "Ozone cross sections and primary standards" during the WMO-BIPM Workshop on Measurement Challenges for Global Observation Systems for Climate Change Monitoring: Traceability, Stability and Uncertainty;

- Reims (France), 6 May 2010, to visit the laboratories of the “Groupe de Spéctrométrie Moléculaire et Atmosphérique” and discuss the construction of an ozone generator;
- Maastricht (Netherlands), 18-20 May 2010, as BIPM liaison to ISO TC 229 (Nanotechnologies) meeting;
- Helsinki (Finland), 28-30 June 2010, to give a lecture on “The BIPM facility for dynamic generation of formaldehyde standards: progress towards an international scale for formaldehyde measurements” during the meeting of the WMO/Global Atmospheric Watch Expert Group on Volatile Organic Compounds.

E. Flores to:

- NIST, Gaithersburg (USA), 7-11 December 2009, to visit NIST laboratories for the conception of a new facility for the international comparison of methane in air standards based on gas chromatography;
- San Francisco, California (USA), 14-18 December 2009, to attend the 2009 Fall Meeting of the American Geophysical Union (Greenhouse gas measurements using active optical remote sensing).

S. Maniguet to:

- AACC, Chicago (USA), 18-19 July 2009, to attend the JCTLM Working Groups Meeting and JCTLM/CCQM/NIST Workshop.

M. Petersen to:

- Reims (France), 6 May 2010, to visit the laboratories of the “Groupe de Spéctrométrie Moléculaire et Atmosphérique” and discuss the construction of an ozone generator.

6.9 Visitors to the Chemistry Department

- J. Novák and M. Vokun (CHMI), 31 August – 4 September 2009.
- J. Matos and Á. Marques (Agência Portuguesa do Ambiente), 30 November – 4 December 2009.
- P. Quincy (NPL), 7 December 2009.
- G.S. Heo (KRISS), 29 March 2010.
- Jayne de Vos (NMISA), 8 June 2010.
- R. Wessel (VSL), 11 June 2010.

6.10 Guest workers

- C. Dazhou (NIM), 1 October – 4 December 2009.

7 WATT BALANCE (M. Stock)

7.1 Watt balance (M. Bradley, R. Chayramy, H. Fang, A. Kiss, E. de Mirandés, A. Picard, L. Robertsson, J. Sanjaime, S. Solve, M. Stock, Thanh Hung Duong^{*}, M. Nigoghossian[†], M. Symphon[‡])

The main distinguishing feature between the BIPM watt balance and those built at other NMIs is that the coil displacement (moving phase) and the weighing (weighing phase) can be carried out simultaneously, in addition to the conventional approach in which both phases are separated. The simultaneous measurement approach makes the experiment more insensitive to drifts (e.g. of the magnetic field) and alignment changes during the experiment. 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 us to test the feasibility of simultaneous force and velocity measurements.

During the last year, considerable improvements have been made to the measurement of the voltage-velocity ratio. The synchronization between the voltage and velocity measurements has been significantly refined by using a 10 MHz atomic clock reference to control the data acquisition and by correcting for the differences in trigger response times. The properties of the voltmeter have been studied in great detail. Correction of deviations of gain and integration time from the nominal values led to a reduction of the Type A uncertainty by a factor of 10. The accuracy of the velocity measurements has been improved by bringing the moving mirror from the circumference of the coil to its centre and by minimizing the undesirable horizontal translations and tilts of the coil during travel.

In order to present the status of our experiment at the CPEM conference in June 2010, a campaign of measurements of the Planck constant h , based on

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[‡] Student from the University of Evry (France), April-June 2010

the simultaneous measurement approach, was carried out from late February to early April 2010. These measurements were made using the present configuration of the experiment; in air, without vibration isolation, and with imperfect alignment. In total, more than 1000 individual values for h have been obtained. From the eleventh series, carried out under the same conditions, the typical relative Type A uncertainty of a series of measurements (of about 80 individual h values) was 1.3×10^{-5} . The reproducibility was found to be 5×10^{-6} in relative terms. The relative combined uncertainty is estimated as 5×10^{-5} and is at present dominated by the imperfect alignment of the coil to the magnet and of both, with respect to the direction of gravitational acceleration. The velocity measurement also needs to be improved, probably by replacing the single-axis interferometer by a three-axis interferometer. The relative difference between our mean value and the CODATA 2006 value for h was -5.6×10^{-5} , which was within the expanded uncertainty. We need to reduce the uncertainty to the 10^{-6} level and to compare the results of the simultaneous measurement approach with those of the conventional approach before coming to conclusions about the feasibility of the new technique. The measurements clearly demonstrate that the noise of the voltage/velocity-ratio is ten times larger than the noise of the force/current-ratio, indicating that, at present, the Type A uncertainty is dominated by ground vibrations.

A new laboratory with two heavy concrete blocks for the watt balance and a gravimeter was set up in early 2009. The seismic noise on the watt balance block, expressed as the rms vibrational velocity, is about a factor of 5-10 lower than on the optical table which serves as the present watt balance location. During summer 2009 a map of the distribution of gravitational acceleration in the new laboratory was established. Relative gravity values have been measured at three height levels above forty base points. The data were fitted with a hyperparaboloid function, which allows us to predict relative g -values within about $2 \mu\text{gal}$, which is $2 \times 10^{-9} g$. During the ICAG-2009 comparison three absolute gravimeters and nine relative gravimeters were used to carry out measurements in the new watt balance laboratory. The absolute measurements will provide us with knowledge of the absolute gravitational acceleration within several μgal . In addition, long-term measurements were made with our relative gravimeter to improve our understanding of the behaviour and the calculation of the earth's tides, which influence g at the level of 2×10^{-7} . It appears that, for the near future, gravimetry will not present a major problem for the BIPM watt balance. However, when we reach a relative uncertainty level below 1×10^{-7} , we will

need to find a solution for absolute gravimetry, since work in this field was discontinued at the BIPM following a decision by the CIPM in October 2009.

Work on the definitive magnetic circuit is progressing, with the assembly of the device ongoing in the BIPM workshop since early 2010. Machining of the first parts of the magnet began in June 2010. The pre-machining of all parts, except the large housing, will be carried out at the BIPM. Precision machining of the critical parts will be undertaken at a specialized company in Germany. The assembly of the magnetic circuit will be carried out at the Technical University of Aachen (RWTH), Germany. The process is complex and involves several different groups but we plan to assemble the system in early 2011.

The magnetic field alignment technique based on the use of a large precision solenoid, lent to us by the NIST, has been successfully applied to a coil with similar characteristics as the watt balance coil. The technique allows us to align the electric plane of the coil perpendicular to the direction of gravitational acceleration within $50 \mu\text{rad}$, which is sufficient for an h determination at the 10^{-8} level. This technique will be applied to the watt balance coil when we replace the present coil with the next generation rigid ceramic coil.

In order to compensate for unwanted horizontal displacements and tilts of the coil during its travel, a novel suspension mechanism has been developed. Piezoelectric actuators will be used to dynamically control the coil position and orientation. Preliminary tests of the servo control mode for horizontal displacements and tilts of the coil have been made and position stabilities in the order of $1 \mu\text{m}$ and $2.3 \mu\text{rad}$ have been obtained, respectively. Integration of the system into the watt balance suspension is planned for early 2011, at the same time as the watt balance will be integrated into the future vacuum system.

In September 2009, a research fellow started work on a feasibility study for the future cryogenic version of the experiment. The first problems being studied are related to trapped flux and the Meissner diamagnetism of the superconducting wire. Since the force resulting from the diamagnetic moment and the (small) magnetic field gradient varies with the third power of the wire diameter, the smallest commercially available filaments should be used. To underpin the theoretical predictions with experimental observations, experiments will be carried out at NIST, Boulder (USA), in

August 2010. The objective is to measure the diamagnetic forces and the eventual hysteretic behaviour on different wire samples.

Work on the development of a dedicated Josephson voltage standard is continuing. The system will be based on a SNS-array developed at NIST. To avoid problems related to ground loops the system will operate using a large number of batteries. The battery charging unit has been built and tested and the current bias source will be constructed this year.

A call for tenders was published in mid-2010 for the conception and construction of a vacuum system and the integration of the watt balance. Once the vacuum system is available in early 2011, the experiment will move into the new laboratory and will be integrated into the vacuum chamber. At the same time, several newly developed electro-mechanical systems, including a mass exchanger, a sensitivity calibration system for the force measurements and a device for dynamic control of the coil horizontal displacements and tilts will be integrated into the balance suspension. We will then benefit from the advantages of vacuum operation and reduced vibration noise.

7.2 Publications, lectures, travel

7.2.1 External publications

1. Picard A., Bradley M., Fang H., Kiss A., de Mirandés E., Parker B., Solve S., Stock M., *Digest – 2010 Conference on Precision Electromagnetic Measurements*, p. 66, “The BIPM watt balance: improvements and developments”.
2. de Mirandés E., Fang H., Kiss A., Solve S., Stock M., Picard A., *Digest - 2010 Conference on Precision Electromagnetic Measurements*, p. 522, “Alignment procedure used in the BIPM watt balance”.

7.2.2 Travel (conferences, lectures and presentations, visits)

M. Stock to:

- Daejeon (Rep. of Korea), 12 June 2010, to give a presentation on the status of the BIPM watt balance at the meeting of the CCEM working group on electrical methods to monitor the stability of the kilogram (WGKG).

A. Picard to:

- XIX IMEKO World Conference, Lisbon (Portugal), 7-11 September 2009, to attend the conference and give a talk on the watt balance progress at the workshop on the redefinition of the kilogram;
- EURAMET TC-Mass, Istanbul (Turkey), 3-5 March 2010, to give presentation on “Status of watt balance determinations of h and the Avogadro project determinations of N_A in view of a future redefinition of the kilogram”;
- Daejeon (Rep. of Korea), 14 June 2010, to give a presentation on “The BIPM watt balance: improvements and developments” at the CPEM conference.

E. de Mirandés to:

- Daejeon (Rep. of Korea), 16 June 2010, presented a poster on “Alignment procedure used in the BIPM watt balance” at the CPEM conference;
- IAG Symposium on Terrestrial Gravimetry, St. Petersburg (Russian Federation), 24 June 2010, gave a presentation at on “Evaluation of the local value of the earth gravity field for the BIPM watt balance”.

M. Bradley to:

- NIM (China), 22 June 2010.

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

- Daejeon (Rep. of Korea), 14-18 June 2010, to attend the CPEM conference.

7.3 Visitors

- Dr L. Locascio (NIST, USA), 22 July 2009, to visit the watt balance.
- Mrs E. Barsacq (French Foreign and European Affairs Ministry), 20 August 2009, to visit the watt balance.
- Mr F. Cosandier (METAS watt balance), 18 September 2009, to visit the watt balance and for technical discussions.
- Dr A. Bresson, Dr M. Cadoret, Dr Y. Bidet (ONERA), 22 September 2009, to give a presentation and to visit the watt balance.

