Bureau International des Poids et Mesures

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

(1 July 2004 – 30 June 2005)

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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THE BIPM AND THE METRE CONVENTION

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

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

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

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

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

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

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

The CIPM has eighteen members each from a different State: at present, it meets every year. The officers of this committee present an annual report on the administrative and financial position of the BIPM to the Governments of the Member States of the Metre Convention. The principal task of the CIPM

is to ensure worldwide uniformity in units of measurement. It does this by direct action or by submitting proposals to the CGPM.

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

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

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

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

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

3. The Consultative Committee for Thermometry (CCT), set up in 1937;
4. The Consultative Committee for Length (CCL), new name given in 1997 to the Consultative Committee for the Definition of the Metre (CCDM), set up in 1952;
5. The Consultative Committee for Time and Frequency (CCTF), new name given in 1997 to the Consultative Committee for the Definition of the Second (CCDS) set up in 1956;
6. The Consultative Committee for Ionizing Radiation (CCRI), new name given in 1997 to the Consultative Committee for Standards of Ionizing Radiation (CCEMRI) set up in 1958 (in 1969 this committee established four sections: Section I (X- and γ-rays, electrons), Section II (Measurement of radionuclides), Section III (Neutron measurements), Section IV (α-energy standards); in 1975 this last section was dissolved and Section II was made responsible for its field of activity);
7. The Consultative Committee for Units (CCU), set up in 1964 (this committee replaced the "Commission for the System of Units" set up by the CIPM in 1954);
8. The Consultative Committee for Mass and Related Quantities (CCM), set up in 1980;
9. The Consultative Committee for Amount of Substance: Metrology in chemistry (CCQM), set up in 1993;
10. The Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV), set up un 1999.

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

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

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

The BIPM also publishes monographs on special metrological subjects and, under the title *The International System of Units (SI)*, a brochure, periodically updated, in which are collected all the decisions and recommendations concerning units.

The collection of the *Travaux et Mémoires du Bureau International des Poids et Mesures* (22 volumes published between 1881 and 1966) and the *Recueil de Travaux du Bureau International des Poids et Mesures*

(11 volumes published between 1966 and 1988) ceased by a decision of the CIPM.

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

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

STAFF OF THE
INTERNATIONAL BUREAU OF WEIGHTS AND MEASURES

on 1 July 2005

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

(1 July 2004 – 30 June 2005)

1 INTRODUCTION

1.1 General introduction and summary of scientific work

Last year I reported to you on a number of significant events for the BIPM, notably the outcome of the 2003 General Conference on Weights and Measures (CGPM) and the progress made in implementing the CIPM MRA. During the last year, we have begun the four-year work programme which was approved by the General Conference and have taken steps to develop long-term plans for the BIPM. In addition, we have completed the transition period for the CIPM MRA, have extended our activities in the chemical sector and have consolidated and extended our collaborations with a number of international bodies.

The BIPM is currently in good financial and scientific shape, but we are facing current and future resource limitations. As far as possible, and within the financial and other constraints imposed by the 2005-2008 work programme, we are increasing, and must continue to increase, our resources devoted to the scientific and other needs of new areas of investigation. Many of these needs were not evident when the CGPM approved our work programme in 2003 and we have made regular reports to the CIPM on how we are adapting the work programme to respond to the most urgent priorities. We do, however, appear to be victims of our own success in many of the initiatives we have taken in chemical metrology. We therefore need to be careful that we do not overstretch our resources and lead to unrealistic expectations of our ability to deliver solutions to all the needs and requirements of these communities. Although there has been a substantial shift of resources away from physics at the BIPM in the last few years, we must continue to balance the newer activities against the well-established and continuing needs of Member States and Associates. This is not an easy task. We are, however, grateful that a number of National Metrology Institutes (NMIs) are prepared to lend, or second staff to us in accordance with Resolution 12 of the last General Conference. This will, I am sure, be a subject that will continue to exercise the minds of staff here, as well as those of the members of the CIPM.

Against this background, we must also soon start to prepare reports and position papers for the CIPM so as to draft our next work programme and associated budget proposals for the 23rd CGPM in 2007. The CIPM Secretary, Dr Robert Kaarls, will be updating the review he made for the last CGPM and I have no doubt that we shall again be faced with high priority demands which will out-strip our current resources. To help with this

process, and to continue our programme of change and adaptation, we are, therefore, currently working on long-term plans for the evolving nature and content of the BIPM's scientific and other work. Our aim is to discuss these with individual Consultative Committees for their advice and comments and then to present them to forthcoming meetings of the CIPM.

The Metre Convention: During the last year, we were pleased to welcome Croatia and Estonia as Associate States and Economies of the CGPM so as to bring the number of Associates to 18. The number of Member States of the Metre Convention remains at 51.

The CIPM MRA and the JCRB: Forty-five Members and 17 Associates and 2 international organizations have now signed the CIPM MRA, bringing the number of institutes and designated organizations committed to the CIPM MRA to nearly 150. There are currently over 17 000 Calibration and Measurement Capabilities (CMCs) and 612 comparisons in the BIPM Key Comparison Database (KCDB). We have attempted to simplify the inter-regional review process and focus attention on the Technical Committee Chairs thereby speeding up the reviews. This "fast track" process should encourage NMIs to upgrade their CMCs when they improve their technical capabilities.

The status of Designated Institutes has been causing some concern within the CIPM MRA community. A guidance paper on this topic has been agreed by the CIPM and is available on the BIPM website. The Directors of national coordination organizations are asked to ensure that designated institutes follow these guidelines so that we have a clear statement of their responsibilities, so that we do not have to reject CMCs from laboratories which have not been designated.

The Joint Committee of the Regional Metrology Organizations (RMOs) and the BIPM (the JCRB) met in October 2004 at the BIPM and was hosted by COOMET in May 2005 at BelGIM, Minsk (Belarus). At the first of these two meetings it also held a special workshop on Quality System assessment processes in the RMOs. The workshop helped considerably in the mutual understanding of the way in which each RMO reviewed the Quality Systems at their member laboratories and also endorsed the BIPM's own Quality System, which was presented during the workshop.

The JCRB has focussed on arrangements for the end of the transition period of the CIPM MRA and, in particular, the necessity for signatories to the CIPM MRA to have their Quality Systems fully reviewed and in place by the first JCRB of 2005. This timescale has put pressure on the RMOs and the NMIs to complete this process before the deadline so as to ensure their

CMCs remain in the KCDB. Reports from RMOs to the May 2005 meeting showed that a number of NMIs had already requested the temporary suppression of some CMCs from the KCDB and that only a few additional CMCs, which were not yet covered by a reviewed and approved Quality Management Systems (QMS), needed to be removed. As soon as the QMS is reported to be consistent with the requirements of the CIPM MRA, these CMCs will be reinstated.

A new "clarification" document for the CIPM MRA is available which updates previous documents on the evolving nature and interpretation of the original MRA. In addition, the ISO Guide 34 will be considered as the relevant quality standard requirement for CMCs related to reference material production, with a transition period for implementation by the first JCRB of 2006.

Meeting of directors of NMIs (September 2004): The annual Directors' Meeting dealt largely with matters which concerned the CIPM MRA and several extremely useful presentations were made about NMI experiences, the importance of the CIPM MRA to the regulators and the way in which the Metre Convention worked on behalf of the NMIs with ILAC and ISO. The meeting concluded with a presentation by the Secretary-General of ISO, Alan Bryden. Another Directors' meeting will be held at the end of September 2005.

The Joint Committee for Traceability in Laboratory Medicine (JCTLM): We are especially pleased by the progress in laboratory medicine under the JCTLM. This programme is now well on the way to the creation of a widely acknowledged and internationally accepted framework for the recognition of reference materials "of a higher order" as required by the *In Vitro* Diagnostic community. Lists of "standards of a higher order" will be entered onto the BIPM's JCTLM database later this year or in early 2006. Some 300 reference materials and about 75 reference methods have been nominated for review. We are also finalizing the criteria against which laboratories that are recognized as having the appropriate competences in diagnostic and laboratory medicine will be listed.

In addition to the cooperation with our formal JCTLM partners, the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC) and International Laboratory Accreditation Cooperation (ILAC), we are working with the World Health Organization (WHO), especially in the area of biological units and traceability.

Joint Committee for Guides in Metrology (JCGM): With other collaborators in Working Group 1 of this committee, the BIPM is working on

two supplements to the *Guide to the Expression of Uncertainty in Measurement* (the GUM). The first of these supplements concerns the propagation of distributions using Monte Carlo methods and the second deals with the generalization of the GUM to the case with several output quantities. Both supplements will, we hope, be finalized in 2006.

Working Group 2 of the JCGM has circulated a draft version of the *International Vocabulary of Basic and General Terms in Metrology* (VIM), and is now dealing with the many sets of comments which have been received.

The SI Brochure: The CIPM gave its general endorsement to a draft version of the next SI Brochure at its October 2004 meeting. Subsequently the CCU has finalized the draft and has approved a "mini" version which will be available later this year for widespread distribution by NMIs and others.