- Mrs C. Lorduy (Ministry of Commerce, Industry and Tourism, Columbia), 9 November 2009, to visit the watt balance.
- Mr J. Kallmerten (RWTH, Germany), 11-12 October 2009, for technical discussions on the fabrication of the watt balance magnetic circuit.
- Dr F. Biraben, F. Nez (LKB) and M. Plimmer (LNE), 24 February 2010, to visit the watt balance. F. Nez gave a presentation on the new determination of the proton charge radius.
- Prof. Zhang Zhonghua, Dr He Qing, Mr. Zhang Jian (NIM), 1 March 2010, to visit the watt balance.
- Prof. O. Francis (Univ. of Luxembourg), 18 March 2010, to give a seminar “How well can we model earth tides affecting ground based observations?” He also installed a gPhone gravimeter at the BIPM for measurements in support of the watt balance.
- Dr C. Sutton (MSL, New Zealand), 1 April 2010, to visit the watt balance.
- Dr R. Goldfarb (NIST, USA), 12 May 2010, to give a seminar on measurements for magnetism, for discussions on magnetism and to see the watt balance.
- Dr P. Gallagher and Dr W. Anderson (NIST, USA), 3 June 2010, to visit the watt balance.
- Mrs L. Faxas (Ambassador, Dominican Rep.), 28 June 2010, to visit the watt balance.

8 The CIPM MRA

8.1 JCRB (L. Mussio)

8.1.1 CIPM MRA guides and policy documents

The following four documents were presented by the JCRB for discussion at the CIPM meeting in October 2009:

- CIPM MRA-D-05 – Inter-laboratory Comparisons in the CIPM MRA.

- CIPM MRA-D-04 – Calibration and Measurement Capabilities in the context of the CIPM MRA.
- CIPM MRA-G-02 – JCRB guidelines for the monitoring and reporting of the operation of quality systems by RMOs.
- CIPM MRA-D-06 – Approval of CIPM MRA policy documents.

Discussion of these documents will continue by correspondence and will be included in the agenda of the next JCRB and CIPM meetings.

8.1.2 Status of CMCs temporarily removed from the KCDB

It was resolved that after five years, CMCs with the status of “temporarily removed” (greyed out), cannot be reinstated without a full review and should be deleted from the KCDB. A procedure to enforce this resolution will be discussed in the next meeting of the JCRB.

8.1.3 Policy for traceability in the CIPM MRA

The following policy was proposed by the JCRB and approved by the CIPM:

- A National Metrology Institute (NMI) or other Designated Institute (DI), publishing Calibration and Measurement Capabilities (CMCs) in the BIPM Key Comparison Database (KCDB), has two choices for establishing its traceability route to the SI:
 - 1. via a primary realization of the unit of measurement concerned, in which case traceability must be declared to its own demonstrable realization of the SI;
 - 2. via another NMI or DI having relevant CMCs with appropriate uncertainty published in the KCDB or through calibration and measurement services offered by the BIPM, in which case traceability must be declared through the laboratory providing the service.
- In exceptional cases, where neither of these two routes can be strictly applied, alternative paths for establishing the traceability to recognized standards may be proposed to the CIPM through the corresponding Consultative Committee. The list of these exceptions will be

maintained by the BIPM in the CIPM MRA documents section (www.bipm.org/en/cipm-mra/documents/) of the BIPM website. The list of exceptions for each field should be periodically reviewed by the corresponding Consultative Committee.

- Note 1: In order for a primary realization or representation of the unit of measurement to be considered valid, it requires the approval of the relevant Consultative Committee.
- Note 2: The NMI or DI must make available a full assessment of the uncertainty budget and the traceability route for its measurement activity when submitting CMCs for intra- and inter-Regional review.
- Note 3: For auxiliary influence quantities, which are not part of the main traceability path to the SI for a particular measurand and with uncertainties that can be shown to make only a minor contribution to the total combined uncertainty of the CMC, an NMI or other DI is free to use measurement services provided by laboratories accredited by a signatory to the ILAC Arrangement.
- Note 4: Traceability route 1 includes the case of NMIs or DIs using certified reference materials (CRMs) or high-purity primary chemical reference materials that have been value-assigned by applying their own measurement capabilities as described and recognized within published CMCs.

8.1.4 Quality Systems

Although the BIPM is not a signatory of the CIPM MRA, following the publication of its measuring capabilities on the BIPM website it was decided that the BIPM will include relevant information about its Quality System in the annual reports it submits to the JCRB. It was also decided that every two years, in conjunction with the presentations by the RMO Working Groups on Quality, the BIPM will make a presentation on its Quality System.

The JCRB decided to recommend to the CIPM the adoption of the following policy: “The initial and periodic presentations of the Quality System (QS) of a Designated Institute (DI) to the corresponding RMO QS review panel, must be made directly by the responsible person of the DI and not through its NMI. Similarly, the QS annual reports must be prepared and submitted directly by the DI.”

8.1.5 On-site peer reviews

Noting that the RMOs are moving to a common position in which on-site peer reviews are considered the best practice to assure the capability of the CIPM MRA participants, the RMOs have decided to hold an internal discussion about making the need for on-site peer reviews mandatory and to report the results of this discussion during the next meeting of the JCRB.

8.1.6 Travel (conferences, lectures and presentations, visits): JCRB

L. Mussio to:

- Kazan (Republic of Tatarstan, Russian Federation), 23-24 September 2009, for the 23rd JCRB Meeting;
- Lima (Peru), 26-28 October 2009, SIM General Assembly meeting and SIM QSTF meeting;
- Vancouver (Canada), 15-19 October 2009, ILAC AIC Committee, ILAC-IAF General Assembly;
- Montevideo (Uruguay), 27 February-1 March 2010, SIM TC Meeting.

L. Mussio and A. Henson to:

- Geneva (Switzerland), 30 March-1 April 2010, for the WMO-BIPM Workshop on Measurement Challenges for Global Observation Systems for Climate Change Monitoring: Traceability, Stability and Uncertainty.

A. Henson to:

- OIML, Paris (France), 12 April 2010, for a meeting of the UNIDO-AFRIMETS Steering Committee;
- Vedbaek (Denmark), 30 June-1 July 2010, for a meeting of the ILAC AIC Committee.

P. Espina^{*} to:

- Pretoria (South Africa), 12-19 July 2009, for the AFRIMETS General Assembly;
- Geneva (Switzerland), 11-13 November 2009, for a meeting of ISO CASCO;
- Vienna (Austria), 1-2 December 2009, for a meeting with UNIDO;

^{*} Until end 2009.

- Sarajevo (Bosnia and Herzegovina), 2-6 December 2009, for a EURAMET Meeting;
- Vienna (Austria), 10-11 December 2009, for a meeting with UNIDO.

8.1.7 Visitors

- Christin Bauer from PTB, to prepare a brochure about the CIPM MRA.
- Dr Elsie Meintjies, AFRIMETS International Project Coordinator (from CSIR), regarding the UNIDO-AFRIMETS project.

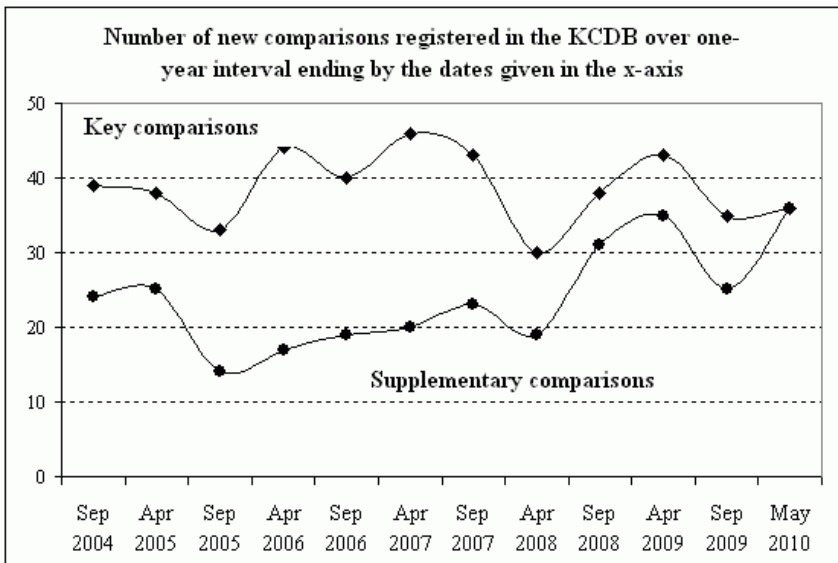
8.2 The BIPM key comparison database, KCDB (C. Thomas)

8.2.1 Content of the KCDB (S. Maniguet, C. Thomas)

8.2.1.1 Key and supplementary comparisons

On 1 June 2010, the key and supplementary comparisons database covered 694 key comparisons (82 from the BIPM, 337 from the CCs, and 275 from RMOs) and 244 supplementary comparisons. One new BIPM key comparison was registered in the KCDB on 20 October 2009: BIPM.RI(I)-K7, which corresponds to novel work undertaken by the BIPM Ionizing Radiation Department: measurement of air kerma in mammography beams.

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



The rate of registration of supplementary comparisons is still increasing and has reached the same level as key comparisons, with about 35 new exercises declared to the KCDB Office over one year.

On 1 June 2010, among the 694 key comparisons that were registered:

- 88 corresponded to exercises prior to the implementation of the CIPM MRA (they were “Approved for provisional equivalence”);
- 74 of the 82 ongoing BIPM key comparisons had results published in the KCDB; these are regularly extended when new data becomes available; and
- another 313 CC and RMO key comparisons had their final reports approved and posted in the KCDB website, and corresponding tables of numbers and graphs were entered in the database.

At that date, and all together, the KCDB displayed a total of about 1450 graphs of equivalence, including more than 250 new graphs of equivalence published over the last year.

The results of 119 RMO key comparisons are 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 more than 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*.

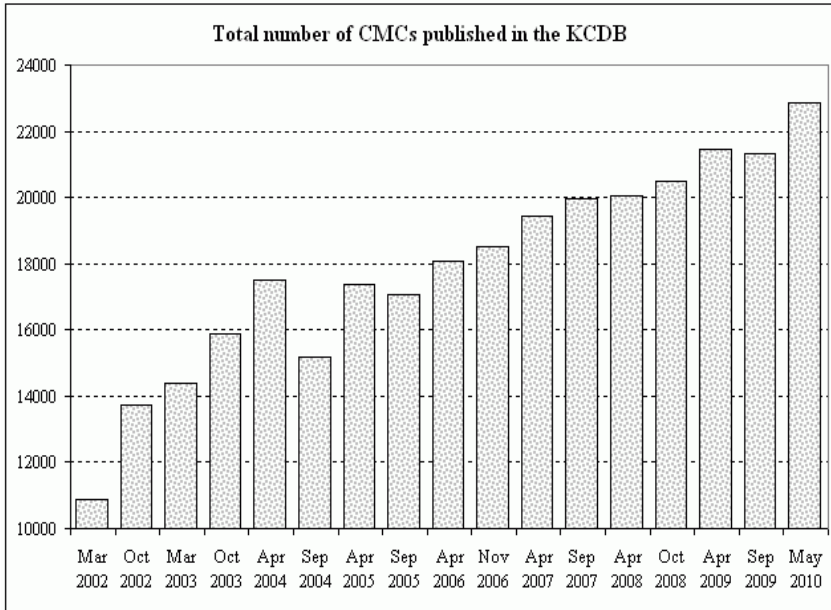
A number of key comparison results are also regularly updated. These mainly concern the ongoing BIPM key comparisons in electricity (voltage, resistance, and capacitance), in chemistry (ozone measurements), on radionuclide activity conducted within the framework of the SIR, and on dosimetry. These updates correspond to new bilateral comparisons that are regularly carried out between the BIPM and various NMIs.

Updated graphs illustrating the participation in key and supplementary comparisons were made available from the Statistics page of the KCDB website (see http://kcdb.bipm.org/kcdb_statistics.asp) on 18 May 2010.

8.2.1.2 Calibration and Measurements Capabilities – CMCs

At the beginning of June 2010, about 23 000 CMCs were published in the KCDB. This represented an additional 1 800 CMCs compared to June 2009.

Indeed, over the last year a large number of newly approved sets of CMCs have been published.



The decrease in number observed in September 2004 was the consequence of the introduction of uncertainty tables used to display the complete set of uncertainty values when several parameter ranges are involved in the CMC claim. This is currently applied in the domains of Electricity and Magnetism. There is a continuous movement linked to approval of Quality Systems: temporary removal (so-called “greying-out”) of CMCs not covered by an approved QS, and re-instatement of CMCs once the QS covering them is approved. As of 1 June 2010, 451 CMCs were greyed-out from the KCDB. This number has remained almost constant since the 21st JCRB meeting (2008) when action was taken to clear up the long-standing issue of the hundreds of CMCs that were greyed-out from the KCDB in July 2005 (just after the 15th JCRB meeting), in particular, through definitive deletion of a number of CMCs.

Details on the number of CMCs currently published in the KCDB, by country and by metrology area, are available in real-time from the Statistics page of the KCDB (see kcdb.bipm.org/kcdb_statistics.asp) as well as the situation regarding greyed-out CMCs. A record of the history of CMC publications (including greying-out and re-instatement following QS

approval) is kept in an EXCEL file, which is made available in real-time from the restricted-access section of the JCRB CMC website. Following a request by the JCRB at its 24th meeting (2010), the dates of greying-out of CMCs are now included in this file. This makes it possible to spot those CMCs that have been greyed-out for more than five years, and for which further examination may be needed.

In addition to publication of newly approved CMC sets and maintaining temporary removal and re-instatement of CMCs linked to QS status changes, the KCDB Office deals with numerous corrections: editorial changes, deletion of services that are no longer available, and changes of laboratory names and acronyms.

8.2.2 Visits to the KCDB website (C. Thomas)

As reported previously, new software analysing the connections to the KCDB website was implemented in January 2009.

During 2009, more than 90 000 visitors opened a total of about 821 000 KCDB web pages. The number of monthly visits varied between 5 600 and 10 100, and the number of pages opened each month between 48 800 and 117 500. These counts, however, do not include the additional visitors arriving at the KCDB via the free-text search engine installed on the main BIPM website.

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 are from all over the world, and reach the KCDB website from:

- bookmarking, direct URL address typing or using links given in e-mails for about 70 %,
- Internet search engines (Google, Yahoo, etc.) for about 5 %, and
- links from other websites (especially NMI websites) for the remaining 25 %.

It is difficult to identify the visitors apart from the National Metrology Institutes which obviously constitute a part of the audience. The numbers indicate that the site also attracts other communities, including regulators, accreditors, and commercial and industrial companies.

8.2.3 Modification of the KCDB website (C. Thomas)

A number of changes were made to the KCDB web programming in February 2010. These included re-structuring the box entitled “Related links” and also the introduction of a new web page including answers to frequently asked questions (FAQs), which currently gives answers to about ten different themes identified in the mail received from the KCDB users.

The “Related links” box is visible on all pages of the KCDB website. Among other things, it gives access to the KCDB Statistics page and to the CIPM MRA website, which contains useful procedural documents.

8.2.4 Publicity and KCDB Newsletters (S. Maniguet and C. Thomas)

The KCDB is publicized as often as possible 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 12 and 13 of the KCDB Newsletter were launched on 15 December 2009 and 9 June 2010, respectively.

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

C. Thomas to:

- Institut de France, Paris (France), 19 October 2009, for a seminar on the Quantum Hall Effect organized by the Committee “Science et métrologie” of the Académie des Sciences, and 18 January 2010, for a meeting of the same Committee;
- LNE, Paris (France), 27 November 2009, for the conclusion meeting of the Organizing Committee of the 14th International Congress of Metrology (held in June 2009), and 15 March 2010, for a joint meeting LNE/Committee “Science et métrologie” on the redefinitions of the SI base units.

8.2.6 Activities related to external organizations

C. Thomas acts as the Scientific Secretary of the permanent Committee “Science et métrologie” of the French Académie des Sciences. She also is a member of the Technical and Scientific Committee of the International

Congress of Metrology 2011, to be held in Paris from 3-6 October 2011 (“Metrology’2011”).

C. Thomas acts as the BIPM Liaison for the CODATA Task group on Fundamental Constants and for the ISO TC 12 “Quantities and Units”, and also as the BIPM Contact for the JCGM and its WG 2 (VIM).

8.2.7 Activities related to the work of Consultative Committees

C. Thomas is the Executive Secretary of the CCU. She is a member of the CCEM working groups on proposed modifications of the SI (CCEM WG SI) and on coordination of the RMOs (CCEM RMO WG), 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 (WG 7). In her role as Coordinator of the KCDB. C. Thomas attended a large number of Consultative Committee and Working Group meetings held at the BIPM during the year.

C. Thomas is responsible for the organization of seminars at the BIPM and also acted as the Scientific Secretary of the BIPM Workshop on Physiological Quantities and SI Units held in November 2009.

9 INTERNATIONAL AND COORDINATION ACTIVITIES (A. HENSON)

9.1 Liaison with other intergovernmental organizations and international bodies

9.1.1 Four-partite meeting

The BIPM, ILAC, OIML and ISO held a four partite meeting in March 2010. The purpose of the meeting was to exchange information and provide a discussion forum. The main outputs from this meeting were:

- that the BIPM, the OIML and ILAC will continue to develop a joint policy on traceability. ISO will consider whether it is possible for it also to be part of the policy;
- the common view is that whilst the terms of reference of the DCMAS-Network are appropriate, there is a need to have some positive actions, if at all possible, and there is concern over funding of such actions. ILAC will approach the World Bank.

9.1.2 ILAC

The BIPM and ILAC held a bipartite meeting in March 2010. The main outputs from this meeting were:

- the need to monitor the “delisting” of reference laboratories under the JCTLM (as the JCTLM has made accreditation mandatory and a large number of listed laboratories have not applied);
- that ILAC will approach the World Bank with a view to supporting the work of DCMAS;
- that ILAC will continue to work in the forensic area to promote appropriate means of establishing traceability, particularly in the fields of DNA and toxicology, bringing this community closer to the CCQM, particularly working with ENFSI/the Asian Networks.

With regard to the CIPM MRA and the ILAC MRA:

- a joint document will be prepared on traceability aimed at writers of specifications, and those who use them for procurement or regulatory purposes;
- template wording will be prepared by the BIPM to aid NMIs and DIs who wish to give policy/guidance to regulators on mutual recognition;
- the BIPM committed itself to updating the references to international standards in the CIPM MRA as soon as is practical;
- events were organized to celebrate the 10th anniversaries of the CIPM and ILAC MRAs, and World Metrology and World Accreditation Days;
- ILAC and the BIPM will support each other in the following celebrations:
 - a Bridge to Innovation – World Metrology Day (20 May 2010);

- ILAC General Assembly and Joint General Assembly signing ceremonies (27-29 October 2010).
- ILAC will advise ABs, laboratories, regulators etc. to refer to the BIPM website for useful information on the BIPM and traceability;
- ILAC will explore, with the publication of ISO G34 (Reference Material Providers), whether it is possible for the ILAC MRA to be extended to cover RMPs;
- ILAC and the BIPM will continue to work together developing the ILAC guidance document on the accreditation of NMIs, and continue to explore whether it would be beneficial to issue it as some form of joint ILAC/BIPM document, further work being needed to decide whether it should be a policy or guidance document or some sort of joint statement;
- the BIPM will contribute to the ILAC Policy for the Estimation of Uncertainty in Calibration and Measurements;
- ILAC and the BIPM will continue to liaise on cases where measurement uncertainties being claimed by accredited laboratories or NMIs or DIs appear to be unrealistically small;
- the BIPM and ILAC will participate in each other's major meetings;
- the International Liaison Officer of the BIPM, A. Henson, has been designated liaison delegate to ILAC.

9.1.3 ISO

The former tripartite meeting between the BIPM, ILAC and the OIML was expanded this year to include ISO. The four-partite meeting between the BIPM, ILAC, OIML and ISO was held in March 2010 (see §9.1.1).

9.1.4 OIML

The situation in relation to the relationship between the BIPM and the OIML remains unchanged.

The bureau of the CIPM and the Presidential Council representatives of the CIML met in March 2009 and reviewed the conclusions they came to during their meetings in March 2008, namely that there were no new elements concerning the financial aspects of a rapprochement which indicate possible

savings in moving the BIML onto the BIPM site or merging part of the organs of both organizations.

It was, however, agreed that the BIPM and the BIML must continue to strengthen their cooperation, as it benefited both organizations, in terms of image and in terms of awareness of metrology.

During 2009, the cooperation between the BIPM and the BIML continued in a very positive way. The BIPM was represented at the CIML meeting in Mombasa (Kenya), and the OIML was associated to the World Metrology Day documents. Contacts with some potential new Member States for the BIPM and the OIML were followed in close cooperation between the BIPM and the BIML, the BIML was invited to give a presentation at the symposium organized by the BIPM for the 10th anniversary of the CIPM MRA.

9.1.5 WMO

Preparatory activities and delivery of the joint BIPM/WMO workshop took place throughout 2009 and early 2010.

The "WMO-BIPM Workshop on Measurement Challenges for Global Observation Systems for Climate Change Monitoring: Traceability, Stability and Uncertainty" was held from 30 March-1 April 2010, at the WMO headquarters in Geneva, Switzerland, under the joint chairmanship of Prof. Andrew Wallard (BIPM) and Dr Wenjian Zhang (WMO).

At the occasion of the WMO-BIPM Workshop, the World Meteorological Organization (WMO) joined the CIPM MRA, with three Designated Institutes:

- For surface ozone: Swiss Federal Laboratories for Materials Testing and Research (EMPA);
- For CO₂, CH₄, N₂O, SF₆ and CO concentrations: NOAA Earth System Research Laboratory (NOAA/ESRL);
- For solar irradiance: Physikalisch-Meteorologisches Observatorium Davos and World Radiation Center (PMOD/WRC), Davos Dorf.

The BIPM/WMO workshop was attended by 131 participants.

9.1.6 UNIDO

The BIPM and the OIML held a joint Seminar for the UNIDO Capacity Building staff at their headquarters in Vienna on World Metrology Day (20 May 2010).

The BIPM (and the OIML) continue to support the UNIDO – AFRIMETS initiative for the further development of AFRIMETS. The International Liaison Officer of the BIPM, Andy Henson, has been designated the BIPM representative on the project Steering Committee, and attended the Steering Committee meeting in Paris in April 2010. Early stage planning has been undertaken for a major metrology school event for AFRIMETS, sponsored by UNIDO, and which is scheduled for February 2011 in Nairobi, Kenya.