The CIPM: The CIPM held its usual meeting on October 2004 and welcomed Professor Ernst Göbel in his new role as President as well as two new members, Dr Luc Érard (LNE, France) and Dr Kim Carneiro (DFM, Denmark); and Dr Hratch Semerjian (NIST, United States) present for the first time.

The meeting focussed on our links with ILAC and OIML as well as on a number of important issues which concern the long-term planning of BIPM's scientific and technical work. It also considered a proposal from the materials community for an activity, within the Metre Convention, on traceability and uncertainty in materials metrology. This is currently the subject of a working group led by Dr Seton Bennett of the NPL and which will report to the CIPM in October 2005. Meetings of Dr Bennett's group will look at how a more rigorous approach to SI traceability may be of benefit to the materials community and will outline possible work plans in a number of areas. The CIPM will decide on whether to adopt an activity in materials metrology and how it would be handled administratively.

The CIPM also clarified and updated its policy on the services which could be made available to NMIs from Associates of the CGPM and their participation in comparisons, pilot studies and working groups of Consultative Committees.

Collaboration with ILAC and OIML: The BIPM and ILAC are currently developing a joint statement on the roles of NMIs and National Accreditation Bodies (NABs) and presented a draft to the first meeting of RMOs and Regional Accreditation Bodies at the BIPM in March 2005. The BIPM will also be working with ILAC and the OIML on a statement on the use of their various Mutual Recognition Arrangements or, in the case of OIML, their

Mutual Acceptance Arrangement. This statement, requested by the 22nd CGPM, will urge Governments and other relevant parties to use recognized MRAs as the technical basis for trade and other agreements or treaties.

BIPM's collaboration with the accreditation community continues to develop and ILAC supports BIPM's overall responsibility for the world measurement system – essentially a combination of:

- equivalent national standards, demonstrably traceable to the SI through their realization and maintenance at the NMI level and validated through the CIPM MRA; and
- effective national traceability and measurement systems in which measurements are traceable to these national standards, at whatever level of accuracy is appropriate to the user. This traceability is generally achieved through a network of technically competent calibration and testing laboratories accredited to ISO/IEC 17025 or other appropriate written standard by a NAB which is a signatory to the ILAC Arrangement.

The March 2005 meeting launched a number of actions, largely at the regional level to address issues which will help ensure the coherent and integrated application of the CIPM MRA and the ILAC Arrangement, and to encourage closer cooperation between these bodies. Details of these can be found on the BIPM website.

Representatives from the BIPM, ILAC and OIML will meet again in 2006 to review progress. In the meantime, the BIPM and ILAC will continue to work on the joint statement. This should be based on the roles and responsibilities of the metrology and accreditation bodies as already outlined as well as the results of further discussions at the regional level of the additional points raised at the meeting. The aim is to have an agreed document for the meeting of NMI Directors to be held in September 2005 at the BIPM and the ILAC General Assembly in October 2005. After that, the joint statement will be promoted vigorously to both communities, as well as standardization bodies, regulators and governments.

Collaboration with international organizations: BIPM is now an observer on the CODEX Alimentarius, thereby providing a connection for us to the food industry. Already a number of the CCQM comparisons and pilot studies are already dealing with relevant subjects and we expect this to increase in the future as we have a better view of priorities in this sector.

We have been working with the World Meteorological Organization (WMO) for some time, and are pleased to see that they plan to become a signatory to

the CIPM MRA and to bring some of their Global Atmospheric Watch laboratories into the MRA with CMCs in relevant areas.

On behalf of Member States we have been working more closely with the International Organization for Standardization (ISO), especially in the CASCO and REMCO committees.

Our work with the International Atomic Energy Agency (IAEA) continues, especially in relation to their secondary standard dosimetry network. This is a valuable cooperation and improves the efficiency of traceability dissemination based on calibration by the BIPM of the Agency's standards.

Most recently, we have agreed to collaborate with World Anti Doping Agency, and will cooperate with them in various comparisons to address the international consistency of sports drug measurements.

BIPM's Quality System: Within the BIPM, we have seen the successful implementation of our own self-declared/peer reviewed Quality System. Progressively, other aspects of BIPM's work will be brought within either an ISO/IEC 17025 system or a system based on ISO 9001. Whilst the BIPM does not publish "CMCs" in the KCDB, the BIPM website contains details of the uncertainties normally associated with the BIPM's calibration services.

Science at the BIPM: BIPM's Photometry and Radiometry section finally closed its doors in the summer of 2004 after some 70 years of activity at the BIPM. The previous members of this team are now working with colleagues in the Electricity section to start up new projects on the watt balance and the calculable capacitor in collaboration with our Australian and Canadian colleagues.

There have been substantial successes in other scientific sections. In the Ionizing Radiation section, a large number of comparison reports have been published despite a heavy programme of comparisons and the updating of the SIR electronics, the replacement of the medium energy x-ray tube and improvements in the mountings for the cobalt source. The Mass section has made measurements on a silicon sphere as part of the international Avogadro project and there have been a number of important publications about the FB2 balance, and on air density. Individuals from the Mass and Chemistry sections produced one of the BIPM's most highly cited papers on the composition of air. The Length section published another of the year's most important papers on the performance of frequency combs in *Science*, and the Time section has revised and automated the production and dissemination of TAI and UTC. They have also tackled the difficult subject of uncertainty in UTC and have maintained a successful series of comparisons of GPS

receivers. Details of other progress and achievements are, as usual, summarised below and then expanded in the reports from individual sections.

Length: In laser absolute frequency measurements, this year has largely been one of consolidation after the launch of the femtosecond comb-based key comparison BIPM.L-K11 which replaced the previous heterodyne measurements and the advances in validation of comb performance at the 10^{-19} level. The comb technique is now used routinely in the calibration of lasers from NMIs and, of course, in BIPM.L-K11. We are steadily improving the performance of our comparison and calibration capabilities, simplifying systems and ensuring a reliable and effective electronic measuring system.

A number of small improvements are in hand aimed at system reliability and a more compact comb system which can be used outside the BIPM in comparisons and regional measurements where needed.

The use of direct absolute frequency measurement techniques on the lasers calibrated at BIPM using our combs means that we do not need to make estimates, as in the past, of uncertainties due to iodine cell impurities as any such shift is measured by the comb system. As a result, we can give lower uncertainties for our measurements. This has meant that there is an improvement in the way in which the metre can be realized using such systems.

Other laser work is aimed at maintaining our current competences and at a comb-based measurement of the methane stabilized laser frequency. The inherent difficulties in operating complex infra-red laser systems are still causing problems, and progress on the project will be critically reviewed later this year.

In dimensional metrology, the compact diode-pumped laser systems are showing excellent performance characteristics as sources for interferometry. Our current plans are for these to be used in the calculable capacitor and watt balance projects and in a redesigned and more reliable absolute gravimeter.

In the past year, we have devoted more effort to gravimetry, improving local reference systems and measurement systems in preparation for the next international comparison of gravimeters. The absolute gravimeter belonging to the BIPM will perform the gravity field monitoring during the comparison and several measurements of the links of the gravity network of the BIPM which should provide an additional assessment of the performance of the several similar commercial systems we expect to take part in the comparison.

Finally, the decision to create a joint working group between the CCL and the CCTF to deal with potential secondary representations of the second has

proven to be a wise decision in the light of recent advances in optical laser frequency standards. The opportunity to validate the performance claims of these new sources through the assessment processes of the joint group has stimulated considerable interest amongst this community and is a further step towards the possibility of an "optical" second. At the moment, though, there needs to be considerable improvement in the performance of remote comparison techniques in order to take advantage of the performance of optical clocks for the international time scale.

Mass: Calibration certificates have been issued for seven 1 kg prototypes. Six of these prototypes were newly manufactured, as described in the 2004 Report. In addition, eight 1 kg standards in stainless steel were calibrated at the request of NMIs. Three of these were new and required a volume determination. At this time, a serious, though subtle, problem was identified within the calibration laboratory, causing a major disruption to our service. Although no calibration results were compromised, our normal work was suspended for several months until the problem could be studied and resolved. Steps have been taken to re-establish confidence in our measurements once the problem had been resolved. Part of the work that had been postponed during this episode was the periodic re-calibration of the BIPM working standards with respect to 1 kg prototype No. 25, which we reserve for exceptional use. The re-calibration is now nearing completion.

The Consultative Committee for Mass and Related Quantities (CCM) met in April 2005. Work of the BIPM Mass section has contributed to CCM in several ways: a paper on the amount content of atmospheric argon appeared in *Metrologia* and has been downloaded more than 500 times. This work is based on new measurements, made by KRISS, as well as a critical re-evaluation of all available data, made by the Mass section and Chemistry section of the BIPM. A companion *Metrologia* paper, written in collaboration with the PTB, describing direct determinations of ambient air density has been downloaded more than 200 times. The CCM decided that these papers form the technical basis for a future revision to the CIPM-81/91 equation-of-state for moist air. This work has already been useful for carrying out mass determinations of 1 kg spheres of single-crystal silicon. This is done as part of our participation in the International Avogadro Coordination/CCM Working Group on the Avogadro Constant (IAC/CCM-WGAC). Additional work has been carried out on mass changes between atmosphere and *vacuum* due to physisorption and desorption. Techniques developed in this area for the IAC/CCM-WGAC are also applicable to watt balance experiments.