9.2 Joint Committees

9.2.1 JCGM

The representatives of the eight Member Organizations of the Joint Committee for Guides in Metrology (JCGM) met on 2 December 2009 for the annual plenary session. Two main Resolutions were adopted, one concerning the nomination by Member Organizations of experts to Working Groups, and another resolution about the wording of the JCGM Charter relevant to the production and publication of JCGM documents. Reports were also received on the work of the Working Group on the Expression of Uncertainty in Measurement (JCGM WG 1 - GUM), the Working Group on International Vocabulary of Basic and General Terms in Metrology (JCGM WG 2 - VIM) and the JCGM *ad-hoc* group on measurement software.

The GUM (*Guide to the Expression of Uncertainty in Measurement*, also known as JCGM 100:2008) is now available in both English and French on the BIPM website. The JCGM WG 1 finalized its work on the Introduction to the GUM and related documents. This document, extensively hyperlinked to the other JCGM documents, has also been placed on the BIPM website (www.bipm.org/en/publications/guides/) where it is known as JCGM 104:2009.

Since 2008, the 3rd edition of the VIM (International Vocabulary of Metrology – Basic and General Concepts and Associated Terms), the “VIM 3”, has been made available from the BIPM website for free access by the metrology community where it is known as JCGM 200:2008 (www.bipm.org/en/publications/guides/). The JCGM WG 2, however,

recognized that the versions of the VIM 3 published by ISO/IEC and OIML are slightly different from the main JCGM/BIPM document, and that, in addition, the three texts contained a number of mistakes requiring formal corrections. During the year covered by this report, the JCGM WG 2 drew up the appropriate Corrigenda Sheets, to be attached to each of the three versions of the VIM 3, in order to produce a corrected and unique master file, which may be used for further extension of the vocabulary. The JCGM/BIPM Corrigenda Sheet, both in French and English, was made available on the BIPM website in June 2010.

9.2.2 JCTLM

See §6.3.

9.3 Promotion of the Metre Convention

9.3.1 World Metrology Day - 20 May 2010

A poster “A Bridge to Innovation”, prepared by the BIPM together with the OIML and the PTB, and supported by the RMOs and the NCSLI, was widely distributed. It was available in English, French, Spanish and Portuguese with the opportunity for translation into other languages, and with the graphics available for local adaptation. Other promotional materials and activities included:

- The World Metrology Day Website (<http://www.worldmetrologyday.org/>);
- The BIPM Director’s message to the metrology community;
- A press release;
- A presentation by the Deputy Director of the BIPM, Prof. M. Kühne, at the COOMET WMD Seminar, Moscow (Russian Federation);
- A presentation by the BIPM International Liaison Officer at the UNIDO Capacity Building staff, Vienna (Austria).

9.3.2 Accession

New Member States:

- The Republic of Kenya, previously an Associate of the CGPM, became a Member State on 1st January 2010.

New Associates to the CGPM:

- The Republic of Ghana became an Associate of the CGPM on 17 September 2009.
- The People's Republic of Bangladesh became an Associate of the CGPM on 29 March 2010.

New signatories to the CIPM MRA:

- World Meteorological Organization (WMO), signed the CIPM MRA on 1 April 2010.
- Ghana Standards Board (GSB), Republic of Ghana, signed the CIPM MRA on 24 February 2010.
- Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual (INDECOPI) of Peru, signed the CIPM MRA on 17 November 2009.
- Instituto Nacional de Tecnología y Normalización (INTN) of Paraguay, signed the CIPM MRA on 26 October 2009.

Discussions also took place with a number of additional States, in most cases regarding the possibility of them becoming Associates of the CGPM.

9.4 Workshops

9.4.1 Workshop on Physiological Quantities and SI Units (M. Kühne, C. Thomas)

16-17 November 2009

Chairman: Prof. Michael Kühne, BIPM

Scientific Secretary: Dr Claudine Thomas, BIPM

The BIPM Workshop on Physiological Quantities and SI Units attracted 70 people from about 22 countries around the world. Most of the attendees were from National Metrology Institutes (NMIs), and were active in Technical Committees or Working Groups of international organizations, institutions or unions such as ISO, IEC, CIE, ICRU, IUPAC and IUPAP. The Workshop was also attended by several members of the BIPM's scientific staff.

The workshop was limited to the topic of “Health and Safety for Humans” with presentations by twelve metrology experts covering the six fields selected by the Scientific Steering Committee:

- Optical Radiation (infrared, visible light, ultraviolet);
- Radio Waves and Microwaves;
- Ionizing Radiation;
- Sound and Ultrasound;
- Magnetic Fields; and
- Biological quantities.

The subject of “Physiological Quantities and SI Units” encompasses many different subjects in Physics, Chemistry and Biology that are, or which could be addressed by NMIs and Institutes, and which may need written standards, vocabularies, documentation etc. These written standards etc. could be addressed by dedicated bodies such as ISO, CIE, etc. A direct link should probably be made wherever possible between the relevant Consultative Committee (CC) of the CIPM or the relevant Joint Committee (for instance the JCTLM) and the relevant Technical Committee of the standardization body (often a member of the CC), field by field. There was a strong consensus that the individual CC Working Groups in charge of Strategic Planning should take on board any new challenge related to physiological quantities in their domain of activities, and propose to their CC any appropriate steps forward.

Presentations at the workshop showed that physiological quantities follow a general pattern, in which the challenge lies in developing an appropriate “action spectrum” (or “weighting function”, “weighting factor”, “model”, etc.). When this is established, the resulting quantity is generally expressed in SI units.

- Each community designs its action spectra and models: this involves the relevant metrology community, often at the level of the appropriate CC, and international bodies which carry out standardization activities in the field (for example: collaborative development by the CCPR and the CIE of a new model involving a global parametric weighting function for scotopic, mesopic and photopic vision).
- The uncertainty is generally not well established.
- Psychophysical, mental and behavioural processes are known to affect significantly the human response to various stimuli, making an action spectrum highly variable in some cases.

- There are limitations in the application of the models, for instance to low-level effects or in case of saturation effects, and there is probably a case for computer models development.
- It could be worthwhile to establish a connection with the JCGM WG 1, concerning modelling of “action spectra”, and possibly to include appropriate guidance on this topic in the planned GUM supplement on modelling.
- Though formal regulation and legislation exist in most of the fields, they may not be uniform throughout the world. Regulators should inform the NMIs and the other bodies on how they could be involved most appropriately. In an increasing number of regulatory fields, traditional physiologically-based regulations are now incorporating human factors such as cognitive ability, reflecting the importance of psychophysical, mental and behavioural processes.

Two cases were identified where direct actions could be taken:

- Contact should be established between the CCEM and the ICNIRP, the International Committee for Non-Ionizing Radiation Protection (The ICNIRP provides advice on this matter which is often taken on board by regulatory bodies). Effects induced by magnetic fields on the human body have not been considered in the framework of the CCEM: an appropriate action from the CCEM WG on Strategic Planning may be required;
- It would be desirable for the Working Groups on Strategic Planning of the CCEM and of the CCPR to consider the case of radiation at frequencies of the order of terahertz. This field might best be tackled through the creation of a joint group of the CCEM and the CCPR.

For more information and a report of the workshop, see www.bipm.org/en/events/physiological_quantities/.

9.4.2 Metrology at the Nanoscale

18-19 February 2010

The BIPM Workshop on Metrology at the Nanoscale brought scientists from the NMIs and industry together with experts from the regulatory and standards development community. The two day Workshop was attended by more than 100 participants and approached the very broad topic of

nanotechnology with thematic lectures and round-table discussions in eight topical areas:

- Toxicological testing;
- Nanobiology;
- Aerosols;
- Microscopy;
- Surface analysis;
- Thin films and coatings;
- Mechanical metrology; and
- Electrical and magnetic applications and measurements.

The programme was very lively, and the presentations were uniformly excellent, allowing the attendees to address the focal question of the meeting: “What activities are required to establish an effective international infrastructure for metrology at the nanoscale”

The full report on the workshop includes a comprehensive summary of the discussions on this question, including the drivers to work on the topic, technical issues and barriers to progress, status and needs for traceability to the SI, as well as the anticipated use and need for reference materials and documentary standards. Briefly, however, it can be said that the principal drivers for international involvement are environment, health and safety, in supporting and defining an appropriate regulatory framework and in encouraging and fostering industrial and therefore economic advantage. While the element of curiosity to explore new areas was an overarching theme, one principal barrier to progress was the long lead time required to develop research into innovation. Although there is a varied level of maturity in metrology and standardization, it was acknowledged that there is growing awareness and a high level of anticipation for results.

The current and potential applications of nanotechnology are vast, and there is a great deal of work required to advance the state of the science to ensure the safe and responsible introduction of these new technologies. Perhaps the most rewarding element of the Workshop was the opportunity to meet and establish connections outside of our normal communities: a sentiment echoed with equal enthusiasm by participants from the world of metrology, by the industrial delegations, and by the attendees from international standards and policy development. The workshop was presented with a very broad spectrum of measurement techniques and instrumentation, and of the need to act across traditional organization- and discipline-based boundaries

to ensure that these pressing needs are met. A follow up workshop is anticipated within a few years but, as far as the specific case of a proposal for the BIPM's 2013-2016 programme of work is concerned, the conclusion was that this is premature.

For more information and a report of the workshop, see www.bipm.org/en/events/nanoscale/.

9.4.3 WMO-BIPM Workshop on Measurement Challenges for Global Observation Systems for Climate Change Monitoring: Traceability, Stability and Uncertainty

30 March-1 April 2010

The WMO-BIPM Workshop on Measurement Challenges for Global Observation Systems for Climate Change Monitoring: Traceability, Stability and Uncertainty was held at the WMO headquarters in Geneva, Switzerland.

The BIPM's work with the World Meteorological Organization continues to intensify and the two bodies held a joint symposium on the broad subject of Metrology and Climate Change, and how satellite-based, ground-based, and other monitoring techniques can be improved by the adoption of best-practice metrology. Led by a series of high-level expert speakers, parallel discussion sessions helped create a great deal of commitment by our colleagues in the meteorological community to take much greater advantage of the expertise that is in National Metrology Institutes.

For the BIPM, the workshop was a major step forward because, although there have been many working-level contacts in a variety of different disciplines between the metrologists and parts of the observation networks – the Global Atmospheric Watch and GEOS networks for example – the workshop provided the opportunity to complete a long negotiation when the WMO Director General Michel Jarraud signed the CIPM MRA.

The general conclusions were that:

- Measurement results from climate monitoring and earth energy balance by remote sensing from satellites as well as ground-based methods and observation should, where practical, be traceable to the SI so as to help provide continuous, quality – assured data sets over the long term;

- The meteorological community should continue to specify its measurement needs and that these should be formally communicated to NMIs;
- The WMO, the BIPM, the NMIs and the academic communities should work together to meet stated requirements for measurement standards with accuracies that meet the needs of climate scientists and modellers and, where relevant, legislators and regulators; and
- Calibrations of instruments used by the meteorological community should be made at all stages in space missions as well as for earth based projects and that the NMI community should be involved in planning and execution.

The WMO and the BIPM have established a common strategy to identify the need for accurate measurements and to ensure that the recommendations of the workshop are fully followed up, implemented, and monitored.

The result is a commitment of two of the world intergovernmental organizations to collaborate to tackle the measurement issues in one of the most major challenges of the world at the moment. A report is being finalized and will be circulated very widely, including governments, intergovernmental organizations, NMI Directors, the International Panel on Climate Change, and the UNCCC .

For more information, see www.bipm.org/en/events/wmo-bipm_workshop/.

9.4.4 10th Anniversary of the CIPM MRA

8-9 October 2009

A major symposium to mark 10 years of the CIPM MRA was held in conjunction with the annual meeting of NMI Directors in Paris in October 2009. During a day and a half of discussion, attendees heard of the use to which the CIPM MRA is put by a number of NMIs, intergovernmental and international organizations and by industrial companies.

The symposium highlighted the benefits that the CIPM MRA has brought to its participants, the impact it has had in the world metrology system, and explore what can be expected in the future.

The CIPM MRA is the result of years of discussion and negotiation. Signature to it eliminated the need for bilateral agreements between

countries, since the CIPM MRA provides the tools for world-wide recognition of equivalence of measurements. One of the key elements introduced by the CIPM MRA was the introduction of key comparisons, which have become the main source for underpinning the equivalence of national standards and the recognition of measurement and calibration certificates of NMIs. The CIPM MRA also introduced the concept of Calibration and Measurement Capability (CMC) as a standard way to describe the services offered by its participants. The results of key comparisons and the list of CMCs are published in the BIPM key comparison database - the KCDB, which has become an essential tool in removing technical barriers to trade.

Presentations from international organization stakeholders (WTO, UNIDO, WMO, ISO and OIML) all illustrated how the CIPM MRA has contributed and supported their international roles. Without internationally recognized standards and measurements that are equivalent and traceable, global trade, science and innovation would not have progressed the way they have over the last 10 years.

The symposium concluded that the CIPM MRA has been instrumental in setting the stage for world-wide equivalence in measurements, through tremendous efforts and inputs from the BIPM, National Metrology Institutes and Designated Institutes. Though the last 10 years demonstrate a job well done, there are challenges ahead to ensure that the CIPM MRA stays manageable. For the way forward, the CIPM MRA and the KCDB will play an important role in how measurement equivalence and traceability are defined and established, and disseminated in the emerging and challenging environmental, health and nanotechnology sectors.

For more information, see www.bipm.org/en/events/10-year_symposium/.

10 COMMUNICATION AND INFORMATION (F. JOLY)

10.1 General

This year has seen the creation of a new structure at the BIPM: the “Communication and Information Section”, grouping the teams previously divided between the “Secretariat” and the “Publications and IT Section”.

Various staff changes have occurred due to departures and hiring of new staff. A list of the various departures and recruitments is given in §13.2 of the present report. Officially the Communication and Information Section still contains one vacancy, for a second IT person.

10.2 Reports of the CIPM and Consultative Committees

(N. De Sousa Dias*, D. Le Coz[†], J.R. Miles, C. Planche[‡], R. Sitton[#] and C. Thomas)

Since July 2009 the following reports have been published:

- International Committee for Weights and Measures, 97th meeting (2008), 2010, **76**, 214 pp.
- Director's Report on the Activity and Management of the BIPM (2009), 2010, **10**, 320 pp.
- General Conference on Weights and Measures, 23rd meeting (2007), 2010, 540 pp.
- *Notification des parts contributives dues par les gouvernements des hautes parties contractantes pour l'entretien du Bureau international des poids et mesures et des souscriptions des États et Entités Économiques associés à la Conférence générale en 2010*, 2009, 4 pp.
- *Rapport annuel aux gouvernements des hautes parties contractantes sur la situation administrative et financière du Bureau international des poids et mesures en 2009*, 2010, 52 pp.
- BIPM Annual Report on Time Activities (2009), 2010, 110 pp.
- Consultative Committee for Electricity and Magnetism, 26th meeting (2009), 2010, 62 pp.
- Consultative Committee for Amount of Substance – Metrology in Chemistry, 15th meeting (2009), 2009, 56 pp.
- Consultative Committee for Ionizing Radiation, 21st meeting (2009), 2009, 85 pp.
- Consultative Committee for Time and Frequency, 18th meeting (2009), 2010, 50 pp.
- Consultative Committee for Units, 19th meeting (2009), 2009, 23 pp.

* from 15 April 2010.

[†] until 30 September 2009.

[‡] from 14 September 2009.

[#] from 29 March 2010.

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. As of this year, the BIPM Annual Report on Time Activities is similarly published only in electronic form.

The last year has also seen the publication on the BIPM website of the French version of the Guide to the Expression of Uncertainty of Measurement (GUM 1995 with minor corrections), titled in French “*Évaluation des données de mesure – Guide pour l’expression de l’incertitude de mesure*”, reference JCGM 100:2008; the JCGM-WG2 Corrigendum (2010) to JCGM 200:2008 (VIM); and volume 5 of *Monographie BIPM-5* (“Table of radionuclides”).

In 2009-2010 the Section was responsible for producing printed material associated with the Symposium to celebrate the ten-year anniversary of the CIPM MRA and with the WMO-BIPM Workshop on Metrology and Climate Change.

Finally the Section is responsible for producing the Director’s short report of highlights from the BIPM, to draw the attention of Member State Governments to political and financial issues. The second such report, covering the second half of 2009, was published in early 2010.

The scientific publications of the BIPM are listed in the appropriate sections of the present report.

10.3 Metrologia (J.R. Miles)

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 (IF) of *Metrologia* stands at 1.634 for 2009, just slightly lower than for the previous year (it was 1.780 in 2008). The 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. *Metrologia*’s Impact Factor remains the highest amongst all the related journals. This is important in maintaining and boosting subscription levels as well as in maintaining high-quality submissions. Recent figures for *Metrologia* are shown below:

Year	2003	2004	2005	2006	2007	2008	2009
IF	0.983	1.314	1.479	1.657	1.667	1.780	1.634

The journal has seen a marked increase in number of submissions over the last year, with a total of 246 papers submitted during the period covered by this Report.

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.

Authors submit their manuscripts through the IOPP's internet-based manuscript submission system, which is also used for correspondence with the referees. Publication times remain competitive, and in addition to appearing in the printed journal, all published articles are available in the online version of *Metrologia* (stacks.iop.org/met) and are accessible free of charge for one month after publication

The *Technical Supplement to Metrologia* is also doing well, with 87 Abstracts published during the period of this Report. The *Technical Supplement* provides a convenient means of publishing the (usually long) full reports of key and supplementary comparisons as published in the KCDB, as well as of Pilot Studies as published on the BIPM website. It provides these peer-reviewed reports with a citable journal reference, facilitating formal publication without requiring the authors to re-write their work. Further, the *Technical Supplement* is completely free of charge to subscribers and non-subscribers alike, so guaranteeing that the reports are openly available.

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. Two special issues of *Metrologia* were published during the period of this report: issues **46(4)** on NEWRAD 2008 and **47(2)** on Materials Metrology. Several review articles have also been published, and the members of the CIPM join the Editor in encouraging the submission of relevant review papers and the development of further special issues.

The Editor regrets that due to short-staffing in the Editorial Office at the BIPM it has not been possible to hold a meeting of *Metrologia's* Editorial Board in this last year. However, over the next twelve-month period the

intention is to re-invigorate and expand the Board to meet the needs of today's metrological community.

Finally, readers of the printed copy will have noted that issues **47(1)** and **47(2)** appeared with a different colour of cover. In fact the covers of these issues were produced by digital (rather than lithographic) printing. As the result – obtained using the printing industry's official standard for approximating *Metrologia's* usual Pantone colour – was noticeably different from normal, the IOPP has reverted to lithographic printing of the cover until a more satisfactory colour match can be obtained.

10.4 The BIPM website (N. De Sousa Dias*, L. Le Mée, J.R. Miles, C. Planche‡, R. Sitton# and C. Thomas)

As the BIPM's primary means of communication, our 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.

Due to some short-staffing since November 2008, 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 is grateful to Miss A. Bêche for her assistance as a part-time interim Publications Assistant.

Amongst the improvements to the website made during the period of this report, new software for the restricted-access Discussion Forum has been installed (see www.bipm.org/jforum/). The Discussion Forum is used mainly by various Working Groups of the CCT, who find it convenient for circulating documents requiring review, and maintaining a record of the ensuing discussion and decisions taken. The new software is expected to provide a more reliable service in terms of e-mail alerts to users.

* from 15 April 2010.

‡ from 14 September 2009.

from 29 March 2010.

Continuing the BIPM's collaborative project to promote the benefits of metrology to society, the World Metrology Day (WMD) website (www.worldmetrologyday.org) was duly updated with the BIPM Director's 2010 message on "Measurements in science and technology – A bridge to innovation". This work was undertaken by Mr Mussio on behalf of the BIPM and its partners in the WMD 2010 Team: NCSLI, NIST, NMIJ AIST, NMISA, NPL, OIML, and the PTB.

10.5 Information Technology (L. Le Mée)

During the period of this report, the IT group has updated the BIPM's principal security software and replaced the two messaging gateways with more recent models.

Through a system of automatic alerts as a function of various triggers, a flow-control system installed on the BIPM's local network and a log-file analyser installed on the firewalls assist the IT group in identifying the source of any problems and detecting any abnormal behaviour of the applications.

Our first virtualized platform has been set up for the web and FTP sites of www.worldmetrologyday.org. Virtualization allows us to consolidate (mutualize) the BIPM's web resources and hence to economize on the purchase of physical platforms.

Following a study of a range of open-access options for discussion forum software, the IT group has proceeded with a change in software for the BIPM Discussion Forum, which is used by a number of working groups. The new application forms an integral part of the software architecture of the BIPM's web servers. Particular effort was devoted to increasing the reliability of the associated database, by integrating mechanisms of synchronized replication.

The IT group has also developed new applications on the intranet site, making use of the latest advances in Web 2.0 technology. These applications facilitate the interaction between the user and the service provided by the web server.

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.

10.6 Secretariat (F. Joly, N. De Sousa Dias*, C. Fellag-Ariouet, F. de Hargues, C. Planche‡)

In addition to providing secretarial support to the Director, Director Designate and members of staff, the BIPM secretariat deals with a multitude of secretarial matters related to the large number of meetings held at the BIPM, as well as dealing with visitors and telephone enquiries.

There continues to be a heavy workload linked to the numerous meetings held at the BIPM (see §11). These are essentially those of the Consultative Committees and their Working Groups, but also those of the CIPM and CIPM bureau, meetings of the Joint Committees and various special Workshops, which can be away from the BIPM's premises. In collaboration with the Finance and Administration Department, the Secretariat ensures the smooth running of all these meetings along with the mailing of the associated documents and BIPM publications. Some of these meetings are large and involve parallel sessions across the BIPM, and even some sessions in locations off-site. In particular the CCQM presents a heavy logistical challenge for the BIPM, with meetings spanning a weekend and with parallel Working Group sessions held both on- and off-site. This year also saw the off-site symposium organized to celebrate the ten-year anniversary of the CIPM MRA, and the use of parallel sessions in the BIPM Workshop on Metrology at the Nanoscale.

The most important documents for communication with Member States, Associates, NMI Directors, Consultative Committees and Working Groups are made available via the BIPM's website.

Amongst its other responsibilities, the BIPM Secretariat maintains records of the BIPM's wide range and growing number of international contacts.

10.7 Library (D. Le Coz[†], C. Planche[‡])

The library is an essential part of the BIPM's infrastructure in the efficient pursuit of its scientific work.