Considerable progress has been made in re-establishing an internal calibration service for pressure measurements near one atmosphere. This work was necessitated by the failure of the BIPM mercury manobarometer and its replacement by a high-quality pressure balance.

Time: From January 2005, the uncertainties of [*UTC* – *UTC*(*k*)] are also published in the *Circular T*, in coincidence with the first publication of the key comparison in time CCTF-K2001.UTC in the KCDB. The results of this key comparison are updated monthly after the publication of *Circular T*. The medium-term stability of TAI, expressed in terms of an Allan deviation, is estimated to be about 0.4×10^{-15} for averaging times of one month. The accuracy of TAI is based on the data from eight primary frequency standards that include, at present, four caesium fountains (IEN CSF1, LNE-SYRTE FO2, NIST-F1, and NPL CSF). Following the recommendation of the CCTF, a monthly correction of order 0.7×10^{-15} is applied to steer the frequency of TAI. Since July 2004, the scale unit of TAI has been estimated to match the SI second to within 2×10^{-15}.

An important part of the activity of the Time section deals with studies of time and frequency comparison using global navigation satellite systems. Common-views of GPS satellites with single and dual frequency receivers and TWSTFT links are routinely used in the calculation of TAI. The incorporation of dual-frequency geodetic type receivers and the TWSTFT observations on a sub-daily scheduled have brought the uncertainty of some time links down to the nanosecond level or less. Calibration programmes of GPS receivers have been organized and run by the section, with more then 50 % of the receivers participating to TAI calibrated.

Research work is also dedicated to space-time reference systems, particularly to the relativistic framework for defining and realizing coordinate times. The BIPM Time section and the USNO jointly provide the Conventions Product Centre of the International Earth Rotation and Reference Systems Service (IERS) with the responsibility of establishing conventions for space-time reference systems; the *IERS Conventions* (2003) have been published and updates are performed on the Conventions website which is maintained at the BIPM. The Time section's other research subjects involve pulsars, future clocks in space and atom interferometry.

As a part of the activities of the Conventions Product Centre of the IERS, a one-year position for a visiting scientist has been established at the BIPM. Dr Jim Ray (US National Geodetic Survey) benefited of this position, having concluded his activities on 31 August 2004.

Electricity: A high-priority item in this year's activities in the Electricity section is the training of the new members of the section (transferred from the Photometry and Radiometry section) in the activities of voltage and impedance metrology. One of the new members is already able to carry out measurements using the BIPM Josephson voltage standard and qualified, in the sense of our Quality System, to use Josephson standards to calibrate other voltage standards. A second staff member is learning to operate the BIPM quantum Hall effect standard and is already qualified to calibrate capacitance standards. As a follow-up to the enthusiastic response to last year's questionnaire on participation in further BIPM on-site comparisons of Josephson standards in which 33 of the 35 specialists polled said they want to participate, we have carried out new comparisons with the NPL and the NRC and have scheduled four more comparisons for 2005. At the same time, work is progressing on two projects: the development of a completely automated facility for calibrating 1.018 V voltage standards and the development of a compact, more easily transported Josephson standard. Through our participation in the key comparison EUROMET.EM.BIPM-K10.a, the comparison results were linked to the BIPM Josephson standard which served as the key comparison reference value. In the area of resistance metrology, we have significantly improved the sensitivity of our CCC (cryogenic current comparator) bridge by replacing the old rf SQUID with a dc SQUID. In the domain of capacitance metrology, we have successfully made delicate modifications of four of our fused silica capacitors to reduce leakage capacitances to negligible levels and we have finished construction of the equipment for accurately measuring the capacitance of a 1 pF standard with respect to the forthcoming BIPM calculable capacitor. The work on the characterization of noise of polarity-reversed dc voltage measurements is completed and has been published. In addition to demonstrating that polarity reversals of a voltage source featuring a high level of $1/f$ noise do not remove this type of noise, we demonstrated that the noise model for Zener voltage standards must contain a surprisingly high level of white noise as well as $1/f$ noise. Our joint project with the NIST on the characterization of noise in precision dc voltage measurements was successfully concluded and the results published. This work triples the number of Zener standards for which the noise processes are now well-characterized. An adjunct to this work was the study of the quantization noise due to the finite resolution of digital voltmeters; from our analysis of voltage measurements, the Allan deviations often decrease below the values predicted by the usual simple noise quantization models. In the general area of time-series analysis, we are working with the Chemistry section on the application of Allan variance and autocorrelation function methods to characterize molar concentration

measurements and on the characterization and experimental design of several measurement routines used in the BIPM measurements of the Newtonian gravitational constant. Some Electricity section staff continue to engage in thermometry activities on a part-time basis. In its role as pilot laboratory for the key comparison of water triple point cells, CCT-K7, the BIPM has identified a statistically-significant difference between the results of participants who applied corrections for the isotopic composition of the water in their triple point cells and those who did not. This has led the CCT to recommend an improved definition of the kelvin by adding a statement about the isotopic composition of the water in triple point cells. To lighten the work load associated with calibrations of thermometers for the other BIPM sections, it was decided to restrict BIPM calibrations to those of platinum resistance thermometers used near room temperature and for which high accuracy is necessary; other thermometer calibrations are now outsourced.

Calculable capacitor: The BIPM workshop is continuing the fabrication of components for the two calculable capacitors being developed in this cooperative project with the NMIA. As part of this work, a complex parallel motion spring was manufactured, making use of electro-erosion techniques. The device to measure the straightness of the electrode bars, the parts of which were made during the previous reporting period, has been assembled and automated at the NMIA and is now in regular use. The NRC has recently signed a bilateral contract with the NMIA to obtain the critical components of the capacitor, of which we will also provide a number. Significant progress has been made on the capacitance bridge for the calibration of 1 pF capacitance standards against the calculable capacitor. All elements have been constructed and it has been shown that the divider ratios can be calibrated to 1 part in 10^9. A prototype of the laser to be used for the interferometer has been modified according to the requirements of this application. We are currently preparing an experimental test of the design of the Fabry-Perot interferometer which is proposed by our colleagues at NMIA.

Watt balance: During the last year we have further developed our plans for a watt balance which allows for simultaneous weighing and the moving mode operation, and have started to assemble the first components of the room-temperature model. We have pursued our idea of a highly symmetric and closed magnetic circuit in collaboration with a consulting company. The finite-element calculations of the magnetic flux distribution made at the BIPM have been confirmed. The geometry initially proposed by us was optimized to obtain a much better uniformity of the magnetic field in the air gap. No fundamental difficulties with this form of the magnetic circuit were identified. In parallel to this work, which should result in the availability of a

high-quality magnet at the BIPM in 2006, we have started to build a simplified magnet with the BIPM workshop to test some of the other components as soon as possible. The functioning of an electrostatic motor for moving the coil through the magnetic field was studied by a numerical simulation. A balance suspension including such a motor has been fabricated. The suspension includes several flexure strips to avoid friction. A constant current source used previously for the calibration of Zener voltage standards was modified and now delivers a current of 1 mA with a stability of about 1 part in 10^7, sufficient to provide the current for the travelling coil of the room temperature model.

Ionizing Radiation: We have completed the experimental determinations and Monte Carlo calculations of correction factors for the ^{60}Co beams and a paper on the new BIPM air kerma determination will be submitted for peer review publication. This new determination was discussed during a Workshop on Dosimetry Uncertainties which was attended by 25 external experts from 18 NMIs that the BIPM organized in May 2005. The CCRI has agreed in principle to the changes and these are likely to take place in 2007. The Compton x-ray spectrometry comparisons, involving experiments and Monte Carlo calculation are progressing satisfactorily with some anomalies to resolve at lower energies before the mammography spectra for dosimetry comparisons are confirmed. The accurate measurement of specific heat capacity has been automated and the system is being used for graphite and sapphire test samples prior to the design and construction of the prototype graphite calorimeter standard for absorbed dose. Following the analysis of the comparisons of present standards for absorbed dose, the results for eleven NMIs are now published in the KCDB. Three new dosimetry comparisons have been made and 17 national secondary standards have been calibrated. A successful internal audit was made of the Quality System for calibrations.

Eighteen laboratories participated in a workshop on activity key comparisons that we held in November 2004. The seven most recent comparisons were discussed and the resulting recommendations on activity measurements were presented to the CCRI in May 2005. Two other key comparisons have been completed recently, the ^{125}I comparison draft A report is circulating and the ^{32}P results are due to arrive shortly. The BIPM radionuclide measurement facilities, particularly the electronics, have been updated and the balance facilities improved to cope with this increased workload. The CCRI has agreed to group radionuclides by category to reduce the number of CCRI(II) key comparisons from three to about one per year for the next ten years. This together with NMI participation in the BIPM ongoing activity comparisons using the International Reference System (SIR) enables coverage of all the radionuclides in CMCs. In addition to several CCRI(II) comparison

ampoules, nine laboratories have submitted twelve different radionuclides to the SIR this year. In the last twelve months, a further twelve SIR comparison reports have been published. We have now published all pre-2004 results while the results from 2004 have been analysed and are circulating in draft A or B reports. Impurity activity levels were measured using the BIPM Ge(Li) gamma spectrometer for five radionuclides submitted for various comparisons. Collaboration with the NPL on the SIR efficiency curves has resulted in a mathematical model with reduced uncertainties to quantify radionuclide impurities and consequently, key comparison reference values (KCRVs).

Chemistry: The Chemistry section has laboratory programmes and coordinates international comparisons in the fields of gas analysis (air quality standards) and organic analysis (primary calibrators for laboratory medicine). The section provides the secretariat for the JCTLM and coordinates the JCTLM database of higher order certified reference materials and reference measurement procedures.

The BIPM is coordinating the ozone reference standard comparison (CCQM-P28), and measurements for the comparison were completed in March 2005. This comparison has allowed the degree of equivalence of 23 reference standards to be determined in relation to the BIPM maintained standards, and will be followed by an on-going key comparison (BIPM.QM-K1). A collaboration with the BAM on the statistical treatment of ozone comparison data has continued, and a software programme (OzonE) developed for the treatment of data. The study of systematic biases and measurement uncertainty in standard reference photometers (SRPs) has been completed, and a new uncertainty budget for the instrument will be published in collaboration with the NIST. A feasibility study has demonstrated the advantage of introducing a laser-based light source into the SRP, and a programme to develop a candidate primary ozone photometer based on a laser light source has been initiated. A gas-phase titration (GPT) facility for ozone concentration measurements has been modified and its performance and measurement uncertainty improved. The system was used in the CCQM-P28 study, producing a result consistent with that of an independently developed GPT facility, but biased with respect to the ozone photometer measurements. The source of this bias will be investigated in the future programme.

The BIPM's primary gas standard facility for the dynamic preparation of nitrogen dioxide gas standards in the range (0.5-10) μmol/mol has been automated and software control developed. A multiple gas mixture sampling module for this facility is currently under construction which will allow static

gravimetric NO_2 gas reference mixtures (prepared in cylinders) to be compared with the facility's dynamically generated reference mixtures.

A feasibility study on high accuracy comparisons of nitrogen monoxide gas standards has been completed, and presented to the CCQM's Gas Analysis Working Group. A BIPM coordinated comparison (CCQM-P73) of NO gas standards from 12 NMIs is planned to start at the end of the year.

The BIPM is coordinating subsequent rounds of the CCQM-P20 series of organic substance purity analysis comparisons, with two comparisons approved by the CCQM: CCQM-P20.e for theophylline; and CCQM-P20.f for digoxin. The substances to be studied have been prioritized taking into account the current programmes of the CCQM and the JCTLM and the ongoing requirements of laboratory medicine. Investigations into the extension of the comparison series to include clinically-important steroid hormones such as progesterone, β-estradiol and testosterone are also being undertaken. Two scientists and a technician have been recruited to the section, and laboratory facilities to support ongoing activities in this area have been established including capabilities for analysis by liquid chromatography with mass spectrometry (LC/MS), gas chromatography with mass spectrometry (GC/MS), gas chromatography with a flame ionization detector (GC/FID) and differential scanning calorimetry (DSC), supplemented by Karl Fischer titration and thermogravimetric analysis.

Collaborations to develop methods for purity determination for therapeutic drug monitoring and steroid hormones have been established with the LGC and the NMIJ, respectively. Theophylline and digoxin materials have been prepared by the LGC and will be transferred to the BIPM. The NMIJ has obtained 200 g batches of testosterone, progesterone and β-estradiol materials. Initial analyses of the materials have been performed at the NMIJ, and will continue at the BIPM.

The Chemistry section provides the secretariat for the JCTLM. The second meeting of the Executive Committee of the JCTLM was held at the BIPM in December 2004 and was followed by meetings with JCTLM Working Group 1 Review Team Leaders, JCTLM members and stakeholders, and a workshop on reference measurement systems for biologicals. A quality manual outlining the procedures used to review materials and methods for publication in the JCTLM database has been published, as well as a second JCTLM list of "higher order reference materials and measurement procedures". These lists are being converted into a web-based searchable database. The technical specifications of the database design have been completed, and construction of the database will start at the end of the year.

1.2 Publications, lectures and travel of the Director

1.2.1 External publications

1. Wallard A.J., News from the BIPM – 2004, *Metrologia*, 2005, **42**, 59-66.
2. Wallard A., BIPM Report, *NCSLI Newsletter*, 2005, **45**(2), 19-20.
3. Wallard A.J., Editorial: *La Convention du Mètre : 130 ans seulement* / The Metre Convention – 130 years young, *La Lettre Diplomatique,* 2004, **67**, 1-6.

1.2.2 Travel (conferences, lectures and presentations, visits)

A.J. Wallard to:

- London (United Kingdom), 1-2 July 2004, to the CPEM, to give the closing address;
- Salt Lake City (United States), 10-15 July 2004, to the NCSLI Board of Management and to present papers at the NCSLI Conference;
- London (United Kingdom), 22 July 2004, to the IOP Council meeting;
- Geneva (Switzerland), 28-29 July 2004, to meetings of ISO TC 21, WG 5 and ISO CASCO;
- London (United Kingdom), 14-15 September 2004, for a materials metrology meeting at the NPL and to the IOP Membership and Qualifications Board;
- Paris (France), 22 September 2004, to speak at the celebrations of the 50th anniversary of the BNM (now the LNE);
- Beijing (China), 17-22 October 2004, for the APMP General Assembly;
- Isla Margharita (Venezuela), 2-7 November 2004, for the SIM General Assembly;
- Los Angeles (United States), 21-25 January 2005, to the NCSLI Board of Management;
- London (United Kingdom), 14-15 February 2005, to attend the Royal Society Scientific Discussion meeting on "The fundamental constants of physics, precision measurements and the base units of the SI";
- London (United Kingdom), 1-2 March and 21 April 2005, to chair the Institute of Physics Membership and Qualifications Board;
- London (United Kingdom), 19-20 April 2005, to address to the CCM International Conference on "International Metrology and Trade" at the NPL;

- Minsk (Belarus), 11-12 May 2005, to the 14th meeting of the JCRB and to speak at the Belarus metrology symposium;
- Sofia (Bulgaria), 24-26 May 2005, to a meeting of EUROMET;
- Braunschweig (Germany), 29-31 May 2005, for a meeting of the bureau of the CIPM.

1.3 Activities of the Director related to external organizations

The Director is a member of the Scientific Councils of the IMGC and the IEN, Turin; he replaced Dr Quinn as a member of IUPAC's Interdivisional Committee on Terminology, Nomenclature and Symbols; and is a member of IUPAP-C.2 Commission on symbols, units, nomenclature, atomic masses and fundamental constants. He is a member of the external advisory panel of the University of Wales at Aberystwyth and a Visiting Professor in the Institute of Mathematics and Physical Sciences; Vice President for Membership and Qualifications of the Institute of Physics (IOP, United Kingdom), a member of IOP Council, Chair of its Membership and Qualifications Board and a member of its Professional Standards Committee; a member of the Board of the National Conference of Standards Laboratories International (NCSLI); a member of the Scientific Academy of Turin; and replaced Dr Quinn as Chairman of the NEWRAD scientific committee, the JCRB and the JCGM.

2 LENGTH (A.J. WALLARD)

2.1 Comb "development" (L.-S. Ma, L. Robertsson and M. Zucco)

The second femtosecond laser frequency comb has been refined and completed. This second comb system was earlier compared and tested against our first comb and has now also been used for absolute frequency measurements; e.g., on one of BIPM's 633 nm reference laser systems.

Work on testing the ultimate limits of this technique was started in cooperation with NIST and the East China Normal University (ECNU) and published in *Science* last year. These tests have continued in collaboration with NIST.

A collinear self-referencing set-up for control of the carrier-envelope offset frequency has been developed in collaboration with the ECNU. In this, the infrared part of the comb spectrum is frequency doubled in a periodically-poled non-linear crystal. Such a crystal provides perfect synchronisation between the green and the frequency doubled pulses through the phase-matching conditions in the crystal. Furthermore, the zero walk-off in this frequency doubling process assures the alignment between the two beams. This set-up can be used to make even more compact comb systems.