Every effort is made to keep its cost down to a minimum and in 2009 the library saw no increase in budget despite the continuing increase in journal

* from 15 April 2010.

‡ from 14 September 2009.

† until 30 September 2009.

‡ from 14 September 2009.

subscription prices. Recognizing that increasing use is being made of electronic resources in favour of the traditional printed publications, a number of the journal subscriptions have been converted to electronic-only versions.

10.8 Travel (conferences and visits): Communication and Information Section

J.R. Miles to:

- Institute of Physics Publishing (IOPP, Bristol, UK), 1 March 2010, for the annual *Metrologia* Partners' Meeting.

11 MEETINGS AND LECTURES AT THE BIPM

11.1 Meetings

The following meetings were held at the BIPM:

- The JCGM-WG2 (VIM) met on 2-4 September 2009, 30 November-1 December 2009 and 19-21 May 2010.
- A meeting of EURAMET TC-PR and APMP TC-PR was held on 14 September 2009.
- The CCPR and its working groups met on 14-18 September 2009.
- A meeting of NMI Directors was held on 7 October 2009.
- A symposium to celebrate the ten-year anniversary of the CIPM MRA was held on 8-9 October 2009 (at the OIE, Paris).
- A coordination meeting between CIE and BIPM was held on 9 October 2009.
- The 98th meeting of the CIPM took place on 13-16 October 2009, preceded by a meeting of the bureau of the CIPM on 12 October 2009. The bureau also met on 8-9 March, 1 June and 4 June 2010.
- A BIPM Workshop on Physiological Quantities and SI units was held on 16-17 November 2009.
- The JCGM met on 2 December 2009.

- The JCTLM Executive met on 3-4 December 2009.
- A BIPM Workshop on Metrology at the Nanoscale was held on 18-19 February 2010.
- A four-partite meeting of the BIPM, ILAC, ISO and OIML was held on 10 March 2010, followed by bilateral meetings of the BIPM and OIML on 11 March and the BIPM and ILAC on 12 March.
- The JCRB met on 16-17 March 2010.
- The 12th meeting of the CCM took place on 26 March 2010, preceded by a meeting of the CCM Chairpersons and WGKC on 22 March 2010, by meetings of CCM-WGM Task Groups 1 and 2 on 23 March and the CCM-WGM itself on 24 March. A CCM Workshop on the proposed redefinition of the kilogram was held on 25 March.
- A meeting of the International Avogadro Coordination (IAC) was held on 29-30 March 2010.
- The WMO/BIPM Workshop on “Measurement Challenges for Global Observation Systems for Climate Change Monitoring: Traceability, Stability and Uncertainty” was held from 30 March-1 April 2010 (at the WMO headquarters, Geneva).
- The 16th meeting of the CCQM and meetings of the CCQM working groups took place from 9-16 April 2010.
- The CCRI(II) Key Comparisons Working Group met on 27 April 2010 followed by the CCRI(II) Uncertainties Working Group on 28 April and the CCRI RMO Working Group on CMCs on 29 April.
- The 25th meeting of the CCT took place on 6-7 May 2010, and was preceded by: a CCT Workshop on “Design and Implementation of Key Comparisons” and a Strategy Meeting on 4 May, meetings of the CCT-WG2, -WG4, -WG6 and -WG9 were held on 5 May, and meetings of the -WG5 and -WG8 on 6 May.
- The CCRI(I) Key Comparisons Working Group met on 17 May 2010 followed by the CCRI(I) Accelerator Dosimetry Working Group on 18 May. A Special meeting of the CCRI on Strategy was held on 19 May.
- The JCGM-WG1 (GUM) met on 25-28 May 2010.
- A meeting of NMI Directors was held on 2-3 June 2010.

11.2 Presentations at the BIPM

- A. Bresson (ONERA), 'Atom interferometry for on-board gravimetry', 22 September 2009.
- A. Proia (CNES/BIPM), '*Contribution à l'étalonnage en absolu d'une chaîne de réception GNSS*', 10 February 2010.
- F. Nez (Laboratoire Kastler Brossel, CNRS, UPMC, ENS, Paris), 'Laser spectroscopy of muonic hydrogen: new determination of the proton charge radius', 24 February 2010.
- O. Francis (University of Luxembourg), 'Earth tides: theory and practice', 18 March 2010.
- E. de Mirandes (BIPM), 'La balance du watt du BIPM : les alignements', 20 April 2010.
- A.J. Wallard (BIPM), 'The international organization of metrology and the BIPM', 10 May 2010.
- R. Goldfarb (NIST, Boulder), 'Magnetism and magnetic measurements', 12 May 2010.
- E.F. Arias (BIPM), 'Come in! We are calculating *Circular T*', 7 June 2010.
- G. Petit (BIPM), 'Time and frequency transfer for dummies', 7 June 2010.
- P. Launey (Directeur Qualité du LNE), '*Présentation du Système Qualité du LNE*', 23 June 2010.

12 CERTIFICATES AND STUDY NOTES

In the period from 1 July 2009 to 30 June 2010, 78 Certificates and 6 Study Notes were issued.

12.1 Certificates

2009

46.	Ozone analyser Environnement SA O3-42M, No. 32	SP, Sweden
47.	Electronic voltage standard, No. 9170 714*	DMDM, Serbia
48.	1 kg mass standard, "3S2"	VSL, Netherlands
49.	1 kg mass standard, "4S2"	Id.
50.	1 kg mass prototype, No. 21*	Mexico
51.	1 kg mass prototype, No. 67*	Czech Republic
52.	Volume magnetic susceptibility of sample, IT-Alac	INRIM, Italy
53.	Volume magnetic susceptibility of sample, IT-Ti	Id.
54.	Étalon de tension à diode de Zener, n° 5940003*	INM, Romania
55.	Zener diode voltage standard, No. 8140009	NIS, Egypt
56.	Zener diode voltage standard, No. 8140006*	Id.
57.	1 kg mass prototype, No. 60*	China
58.	1 kg mass prototype, No. 64*	Id.
59.	1 kg mass prototype, No. 94	Japan
60.	1 kg mass standard, 1K1	NML- SIRIM, Malaysia
61.	1 kg mass standard, 1kr2*	Id.
62.	Ionization chamber Exradin A3, No. 229 in gamma-ray beams*	NRPA, Norway
63.	Ionization chamber NE 2575, No. 116 in gamma-ray beams	Id.
64.	1 Ω resistance standard, No. 1681958*	NIS, Egypt

* Standards marked with an asterisk have been calibrated previously at the BIPM.

65.	1 Ω resistance standard, No. 1684330*	Id.
66.	1 Ω resistance standard, No. 1679692*	Id.
67.	10 000 Ω resistance standard, No. 307106	Id.
68.	1 Ω resistance standard, No. 1910 466*	NML- SIRIM, Malaysia
69.	100 Ω resistance standard, No. A2011101SR102	NMC, A*STAR Singapore
70.	1 Ω resistance standard, No. 076165	BIM, Bulgaria
71.	1 Ω resistance standard, No. 1100574	Id.
72.	1 Ω resistance standard, No. 1100576	Id.
73.	100 Ω resistance standard, No. 146308	Id.
74.	100 Ω resistance standard, No. 11769/11	Id.
75.	100 Ω resistance standard, No. 11769/12	Id.
76.	10 000 Ω resistance standard, No. J1-0824603	Id.
77.	10 000 Ω resistance standard, No. J1-0824604	Id.
78.	10 000 Ω resistance standard, No. J1-0824605	Id.
79.	100 pF capacitance standard, No. 01110*	NML- SIRIM, Malaysia
80.	10 pF capacitance standard, No. 01111*	Id.
81.	10 pF capacitance standard, No. 01112*	Id.
82.	1 pF capacitance standard, No. 01245	NMC, A*STAR Singapore
83.	10 pF capacitance standard, No. 01244	Id.
84.	100 pF capacitance standard, No. 01240	Id.
85.	Volume magnetic susceptibility of sample, P17 1kg D	MIKES, Finland

86.	1 Ω resistance standard, type 4210B, No. 1711458*	INMETRO, Brazil
87.	1 Ω resistance standard, type 4210, No. 1883427*	Id.
88.	10 000 Ω resistance standard, ESI type SR 104, No. 043007*	Id.
89.	100 pF capacitance standard, No. 01256	PTB, Germany
90.	10 pF capacitance standard, model AH11A, No. 01257	Id.
91.	10 pF capacitance standard, model AH11A, No. 01258	Id.

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1.	10 000 Ω resistance standard, ESI type SR 104, No. 43021*	SMD, Belgium
2.	100 Ω resistance standard, Tegam type SR 102, No. A2010199SR102	Id.
3.	Ionization chamber NE 2571, No. 2719 in x-ray beams*	NMISA, South Africa
4.	Ionization chamber NE 2571, No. 2719 in a ^{60}Co gamma- ray beam*	Id.
5.	Ionization chamber PTW 30012, No. 0064 in x-ray beams*	Id.
6.	Ionization chamber PTW 30012, No. 0064 in a ^{60}Co gamma-ray beam*	Id.
7.	Ionization chamber NE 2530, No. 649 in gamma-ray beams*	Id.
8.	Ionization chamber NE 2561, No. 097 in a ^{60}Co gamma-ray beam*	STUK, Finland
9.	Ionization chamber NE 2561, No. 097 in medium-energy x-rays*	Id.
10.	Ionization chamber PTW 23344, No. 620 in low-energy x- rays*	Id.
11.	Ionization chamber Radcal RC6M, No. 9066 in low-energy x-rays	NIM, China
12.	Ionization chamber Radcal RC6M, No. 9066 in mammography x-rays	Id.

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|-----|--|------------------------|
| 13. | Ionization chamber NE 2571, No. 708 in a ^{60}Co gamma-ray beam | Id. |
| 14. | Ionization chamber PTW 30010, No. 2369 in a ^{60}Co gamma-ray beam | Id. |
| 15. | Ionization chamber PTW 30012, No. 163 in a ^{60}Co gamma-ray beam | Id. |
| 16. | 10 000 Ω resistance standard, TEGAM type SR 104, No. J1-0919617 | KRISS, Korea, Rep. of |
| 17. | 100 Ω resistance standard, Guildline type 7334, No. 69156 | Id. |
| 18. | 1 Ω resistance standard, Leeds and Northrup type 4210, No. 1 915 096 | NIMT, Thailand |
| 19. | 100 Ω resistance standard, TEGAM type SR102, No. A2010106SR102 | Id. |
| 20. | 10 000 Ω resistance standard, Leeds and Northrup type 4214B, No. 1 917 542* | Id. |
| 21. | 1 kg mass prototype, No. 52* | Germany |
| 22. | 1 kg mass prototype, No. 83* | Singapore |
| 23. | 1 kg mass standard in stainless steel, No. 83700* | NMC, A*STAR, Singapore |
| 24. | 1 kg mass standard in stainless steel, S* | MSL, New Zealand |
| 25. | 1 kg mass standard in stainless steel, TLT | Id. |
| 26. | 1 kg mass standard in stainless steel, KZ1 | KazInMetr, Kazakhstan |
| 27. | 1 kg mass standard in stainless steel, KZ2 | Id. |
| 28. | 1 kg mass standard in stainless steel, KZ3 | Id. |
| 29. | 100 pF capacitance standard, Andeen-Hagerling model AH11A, No. 01323* | CMI, Czech Republic |
| 30. | 1 pF capacitance standard, Andeen-Hagerling model AH11A, No. 01358* | NIMT, Thailand |
| 31. | 10 pF capacitance standard, Andeen-Hagerling model AH11A, No. 01359* | Id. |
| 32. | 100 pF capacitance standard, Andeen-Hagerling model AH11A, No. 01360* | Id. |