2.2 Absolute frequency measurements and the BIPM key comparison BIPM.L-K11 (L.-S. Ma, L. Robertsson and M. Zucco)

Absolute frequency measurements are essentially organized under the new key comparison, BIPM.L-K11 (K11) that was initiated by the 11th meeting of the CCL in 2003. K11 serves today as the backbone of the effective implementation of the metre. The prescribed method c in the *Mise en Pratique* (MeP), associated with the former BIPM.L-K10 comparison, provided a traceability to the recommended value to within a 10 kHz uncertainty. For K11, the uncertainty for each laser is estimated individually and does not need to include an estimate of shifts due to impurities of the iodine cell. As a consequence, the individual national metre realizations have, under K11, been associated with a typical reduction in uncertainty of a factor of 5.

During the last year, two calibration campaigns were carried out in November 2004 and in May 2005 in which 10 lasers from DFM (Denmark), EIM (Greece), INM (Romania), LNE (France), NIM (China), NMi (Netherlands), SMU (Slovakia) and SP (Sweden) were investigated. In addition, a regional comparison APMP.L-K11 was held in Beijing and from which eight more lasers can now be linked to the BIPM.L-K11 through an absolute frequency measurement. In total, this corresponds to 18 lasers over a 12 months period.

Besides providing a lower measurement uncertainty, K11 can provide a more frequent validation of national primary wavelength standards. The easy and straightforward way in which regional comparisons can be linked to the BIPM.L-K11 provides a means of repeating comparisons for a laser where there may be a suspicion that it may have, for example, a technical problem. This leads to additional confidence in national metre realizations. Furthermore, redundancy in the network of measurements provides a consistency check both on laser frequencies and uncertainty estimations, which consequently can help in the process of refining the uncertainty budget for such standards.

2.3 Laser standards, 633 nm and 532 nm
(L.-S. Ma, L. Robertsson and M. Zucco)

Since the introduction of absolute frequency measurements at the BIPM, direct work on the development of laser standards has been reduced to a maintenance level. However, standards at 633 nm and 532 nm are still needed in connection with the BIPM.L-K11 measurements and for the verification of the quality of iodine cells made at the BIPM.

For some applications, longer iodine cells are advantageous. A cell of 1.8 m length was made during the year and tested in the Nd:YAG reference laser system C. For this long cell, a laser frequency stability of $\sim 3 \times 10^{-14}$ at one second was estimated based on measurements of signal to noise measurements and transition linewidth.

2.4 Iodine cells (L. Robertsson and M. Zucco; J. Labot)

We have received a continuous and strong demand for iodine cells from NMIs and laboratories for use in stabilized lasers and spectroscopy. This year, we have sold a total of 24 iodine cells. The technical problems for the assembling, soldering and filling of the long cell of 1.8 m have finally been solved and this cell is now used in the Nd:YAG standard. Some NMIs have demonstrated interest in the use of this long cell in their Nd:YAG standards. Some refinements of the vacuum systems were completed and others are under study for implementation in the next year.

2.5 Methane-stabilized He-Ne lasers at 3.39 μm using internal and external cells (R. Felder; D. Rotrou)

2.5.1 Maintenance of lasers

The construction and study of He-Ne laser tubes and methane cells is essential for the maintenance of our systems, but some stages of the process have to be realized by an external company: this is the case for the molecular bonding of the end-windows. For this purpose, several laser-tube glasses had been delivered to a company last year but due to some difficulties in the process of glass cutting and polishing, we have not yet received these ready-to-fill laser-tube glasses.

A special set-up for a precise filling of the laser tubes has been designed. By monitoring the beat frequency between a CH_4-stabilized laser and laser tube being filled one should be able to minimize spurious frequency shifts due to gas lensing in the amplifying medium of the frequency emitted by a two-mode laser.

2.5.2 Measurement of the absolute frequency of the reference laser BIDM1

The aim of this project is to provide us with the ability to calibrate 3.39 μm frequency standards from NMIs against our comb generator.

This arrangement currently provides for the operation of two independent two-mode lasers and the single-mode laser, VB, used in previous experiments, as well as a powerful heterodyne laser for injection into the optical fibre which connects the measuring system to the BIPM's comb generator. Eight lasers have then to be maintained in good operating conditions. However, due to fabrication difficulties mentioned above, the heterodyne laser and the reference two-mode laser designed for the independent running of the 2-mode second telescopic laser (Tel-100) are still under construction.

2.6 **Dimensional metrology** (L.F. Vitushkin and O.A. Orlov*)

2.6.1 Laser interference diffractometer

A new argon-ion laser has been installed in the laser interference diffractometer.

2.6.2 Iodine-stabilized diode-pumped solid-state lasers for dimensional metrology and absolute gravimetry

A modified compact Nd:YVO_4/KTP/I_2 laser at 532 nm with third harmonic stabilization has been investigated at the BIPM. The frequency stability in terms of Allan variances is 2×10^{-12}, 1×10^{-13} and 3×10^{-14} at time intervals of 0.1 s, 10 s and 100 s, respectively. Testing of a Yb:KGW/KTP/I_2 laser at 515 nm has continued at the BIPM. Single-mode single-frequency radiation was obtained at 515 nm and the hyperfine structure of the lines of the iodine spectrum in the vicinity of 515 nm have been observed.

Lasers based on these designs will be used in the calculable capacitor and watt balance projects.

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* VNIIM.

2.7 **Gravimetry** (L.F. Vitushkin, V. Nalivaev* and O. Orlov*)

2.7.1 Absolute gravimetry

Regular measurements of a free-fall acceleration g at the site A of the BIPM, using the absolute gravimeter FG5-108 were performed with a periodicity of about two weeks. Mean g-value obtained at A in the period from May 2004 to May 2005 coincide within the uncertainty of the measurements, with the mean g-value obtained in the measurements, in the period from 1997 to 2001, demonstrating the stability of the BIPM reference environment.

In addition, there have been several improvements to the BIPM systems:

- the design of a new dropping mechanics for an absolute ballistic gravimeter is in a progress in collaboration with the Mendeleyev Institute for Metrology (VNIIM);
- the first tests of the new system for the measurement of the time taken by the free-falling test body have been performed; and
- a modification of the optical system of the interferometer of the FG5-108 making use of the compact Nd:YVO_4/KTP/I_2 laser at 532 nm simultaneously with the He-Ne/I_2 laser at 633 nm. The photodetection board with the TTL and analogue outputs for the interferometer of FG5-108 at 532 nm have been developed and investigated.

2.7.2 Investigation of the influence of the short-time interval frequency instability on the measurement of free-fall acceleration using an absolute gravimeter (L.F. Vitushkin and M. Zucco, G. D'Agostino** and O. Orlov*).

The short-time interval stability of He-Ne/I_2 laser at 633 nm and of the compact Nd:YVO_4/KTP/I_2 laser at 532 nm were measured for time intervals from 1 ms to 1 s. It was observed that the laser at 532 nm is much more stable in frequency at the short-time intervals than He-Ne laser at 633 nm.

A mathematical simulation of the influence of the frequency instability on the g-measurements in the absolute gravimeter was performed using the special software for the absolute gravimeter data processing, which was developed at the IMGC for the rise-and-fall gravimeter, and modified for the free-fall gravimeters. The residuals of the path of free-falling body were calculated by least-square methods using the variable wavelength of the laser radiation during the drop of the test body. The wavelength variations were simulated

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* VNIIM.
** IMGC.

to fit measured laser frequency noise characteristics. The results of the preliminary simulations of the residuals correspond to those observed in measurements using the gravimeter FG5-108 with the He-Ne/I_2 laser at 633 nm.

2.7.3 The 7th International Comparison of Absolute Gravimeters (pilot L.F. Vitushkin, coordinator of the relative measurements Z. Jiang)

We are currently preparing for the 7th International Comparison of Absolute Gravimeters (ICAG-2005) at the BIPM. For the first time, the Technical Protocol for the ICAG-2005 is being prepared in collaboration with the Discussion Group on the Technical Protocol of the CCM Working Group on Gravimetry.

Two new sites C1 and C2 for the relative and absolute *g*-measurements have been constructed in the garden of the BIPM. The difference of about 9 mGal of the *g*-values at these sites will enable us to calibrate relative gravimeters.

A new software, 'Gsoft', for the combined adjustment of the data from absolute and relative measurements taken during ICAG-2005 has been developed by Z. Jiang. This software allows a flexible means of realizing the various measurement strategies and data comparison from different gravimeters.

2.8 Publications, lectures, travel: Length section

2.8.1 External publications

1. Felder R., Practical realization of the definition of the metre, including recommended radiations of other optical frequency standards (2003), *Metrologia*, 2005, **42**, 323-325.
2. Jiang Y., Bi Z., Robertsson L., Ma L.-S., A collinear self-referencing set-up for control of the carrier-envelope offset frequency in Ti: sapphire femtosecond laser frequency combs, *Metrologia*, 2005, **42**, 304-307.
3. Ma L.-S, Bi Z., Bartels A., Robertsson L., Zucco M., Windeler R., Wilpers G., Oates C., Hollberg L., Diddams S., International comparisons of femtosecond laser frequency combs, *IEEE Trans. Instr. Meas.*, 2005, **54**, 746-749.
4. Ma L.-S., Bi Z., Bartels A., Robertsson L., Zucco M., Windeler R., Wilpers G., Oates C., Hollberg L., Diddams S., Femtosecond Laser

Optical Frequency Synthesizers with Uncertainty at the 10^{-19} Level, Proc. 14th Int. Conf. Ultrafast Phenomena (Niigata, Japan, 25-30 July 2004), Springer, 2005, 837-839.

5. Mücke O.D., Kuzucu O., Wong F.N.C., Ippen E.P., Kärtner F.X., Foreman S.M., Jones D.J., Ma L.-S., Hall J. L., Ye J., Experimental implementation of optical clockwork without carrier-envelope phase control, *Opt. Lett.*, 2004, **29**, 2806-2808.
6. Notcutt M., Hall J.L., Ma L.-S., Ludlow A., Ye J., Simple and compact Hz-level linewidth laser system *via* improved mounting configuration of a reference cavity, CLEO (22-27 May 2005, Baltimore, United States) (CD-Rom).
7. Vitushkin L.F., Orlov O., A compact frequency-stabilized Nd:YVO_4/KTP/I_2 laser at 532 nm for laser interferometry and wavelength standards, *SPIE Proc.*, 2005, **5865**, 281-286.
8. Vitushkin L.F., Current status and perspectives in development of instrumentation and metrology in absolute gravimetry, *Abstracts of the Conference "Fundamental and applied time-coordinates measurements. KVO-2005"* (11-15 April 2005, St Petersburg, Russia), Institute for Applied Astronomy, 2005, 131-132.

The report of the 11th meeting of the Consultative Committee for Length has been completed and published on the BIPM website. In order to facilitate future updating of the *Mise en Pratique* list of the CCL, the whole document has been rewritten and also placed on the BIPM website.

2.8.2 Travel (conferences, lectures and presentations, visits)

L.-S. Ma to:

- JILA, Boulder (United States), Sub-hertz laser frequency stabilization: Invited talk, John Hall Symposium, 13-15 August 2004;
- ECNU, Shanghai (China), March 2005.

L.-S. Ma, L. Robertsson and M. Zucco to ESA (Netherlands), 8-10 June 2005, for a workshop.

L. Robertsson to Cairngorms National Park (Scotland), 19-24 June 2005, to the International Conference on Laser Spectroscopy.

L.F. Vitushkin to:

- Moscow (Russia), 15-16 March and 7 April 2005, for the presentations on the research and development of the laser interferometers for

nanometrology, absolute gravimetry, and for the measurement of gravitational constant;

- St Petersburg (Russia), 12–15 April 2005, to participate in the conference "Fundamental and applied time-coordinates measurements. KVO-2005".

L.F. Vitushkin and Z. Jiang to IMGC, Turin (Italy), 29 November 2004, for the participation in the meeting of the steering committee of the ICAG-2005.

Z. Jiang to:

- Munich (Germany), 14-15 September 2004, for the Technical Meeting on the relative campaign of ICAG-2005 at the University of Bundeswehr;
- Beijing (China), 26-27 October 2004, for lectures at the Gravity Division of China National Meteorological Institute.

2.9 Activities related to the work of Consultative Committees

R. Felder is the Executive Secretary of the CCL, and Joint Secretary to the Joint Working Group CCL/CCTF.

L.F. Vitushkin is Chairman of the Working Group on Gravimetry of CCM and of a Study Group on Comparison of Absolute Gravimeters within the Commission 2 "Gravity field" of the IAG.

2.10 Visitors to the Length section

- Dr J.-L. Peng (CMS-ITRI), 6 July 2004.
- Dr H. Inaba (NMIJ/AIST), 7 July 2004.
- Dr N. Nishimiya, Dr K. Katoh and Prof. M. Suzuki (Tokyo Polytechnic University, Kanagawa, Japan), 12 July 2004.
- Dr L. Lorini (IEN), 3 September 2004.
- Prof. L. Issaev (Rostekhregulirovaniye of Russia, Moscow, Russian Federation), 6 October 2004.
- Dr J.-P. Wallerand and Dr T. Badr (LNE-INM), 10 September 2004.
- Dr G. Mana (IMGC), 28 September 2004.
- Dr Tai Hyun Yoon (KRISS), 7 October 2004.
- Dr S. van den Berg (NMi), 15 November 2004.
- Dr R. Johansson and Dr H. Skoogh (SP), 22 November 2004.
- Mr P. Plombin (Ets. Dumas, Noizay, France), 24 January 2005.

- Prof. V. Melnikov (President of Russian Gravitation Society), 2 February 2005, for the discussion on the problems in the measurement of gravitational constant.
- Prof. Y. Tomoda (Japan Academy, Tokyo, Japan), 24 March 2005, for the discussion on the perspectives in the development of absolute gravimetry.
- Dr D. Rovera (LNE-SYRTE), 21 April 2005, for discussions on comb developments and noise measurements.
- Mr J. Posthumus (Toptica, Graefeling, Germany), 12 May 2005.
- Drs A. Duta, D. Boiciuc and D. Georgescur (INM), 17 May 2005.
- Dr C. Bandis (EIM), 23 May 2005.
- Dr Yang Xuhai and Dr Lu Xiaochun (NTSC and Chinese Academy of Science), 26 May 2005.
- Dr R. Fox (NIST), 20 June 2005.
- Mrs M. Leseignoux and Mr C. Deverdun (OSYRIS), Mr J.-P. Moeglin (ISL), Mr A. Bartels (GigaOptics), 22-23 June 2005.
- Drs O. Acef, G. Crepin, S. Bize, M. Petersen, O. Tcherbakoff (LNE-SYRTE), 23 June 2005.
- Dr R. Haleck (CEA), 23 June 2005.
- Dr T. Fortier (Los Alamos Res. Centre/NIST), 27 June 2005.

2.11 Guest workers and students

- Mr G. D'Agostino (IMGC), 15 September – 17 December 2004, to participate in the investigations of short-time frequency instability of the iodine-stabilized lasers at 532 nm and 633 nm and its influence on the absolute measurement of free-fall acceleration.
- Dr O. Orlov (VNIIM), 30 September – 17 December 2004, for the investigations of the Nd:YVO_4/KTP/I_2 laser at 532 nm and Yb:KGW/KTP/I_2 laser at 515 nm.
- Mr F. Dupont (BRGM), 16-17 November 2004, for the measurement with the relative gravimeter at the site B.
- Drs Liu Xiuying, Liu Zhongyou and Qian Jin (NIM), 25 November – 5 December 2004.
- Dr P. Medvedev (Geophysical Centre of Russian Academy of Sciences, Moscow, Russia), 14-22 December 2004, for the tests of software "absGRAV" for the absolute gravimeter.

- Dr J.-P. Wallerand and Dr T. Badr (LNE-INM), 7 February 2005, for measurements of 661 nm.
- Drs S. Bonvalot and G. Gabalda (IRD); J. Verdun, T. Gattacceca and S. Deroussi (IGN), D. Van Westrum (Micro-g Solutions, United States), M. Diament and J. Ammann (IPGP), 25 February and 1 March 2005, for the measurement at the sites of the BIPM with the absolute gravimeter A10-14.
- Miss Yimei Liu (École Nationale Supérieure de Physique de Strasbourg), 7 March – 19 September 2005.
- Dr J. Henningsen and Dr J. Hald (DFM), Dr R. Fira and Dr P. Dorsic (SMU), 23-28 May 2005.
- Dr B. Kopacz and Dr B. Pages (Compagnie Générale de Géophysique, France), 24 May 2005, for the measurement with the relative gravimeter at the sites B, C1 and C2.

3 MASS AND RELATED QUANTITIES (R.S. DAVIS)

3.1 Calibrations

(R.S. Davis and C. Goyon-Taillade; P. Barat and J. Coarasa*)

During the past year, certificates were issued for the following 1 kg prototypes (in platinum-iridium): No. 80 (Thailand), No. 86 (Sweden); No. 87 (Australia); No. 89 (Switzerland); No. 90 (Mexico). This is the first calibration for Nos. 86 through 90, which were newly fabricated. In addition, prototypes Nos. 88 and 91 have been attributed to the BIPM and we have begun to use them as working standards.

Certificates for 1 kg standards in stainless steel were issued to: METAS (two); Mettler-Toledo GmbH (one, request received through METAS); NCM (one), NIMT (three); SPRING Singapore (one).

One certificate for magnetic susceptibility of a metal sample was issued to CEM. We recall that the magnetic properties of stainless steel 1 kg standards are routinely determined by the BIPM and reported in an annex to the certificate for the mass calibration. However, we also issue certificates for

* Retired on 1 January 2005.

the magnetic properties of samples destined for use with the BIPM susceptometer or similar device.