12.2 Study Notes

2009

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|----|---|----------------------------|
| 5. | 1,018 V tension continue électronique, n° 5940003 | INM,
Romania |
| 6. | 1.018 V electronic voltage standard, No. 8140003 | NIS, Egypt |
| 7. | 1 pF capacitance standard, No. 01113 | NML-
SIRIM,
Malaysia |
| 8. | 10 pF capacitance standard, model AH11A, No.01176 | PTB,
Germany |

2010

- | | | |
|---|---|-----------------------------|
| 1 | 100 Ω resistance standard, TEGAM type SR102, No. J1-0919615 | KRISS,
Korea, Rep.
of |
| 2 | 10 000 Ω resistance standard, Guildline type 7334, No. 69159 | Id. |

13 FINANCE, ADMINISTRATION AND GENERAL SERVICES DEPARTMENT (B. PERENT)

The Finance, Administration and General Services Department is responsible for the smooth running of the financial and administrative management of the BIPM as well as a wide range of other support services. This includes, in particular: financial, human resources, legal and other services; relations with the French authorities, Member States and Associates, and other States and international organizations and bodies regarding financial, legal and administrative affairs; and the negotiation and daily management of all contracts and agreements entered into by the BIPM. Over the last year it arranged more than 140 customs operations for import and export of standards for calibrations and comparisons; it worked on

arrangements for 11 recruitments and launched a number of calls for tenders for the purchase of scientific equipment and services.

The Finance, Administration and General Services Department finalized the draft amendments to the Regulations and Rules of the BIPM Pension and Provident Fund. These amendments were submitted to the CIPM at its 98th session and approved on 16 October 2009. A presentation of these amendments was made to the staff members in November 2009, and the amendments entered into force on 1 January 2010.

The Finance, Administration and General Services Department has also finalized the draft amendments to the BIPM Financial Regulations. These amendments were submitted to the CIPM at its 98th session and approved on 16 October 2009. They entered into force on 1 January 2010.

The Finance, Administration and General Services Department has also worked on the new accounting rules and policies.

In addition, following up on Resolutions 5 and 6 adopted by the CGPM at its 23rd meeting, the Finance, Administration and General Services Department presented two reports to the CIPM at its 98th session. The first report concerned Associate States, following which the CIPM adopted criteria enabling it to review whether it would be appropriate for an Associate State to become a Member State and discussed possible revisions to the status of Associate. The Finance, Administration and General Services Department has consequently prepared a corresponding draft Resolution to be included in the Convocation of the 24th meeting of the CGPM. The second report concerns Economies as Associates of the CGPM, following which the CIPM adopted criteria against which applications from Economies to become Associates of the CGPM should be assessed. The Finance, Administration and General Services Department has consequently prepared a corresponding draft Resolution submitting these criteria for approval to be included in the Convocation of the 24th meeting of the CGPM.

The Finance, Administration and General Services Department has been working on the draft texts of the Convocation of the 24th meeting of the CGPM and the Programme of Work and has prepared the corresponding budget.

The Finance, Administration and General Services Department has been in contact with the authorities of those Member States in arrears for more than 3 years with a view to discussing conditions for the settlement of their arrears, pursuant to the provisions of the Metre Convention and its Annexed Regulations and of Resolution 8 adopted by the CGPM at its 23rd meeting.

13.1 Accounts

Details of the accounts for 2009 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*”.

The headings for the tables may be translated as follows:

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

Three additional tables detail the income and the payments made against budget in 2009 and the balance sheet at 31 December 2009. They are presented under the headings:

<i>Détail des recettes budgétaires</i>	Statement of budgetary income
<i>Détail des dépenses budgétaires</i>	Statement of budgetary expenditure
<i>Bilan au 31 décembre 2009</i>	Balance at 31 December 2009

In accordance with Resolution 13 voted by the CGPM at its 21st meeting, since 2001 the unit of currency in all these tables is the euro.

13.2 Staff

13.2.1 Appointments

- Miss Charline Mesquida, born 18 October 1981 in Mont Saint Aignan (France), French nationality, was appointed *technicien* in the Chemistry Department for a fixed period of seven months starting 20 July 2009.
- Mr Bruno Amaro Coelho, born 1 August 1978 in Vimioso (Portugal), Portuguese nationality, previously Quality, Health and Safety Manager

in a private company in Portugal, was appointed *responsable Qualité, Santé et Sécurité* from 4 September 2009.

- Miss Céline Planche, born 8 July 1978 in Nancy (France), French nationality, previously translator in a French translation company, was engaged as *bibliothécaire – rédacteur* in the Secretariat from 14 September 2009.
- Miss Aurélie Messias, born 8 January 1983 in La Tronche (France), French nationality, previously intern in a French territorial collectivity, was appointed *secrétaire* in the Communication and Information Section from 4 January 2010.
- Mr Robert Sitton, previously Commissioning Editor in a British publishing company, was appointed *chargé de publications* in the Communication and Information Section from 29 March 2010.
- Mr Andrew Henson, born 28 February 1957 in West Kirby (UK), British nationality, previously Head of the NPL's International Office (UK), was appointed *responsable des relations internationales* from 1st April 2010.
- Miss Nina De Sousa Dias, born 2 June 1980 in Perpignan (France), French nationality, previously assistant in a French private company, was engaged as *secrétaire* in the Communication and Information Section from 15 April 2010.

13.2.2 Changes of title

The following changes of title resulted from a decision of the CIPM during its 98th session (2009) and were effective as of 8 December 2009:

- Mrs Brigitte Perent, *administrateur principal*, formerly head of the Finance and Administration Section, was designated Financial and Administrative Director.
- Dr Richard Davis, *physicien chercheur principal*, formerly head of the Mass Section, was designated Director of the Mass Department.
- Dr Penelope Allisy-Roberts, *physicien chercheur principal*, formerly head of the Ionizing Radiation Section, was designated Director of the Ionizing Radiation Department.

- Dr Felicitas Arias, *physicien chercheur principal*, formerly head of the Time, Frequency and Gravimetry Section, was designated Director of the Time, Frequency and Gravimetry Department.
- Dr Michael Stock, *physicien chercheur principal*, formerly head of the Electricity Section, was designated Director of the Electricity Department.
- Dr Robert Wielgosz, *chimiste chercheur principal*, formerly head of the Chemistry Section, was designated Director of the Chemistry Department.
- Mr Alain Picard, *physicien chercheur principal*, formerly Deputy Head of the Mass Section, was designated Deputy Director of the Mass Department.

13.2.3 Changes of post and transfer

To improve the efficiency of the organizational structure of the BIPM, a new “Communication and Information” Section has been created to integrate the secretarial, publications and IT services into one section.

- Mrs Françoise Joly, *secrétaire de direction*, formerly head of the Secretariat, was designated head of the Communication and Information Section from 1st January 2010.
- Mrs Céline Fellag Ariouet, *secrétaire principale* in the Secretariat, was transferred to the Communication and Information Section from 1st January 2010.
- Mrs Frédérique de Hargues, *secrétaire* in the Secretariat, was transferred to the Communication and Information Section from 1st January 2010.
- Miss Céline Planche, *bibliothécaire – rédacteur* in the Secretariat, was transferred to the Communication and Information Section from 1st January 2010.
- Mr Laurent Le Mée, *informaticien principal* in the Publications and Information Technology Section, was transferred to the Communication and Information Section from 1st January 2010.
- Dr Janet Miles, *responsable des publications*, was transferred to the Communication and Information Section from 1st January 2010.

13.2.4 Research fellows

- Dr Michael Bradley, born 24 January 1971 in Victoria (Canada), Canadian nationality, previously Associate Professor in the Department of Physics and Engineering Physics, at the University of Saskatchewan (Canada), was appointed Research Fellow in the Electricity Department from 3 September 2009.
- Dr Estefania de Mirandés, Research Fellow in the Electricity Department since 7 January 2008, has had her research fellowship extended until 18 December 2011.

13.2.5 Departures

- Mr Jacques Labot, *technicien principal* in the Time, Frequency and Gravimetry Section, retired on 31 July 2009 after 20 years of service.
- Mr Raymond Felder, *physicien principal* in the Time, Frequency and Gravimetry Section, retired on 31 August 2009 after 32 years of service.
- Mrs Danièle Le Coz, *secrétaire de rédaction – bibliothécaire* in the Secretariat, retired on 30 September 2009 after 26 years of service.
- Dr Leonid Vitushkin, *physicien chercheur principal* in the Time, Frequency and Gravimetry Section, retired on 30 November 2009 after 16 years of service.

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

- Miss Aurélie Messias, *secrétaire* in the Communication and Information Section since 4 January 2010, left the BIPM on 25 February 2010.

13.3 Buildings

13.3.1 Pavillon de Breteuil

- Refurbishment of an office on the first floor.
- Plumbing work in the sanitary facilities in the basement.

13.3.2 Observatoire

- Refurbishment of room 7 to create a place for waste chemicals.
- Electrical work in room 116.

- Completion of the refurbishment of room 2.
- Refurbishment of room 104 including a concrete screed.
- Replacement of the wooden floor in the corridor.
- Maintenance of the roof.

13.3.3 Ionizing Radiation building

- Technical and financial feasibility study for the construction of a vault for a linear accelerator at the BIPM.

13.3.4 Laser building

- Painting of the security officer's apartment.
- Conversion of the electronic workshop into a reception area with sanitary facilities.

13.3.5 Nouveau Pavillon

- Replacement of the library ceiling.

13.3.6 All buildings

- Energy audit.

13.3.7 Outbuildings and park

- Work on the fence on the hill behind the Observatory.
- Installation of an additional light on the pedestrian path.
- Partial replacement of the air-conditioning equipment in the greenhouse.
- Replacement of the entrance gate barrier.

13.4 **Travel: Finance, Administration and General Services Department**

B. Perent and S. Arlen to:

- Luxembourg, 20-21 May 2010, to attend the 8th Workshop on Pensions in International Organisations, organized by the Pensions Section of the

Coordinated Organisations and the UN Joint Staff Pension Fund, hosted by the European Investment Bank (EIB).

14 MECHANICAL WORKSHOP (J. SANJAIME)

The staff of the BIPM workshop combine the tasks of providing support for all the BIPM's experimental work, including for visiting scientists during comparisons and calibrations, with that of providing site maintenance and planning services. Of particular note is the continuing effort devoted to construction and improvement of the BIPM's watt balance and its work on ancillary equipment for the Ionizing Radiation Department. The workshop's expertise provides essential support for the Mass Department through its unique facilities for the manufacture of kilogram artefacts and vacuum apparatus.

Site maintenance has increased significantly during the last year as has work associated with the planning of a number of major refurbishments and laboratory upgrades.