Additional calibrations, including those in support of the upcoming CCM.M-K4 for which we are pilot laboratory, were postponed due to the problem of determining the density of air within the calibration laboratory. As mentioned in last year's report, this problem was unresolved as of June 2004. Since then, it became clear that the problem arose from false readings of dew-point meters and that these probably began with an undetected fluid leak within the air-conditioning system of the laboratory. The Chemistry section of the BIPM was able to verify that air sampled from the calibration laboratory contained an unusually high content of a chemical similar to ethylene glycol. However, discussions with experts in humidity measurements convinced us that the vapour pressure of pure ethylene glycol is too low to have caused the problem. In any case, with the repair of the air-conditioning system, the measurement of dew-point temperature within the calibration laboratory slowly returned to normal.

To verify that calibrations could again be made with confidence, we undertook the study described in Section 3.4.2 of this report.

These problems delayed the recalibration of the BIPM working standards with respect to prototypes Nos. 25 and 73, which we reserve for special use. This study is now well underway and should be completed before the summer vacation period.

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

This apparatus is used to determine the density of mass standards.

Densities were determined for three stainless steel mass standards belonging to NIMT (Thailand). In addition, the density of four stainless steel mass standards and one stack of four stainless steel disks was determined for the Mass section. We expect the demand for stackable discs will increase in the future, due to their use in gravimetric studies of surface effects.

The pressure gauge, used to calculate the density of ambient air, was found to have a leak and was replaced. Although the leak did not cause any problems for pressure measurements of ambient air, it made it impossible to calibrate the gauge by connecting it to a closed system. At present, our density standard is doubly distilled water, the density of which is known *via* the CIPM 2001 formula. As in last year's report, we recall that we plan to use

two 500 g cylinders of single-crystal silicon as our standard of density. After their manufacturing, they will be calibrated by NMIJ/AIST.

3.3 Water vapour adsorption on mass standards (H. Fang and A. Picard)

We recall that the purpose of this work is to study the effects of water vapour sorption on mass standards. We are continuing the investigation on silicon in the framework of the International Avogadro Cooperation project.

As mentioned last year, the sorption effects on silicon artefacts obtained (by gravimetry and ellipsometry) at the BIPM were more than five times smaller than those measured at the NPL (by gravimetry). A collaboration between the NPL and the BIPM is ongoing to clarify the source of this difference. Our pair of sorption artefacts was first sent to the NPL for gravimetry measurements. The NPL's measurements made on our artefacts confirmed those obtained previously at the BIPM. The BIPM and the NPL sorption artefacts were then sent to the BIPM. So far, measurements have been performed on both the BIPM and NPL artefacts by means of ellipsometry. We obtained results similar to those previously obtained with the BIPM artefacts. Thus the difference in sorption effects mentioned above seems to be attributable to the initial NPL gravimetry measurements. This hypothesis needs to be confirmed by our gravimetric measurements on the NPL sorption artefacts, to be made in the near future.

Up to now, only reversible physisorption effects on silicon have been investigated. For the Avogadro project, investigations of irreversible water vapour sorption on silicon are necessary. The plan is to make measurements before and after baking silicon artefacts at high temperature in a dry, neutral atmosphere. The reversible sorption effects after baking processes will also be studied.

3.4 FB-2 flexure-strip balance (H. Fang and A. Picard)

3.4.1 NPL air buoyancy artefacts

A relative difference as large as 5×10^{-4} had been observed at the NPL between the air density measured using buoyancy artefacts and that calculated from the CIPM-81/91 formula. This is about ten times the discrepancy observed by both the BIPM and the PTB. At the request of the NPL, the NPL air buoyancy artefacts were weighed simultaneously with those of the BIPM in order to check the reproducibility of the large difference obtained at the NPL. Two sets of measurements in air and in

vacuum were carried out. The air density difference obtained by using the BIPM artefacts and those of the NPL against values predicted by the CIPM formula was 6.7×10^{-5} kg m^{-3} and 8.5×10^{-5} kg m^{-3}, respectively. We note that the results reconfirm the discrepancy of about 8×10^{-5} kg m^{-3} published last year (see item 2 in the Publications section, below). Our results show that the NPL air buoyancy artefacts are suitable for their intended purpose and the large difference observed at the NPL may have been due to the application of the CIPM formula.

3.4.2 Comparisons of two stainless steel mass standards against a 1 kg Pt/Ir mass standard

As mentioned in the Calibrations section of this report, the air-conditioning system in the mass calibrations laboratory developed a catastrophic leak in May 2004. A consequence was that, even after the repair, false measurements of dew-point temperature were obtained by means of a chilled mirror. After some months, the measurements appeared to return to normal but this needed verification. To verify the accuracy of the instruments used to measure air parameters inside the HK1000 MC balance, a comparison between two 1 kg stainless steel mass standards and a 1 kg Pt/Ir prototype was carried out using the FB2 and the HK1000 MC balances. Only the HK1000 MC balance is located in the laboratory affected by the air-conditioning failure. For each balance, the air densities used for air buoyancy corrections were determined by application of the CIPM formula based on the air parameters measured by the instruments with which the balance is equipped. The mass differences of both stainless steel mass standards against the Pt/Ir prototype obtained with the FB2 balance differed by about 4 µg from those measured with the HK1000 balance. This corresponds to a difference in air density of 5×10^{-5} kg m^{-3}. These differences are acceptable, taking into account the uncertainties due to the weighings themselves and to the input parameters used to determine the air density. Thus the results demonstrate a good agreement between the two weighing procedures, including the application of the CIPM formula.

3.4.3 Air-vacuum study of 100 g gold masses from METAS

We are undertaking an air-vacuum mass stability study of 100 g gold masses from METAS. These objects will be used as transfer masses in the METAS watt balance experiment. In total, four gold masses are compared in air. Two of them always remain in air while the two others are weighed in air and in

vacuum, alternately. The stability of the mass differences in air or in vacuum between the two masses going to vacuum and between those masses always remaining in air will be checked. The repeatability of the mass change between air and vacuum will also be determined.

3.5 International Avogadro Coordination project (A. Picard)

To determine a new value of the Avogadro constant with a relative combined standard uncertainty of 2×10^{-8}, the mass determination of a 1 kg ^{28}Si sphere is crucial and, at present, very challenging. By 2008, the laboratories involved in the International Avogadro Coordination project should be able to determine the mass of 1 kg silicon sphere under vacuum with a combined standard uncertainty of 4 µg. An international comparison is planned to evaluate the weighing procedure and to reveal the experimental difficulties encountered in the mass determination of a silicon sphere. Five laboratories are involved in this comparison included the BIPM which is pilot laboratory.

Preliminary results obtained by using the BIPM FB-2 balance have shown that the mass of a 1 kg silicon sphere can be compared in air against a Pt-Ir 1 kg prototype with a standard uncertainty of about 14 µg and 32 µg by using air buoyancy artefacts and the recommended CIPM-81/91 formula, respectively. The difference in mass of the silicon sphere obtained by using the above two methods to determine the air density was within 10 µg.

A method has been developed at the BIPM to carry out the comparison between a 1 kg Pt-Ir prototype staying always in air and the 1 kg silicon sphere weighed under vacuum. This method needs two additional 1 kg Pt-Ir sorption artefacts, one having twice the surface area of the other but both having the volume of a classical 1 kg prototype. These artefacts permit us to link the weighings in air to those in vacuum by taking into account the water desorption amount between the two artefacts in the two ambient conditions. This method offers the advantage of avoiding any air buoyancy correction because only the masses having the same nominal volume are weighed in air. The silicon sphere and the additional sorption artefacts, which have a large volume difference are compared under vacuum. The combined standard uncertainty obtained by this method was about 5 µg but the value of the mass of the sphere differs by about 30 µg from the values obtained in air. The result given by this method is encouraging but more experience will be required in order to perfect this method.

3.6 **Pressure** (R.S. Davis and C. Goyon-Taillade; P. Barat)

After the failure of the BIPM mercury manobarometer in December 2003, we decided to replace it by a primary pressure balance. The pressure balance will be used to calibrate pressure gauges throughout the BIPM. We took delivery of the new pressure balance in July 2004. A dimensional calibration of the piston-cylinder was performed at LNE in November 2004. The BIPM workshop has constructed a manifold so that gauges under test may be reliably connected and disconnected. Preliminary tests have revealed that the vacuum pump initially used to provide the "zero" pressure reference is insufficient and must be replaced. It will also be desirable to replace the Pirani gauge supplied with the pressure balance, and which is used to measure the vacuum that has been attained, by a capacitance diaphragm gauge. We plan to introduce this pressure balance into the Quality System in 2005.

One of us (C. Goyon-Taillade) has taken a one-week training course in pressure metrology in order to make the best use of the new equipment.

3.7 **Humidity generator** (H. Fang and A. Picard)

We recall that the aim of this work is to develop a humidity generator for accurate in-house calibrations of dew point meters or relative humidity sensors.

Some improvements have been made to the system. A new air-tight test chamber made of stainless steel was designed and fabricated. Three manual valves for pressure measurements were replaced by electro-valves controlled *via* electronics assembled in house.