LIST OF ACRONYMS AND INITIALISMS USED IN THE PRESENT VOLUME

AACC	American Association for Clinical Chemistry, Washington DC (USA)
ADWG(I)	CCRI(I) Accelerator Dosimetry Working Group
AFRIMETS	Inter-Africa Metrology System
AIC ILAC	Accreditation Issues Committee
AIST	National Institute of Advanced Industrial Science and Technology, <i>see</i> NMIJ AIST
AOCS	American Oil Chemists's Society (USA)
AOS	Borowiec Astrogeodynamical Observatory/Observatorium Astrogeodynamicznego Borowiec, Borowiec (Poland)
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)
AUC	Automatically Unloadable Container
BEV	Bundesamt für Eich- und Vermessungswesen, Vienna (Austria)
BIM	Bulgarian Institute for Metrology (Bulgaria)
BIML	International Bureau of Legal Metrology/Bureau International de Métrologie Légale
BIPM	International Bureau of Weights and Measures/Bureau International des Poids et Mesures
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/Comité Consultatif de l'Acoustique, des Ultrasons et des Vibrations
CCE	Commission for Conditions of Employment

CCEM	Consultative Committee for Electricity and Magnetism/Comité Consultatif d'Électricité et Magnétisme
CCL	Consultative Committee for Length/Comité Consultatif des Longueurs
CCM	Consultative Committee for Mass and Related Quantities/Comité Consultatif pour la Masse et les Grandeurs Apparentées
CCM-WGM	CCM Working Group on Mass Standards
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/Comité Consultatif de Photométrie et Radiométrie
CCQM	Consultative Committee for Amount of Substance: Metrology in Chemistry/Comité Consultatif pour la Quantité de Matière : Métrologie en Chimie
CCRI	Consultative Committee for Ionizing Radiation/Comité Consultatif des Rayonnements Ionisants
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/Comité Consultatif de Thermométrie
CCTF	Consultative Committee for Time and Frequency/Comité Consultatif du Temps et des Fréquences
CCU	Consultative Committee for Units/Comité Consultatif des Unités
CENAM	Centro Nacional de Metrología, Querétaro (Mexico)
CET	Compton source efficiency tracing
CGGTTS	CCTF Group on GNSS Time-Transfer Standards
CGPM	General Conference on Weights and Measures/Conférence Générale des Poids et Mesures
CGSIC	Civil Global Positioning System Service Interface Committee

CHMI	Czech Hydrometeorological Institute/Český hydrometeorologický ústav (Czech Rep.)
CIE	International Commission on Illumination
CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, Madrid (Spain)
CIPM	International Committee for Weights and Measures/Comité International des Poids et Mesures
CMC	Calibration and Measurement Capability
CMM	3D Coordinate-Measuring Machine
CMI	Czech Metrological Institute/Český Metrologický Institut, Brno (Czech Rep.)
CMI-IIR	Czech Metrological Institute, Inspectorate for Ionizing Radiation/Český Metrologický Institut, Inspektorát Pro Ionizující Zářeni (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/ Consejo Nacional de Investigaciones Científicas y Técnicas, Buenos Aires (Argentina)
COOMET	Cooperation in Metrology among the Central European Countries
CPEM	Conference on Precision Electromagnetic Measurements
CSIR	Council of Scientific and Industrial Research, New Delhi (India)
CRDS	Cavity Ring-Down Spectroscopy/Spectrometer
DFM	Danish Fundamental Metrology, Lyngby (Denmark)
DI	Designated Institute
DMDM	Directorate of Measures and Precious Metals (Serbia)
EAL	Free Atomic Time Scale/Échelle Atomique Libre
EFTF	European Frequency and Time Forum

EIM	Hellenic Institute of Metrology, Thessaloniki (Greece)
EMPA	Swiss Federal Laboratories for Materials Testing and Research (Switzerland)
ENFSI	European Network of Forensic Science Institute, the Hague (Netherlands)
ESA	European Space Agency
EURAMET	(the former EUROMET) European Association of National Metrology Institutes
FCS	Frequency Control Symposium
FTIR	Fourier Transform Infrared (FTIR spectroscopy)
GAW	(WMO) Global Atmosphere Watch, Geneva (Switzerland)
GAWG	CCQM Working Group on Gas Analysis
GC-FID	Gas Chromatography/Flame Ionization Detector
GC-MS	Gas Chromatography/Mass Spectrometry
GEOS	Global Earth Observation System
GGOS	Global Geodetic Observing System
GLONASS	Global Navigation Satellite System
GNSS	Global Navigation Satellite System(s)
GPS	Global Positioning System
GPT	Gas Phase Titration
GSB	Ghana Standards Board, Accra (Ghana)
GUM	Central Office of Measures/Główny Urząd Miar, Warsaw (Poland)
GUM	Guide to the Expression of Uncertainty in Measurement
HCHO	Formaldehyde
HPGe	High-Purity Germanium Spectrometer
HPLC	High-Performance Liquid Chromatography
HPLC-UV	High-Performance Liquid Chromatography with UV Detector
HSC	Health and Safety Committee
IAC	International Avogadro Coordination
IAEA	International Atomic Energy Agency
IAG	International Association of Geodesy

IAM	Inter-Agency Meeting
IAU	International Astronomical Union
ICAG	International Comparison of Absolute Gravimeters
ICG	International Committee for GNSS
ICNIRP	International Committee for Non-Ionizing Radiation Protection
ICRM	International Committee for Radionuclide Metrology
ICRU	International Commission on Radiation Units and Measurements
ICTNS	(IUPAC) Interdivisional Committee on Terminology, Nomenclature and Symbols
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers, Piscataway, NJ (USA)
IERS	International Earth Rotation and Reference Systems Service
IF	Impact Factor
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)
IGS	International GNSS Service
ILAC	International Laboratory Accreditation Cooperation
ILL	Institut Laue-Langevin, Grenoble (France)
IMEKO	International Measurement Confederation
INDECOPI	Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual/National Institute for the Defense of Competition and Protection of Intellectual Property, Lima (Peru)
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)
INTN	Instituto Nacional de Tecnología, Normalización y Metrología, Asunción (Paraguay)
IOPP	Institute of Physics Publishing, Bristol (UK)
IRA	Institut Universitaire de Radiophysique Appliquée (Switzerland)
IRMM	Institute for Reference Materials and Measurements, European Commission, Geel (Belgium)
ISHM	International Symposium on Humidity and Moisture
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
IUPAC	International Union of Pure and Applied Chemistry
IUPAP	International Union of Pure and Applied Physics
IVS	International VLBI Service
JCDCMAS	former 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
JVS	Josephson Voltage Standard
KazInMetr	Kazakhstan Institute of Metrology (Kakakhstan)
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
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-SYRTE	LNE Systèmes de Référence Temps Espace, Paris (France)
MAS	Metrology, accreditation and standardization
METAS	Federal Office of Metrology, Bern-Wabern (Switzerland)
METCHEM	EURAMET Technical Committee on Chemistry
MIKES	Centre for Metrology and Accreditation/Mittatekniikan Keskus, Helsinki (Finland)
MKEH	Hungarian Trade Licensing Office, Budapest (Hungary)
MRA	Mutual Recognition Arrangement
MS	Mass Spectrometry
MSL-IRL	Measurement Standards Laboratory of New Zealand, Industrial Research Limited, Lower Hutt (New Zealand)
NCSLI	NCSL International, Boulder, Co. (USA)
NIBSC	National Institute for Biological Standards and Control, Potters Bar (UK)
NICT	National Institute of Information and Communications Technology, Tokyo (Japan)
NIM	National Institute of Metrology, Beijing (China)
NIMT	National Institute of Metrology, Pathumthani (Thailand)
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	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)
NMO	National Measurement Office, Teddington (UK)
NML-SIRIM	National Metrology Laboratory, SIRIM Berhad (Malaysia)
NMR	Nuclear Magnetic Resonance
NMS	National Measurement System (UK)
NOAA/ESRL	National Oceanic and Atmospheric Administration, Earth System Research Laboratory, Boulder (USA)
NPL	National Physical Laboratory, Teddington (UK)
NRC	National Research Council of Canada, Ottawa (Canada)
NSAI	National Standards Authority of Ireland, Dublin (Ireland)
NTSC	National Time Service Center, The Chinese Academy of Sciences (China)
OAWG	CCQM Working Group on Organic Analysis
OIML	International Organization of Legal Metrology/ Organisation Internationale de Métrologie Légale
OMP	Observatoire Midi-Pyrénées, Toulouse (France)
ONERA	Office National d'Études et Recherches Aéronautiques, Palaiseau (France)
ONRJ	Observatório Nacional/National Observatory, Rio de Janeiro (Brazil)
OP	Paris Observatory/Observatoire de Paris, Paris (France)
ORB	Observatoire Royal de Belgique, Brussels (Belgium)
PFS	Primary Frequency Standard
PMOD/WRC	Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center, Davos (Switzerland)
PPP	Precise Point Positioning
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig and Berlin (Germany)

PTTI	Precise Time & Time Interval
QHE	Quantum Hall Effect
QHR	Quantum Hall Resistance
qNMR	Quantitative Nuclear Magnetic Resonance
QS	Quality System
RISØ	National Laboratory for Sustainable Energy, Technical University Denmark (DTU), Roskilde (Denmark)
RMO	Regional Metrology Organization
RMP	Reference Material Providers
RRI	Regulations, Rules and Instructions
RWTH	Technical University of Aachen/Rheinisch-Westfälische Technische Hochschule, Aachen (Germany)
SI	International System of Units/Système International d'Unités
SIM	Inter-American Metrology System/Sistema Interamericano de Metrología
SIR	International Reference System for gamma-ray emitting radionuclides/Système International de Référence pour les mesures d'activité d'émetteurs de rayonnement gamma
SMD	Service Métrologie Scientifique, Brussels (Belgium)
SMU	Slovak Institute of Metrology/Slovenský Metrologický Ústav, Bratislava (Slovakia)
SNS	Superconductor-normal metal-superconductor
SP	Technical Research Institute of Sweden, Borås (Sweden)
SPRT	Standard Platinum Resistance Thermometer
SRC	Space Research Centre, Warsaw (Poland)
SRP	Standard Reference Photometer
SSDL	Secondary Standards Dosimetry Laboratories
SUNAMCO	IUPAC-C.2 Commission on Symbols, Units, Nomenclature, Atomic Masses and Fundamental Constants
TC	Technical Committee
TAI	International Atomic Time/Temps Atomique International
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
TT	Terrestrial Time
T2L2	Time Transfer by Laser Link
TW	Two-Way
TWSTFT	Two-Way Satellite Time and Frequency Transfer
UCWG(II)	CCRI(II) Uncertainties Working Group
UFFC	IEEE Ultrasonics, Ferroelectrics, and Frequency Control Society, <i>see</i> IEEE
UK	United Kingdom of Great Britain and Northern Ireland
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
U.S.	United States of America
USA	United States of America
USNO	U.S. Naval Observatory, Washington DC (USA)
UTC	Coordinated Universal Time
UV	Ultraviolet
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.)
VNIIFTRI	Institute for Physical-Technical and Radiotechnical Measurements, Rostekhnregulirovaniye of Russia (Russian Fed.)
VOC	Volatile Organic Compound
VSL	VSL (formerly NMI-VSL), Delft (Netherlands)
WADA	World Anti-Doping Agency
WG	Working Group
WGG	CCM Working Group on Gravimetry

WHO	World Health Organization
WMD	World Metrology Day
WMO	World Meteorological Organization
XPS	X-ray Photoelectron Spectroscopy