New measurements were carried out this year with two dew point meters and two relative humidity sensors at dew points of 5 °C, 10 °C and 15 °C. One of the dew point meters was then sent to LNE-CETIAT for recalibration. For the three temperatures, our results agreed to 0.02 °C with those given by LNE-CETIAT, which is very encouraging although, as discussed in the next paragraph, such good agreement is somewhat fortuitous.

In our system, the temperature of air inside the main saturator is measured by means of a 25 Ω PRT placed in a tube centred and immersed in the main saturator. Air temperature at different heights of the tube was evaluated by means of a thermocouple. A maximum gradient up to 60 mK was observed. This effect must be taken into account in evaluating the reference value of dew point temperature. The combined standard uncertainty reported last year should be increased due to this effect. In the future, more investigations on

thermal gradient are necessary. We need also to design new saturators to minimize this effect.

3.8 *G*, torsion balance (R.S. Davis, T.J. Quinn* and C.C. Speake**)

The signal-to-noise ratio of this instrument has greatly improved since we located the source of an intermittent leak in the vacuum system. We hope to complete measurements by the end of 2005.

3.9 Publications, lectures, travel: Mass section

3.9.1 External publications

1. Park S.Y., Kim J.S., Lee J.B., Esler M.B., Davis R.S., Wielgosz R.I., A redetermination of the argon content of air for buoyancy corrections in mass standard comparisons, *Metrologia*, 2004, **41**, 387-395.
2. Picard A., Fang H., Gläser M., Discrepancies in air density determination between the thermodynamic formula and a gravimetric method: Evidence for a new value of the mole fraction of argon in air, *Metrologia*, 2004, **41**, 396-400.
3. Haidar Y., Tollens E., Silvestri Z., de Fornel F., Zerrouki C., Picard A., Pinot P., Study and comparison of two polishing methods for platinum-iridium surfaces by means of three characterization techniques, *Metrologia*, 2005, **42**, 115-128.

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

R.S. Davis to:

- SMU (Slovakia), 2-3 September 2004, for technical assessment of mass and density programmes;
- METAS (Switzerland), 3-5 November 2004, to attend the watt balance technical meeting;
- SPRING (Singapore), 24-28 January 2005, for technical assessment of mass and density programmes, followed by discussions on topics of mutual interest;
- London (United Kingdom), 14-15 February 2005, to attend the Royal Society Scientific Discussion meeting on "The fundamental constants of

* Director Emeritus of the BIPM.
** University of Birmingham (United Kingdom).

physics, precision measurements and the base units of the SI" and to present the invited lecture "Possible new definitions of the kilogram";

- Cairo (Egypt), 20-24 February 2005, to attend the 19th IMEKO TC3 Conference, to present a key-note lecture "New ways to determine very small masses and forces" and to make an oral presentation "Errors due to magnetic effects in 1 kg mass comparisons" (co-authored by J. Coarasa);
- DFM (Denmark), 9 May 2005, for technical assessment of mass programme;
- LNE (France), 20 May 2005, to serve as examiner of a doctoral thesis;
- VNIIM (Russia), 6-8 June 2005, to discuss current technical problems relating to the definition of the kilogram;
- Université de Bourgogne, Dijon (France), 15 June 2005, to serve as examiner of a doctoral thesis.

A. Picard to:

- METAS, Bern (Switzerland), 4-5 November 2004, to attend the watt balance technical meeting, with H. Fang;
- PTB, Braunschweig (Germany), 1-3 December 2004, to attend the International Avogadro Coordination (IAC) committee;
- EIM (Greece), 28 February – 3 March 2005, to attend the EUROMET mass contact persons meeting;
- IKZ, Berlin (Germany), 10-14 March 2005, to attend the International Avogadro Coordination (IAC) committee;
- METAS (Switzerland), 19-20 May 2005, to have discussions with the watt balance team, and to present the lecture "Water vapour sorption study: application in Avogadro project".

C. Goyon-Taillade to LNE, Paris (France), 17-20 May 2005, to attend a training course on "Métrologie des pressions".

3.10 Activities related to the work of Consultative Committees

R.S. Davis is Executive Secretary of the CCM, which had its last meeting in April 2005.

A. Picard spends 20 % of his time working as coordinator for mass measurements in the International Avogadro Coordination project/CCM Working Group on the Avogadro Constant (see Section 3.5). [Note: A. Picard has been transferred to the watt balance experiment, where he devotes the remaining 80 % of his time.]

3.11 Other activities

R.S. Davis continues as one of two external members of the NPL Watt Balance Experiment Design Review Group. The Group has not met during the past year.

3.12 Visitors to the Mass section

- Miss A. Duarte (CENAM), 17 December 2004.
- Prof. J. Faller (JILA), 29 December 2004.
- Mr P. Delajoud (DHI, United States), 7 January 2005.
- Mr T.K. Chang (SCL), 2 February 2005.
- Dr M. Takamoto (NMIJ/AIST), 17 March 2005.
- Dr C.-S. Chang (CMS-ITRI), 29 March 2005.
- Dr M. Tanaka (CIPM), 8 April 2005.
- Mr G. Bairy (SMD), 21 April 2005.
- Mr K.-H. Chang and Dr W.G. Lee (KRISS), 27 April 2005.
- Prof. Y. Alayli, Mr S. Topçu (Université de Versailles) and Mr P. Pinot (LNE-INM/CNAM), 24 May 2005.
- Dr K. Fujii (NIMJ/AIST), 27 June 2005, accompanied by Messrs S. Asanuma, H. Sasagawa (Asanuma Giken Co. Ltd.) and H. Mozoguchi (MST Co. Ltd.).

4 TIME (E.F. ARIAS)

4.1 International Atomic Time (TAI) and Coordinated Universal Time (UTC) (E.F. Arias, Z. Jiang, W. Lewandowski, G. Petit and P. Wolf; H. Konaté 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 *Annual Report of the BIPM Time Section for 2004*, volume **17**, complemented by computer-readable files on the BIPM website, provides the definitive results for 2004.

4.2 **Algorithms for time scales** (Z. Jiang, L. Lewandowski and G. Petit)

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

4.2.1 EAL stability

Some 85 % of the clocks used in the calculation of the time scales are now either commercial cæsium clocks of the HP/Agilent 5071A type or active, auto-tuned hydrogen masers. To improve the stability of EAL, the weighting procedure applied to clocks sets the maximum relative weight each month to 2.5/N, where N is the total number of participating clocks. A clock reaches the maximum weight when its variance computed from 12 consecutive 30 day samples is, at most, about 6×10^{-15}. About 13 % of the participating clocks have been at the maximum weight, on average, during 2004. This procedure generates a time scale which relies upon the best clocks.

A new estimation of the medium-term and long-term stability of EAL has been completed. Expressed in terms of an Allan deviation, it is estimated to be 0.4×10^{-15} for averaging times of one month since 2003. Slowly varying long-term drifts limit its stability to 2×10^{-15} for averaging times of six months.

4.2.2 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 2004, individual measurements of the TAI frequency have been provided by eight primary frequency standards including four cæsium fountains (IEN CSF1, LNE-SYRTE FO2, NIST F1, and NPL CSF). Reports on the operation of the primary frequency standards are regularly published in the *Annual Report of the BIPM Time section*.

Following Recommendation CCTF 3 (2004), the procedure for the frequency steering of TAI has been revised. Starting in July 2004, a monthly steering correction of order 0.7×10^{-15} is applied as deemed necessary. Since July 2004, 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 $+2.1 \times 10^{-15}$ to $+5.8 \times 10^{-15}$, with a standard uncertainty

of about 2×10^{-15}. Over the year, six steering corrections have been applied for a total correction of $[f(EAL) - f(TAI)]$ of -2×10^{-15}.

4.2.3 Determination of uncertainties in [*UTC* – *UTC*(*k*)]

Since January 2005, the values of the uncertainties of [*UTC* – *UTC*(*k*)] have been published in the BIPM publication *Circular T.* This has been recommended by the CCTF, and is required by the CIPM MRA for publication of the key comparison in time in the KCDB. The BIPM Time section addressed this issue in cooperation with the IEN and the USNO. An analytical solution was derived from the law of the propagation of uncertainty, taking into account that leap seconds and deterministic frequency steering of EAL do not affect these uncertainties. The analytical results were verified through Monte Carlo simulations using the software that generates UTC, and good agreement was found, giving confidence in the analytical estimation. A more detailed analysis is in progress, using full inclusion of all available calibration information, more details for the correlation between the links, methods for optimizing the link structure, given uncertainty information, non-Gaussian behavior and different correlation properties of uncertainties due to calibration or due to random noise.

4.2.4 Independent atomic time scales

The BIPM staff is involved in the organization and elaboration of the Polish independent atomic time scale TA(PL). Specially devised software for a limited number of clocks has been developed, and is being improved. For an averaging time of about one month, the stability of TA(PL) is approximately 2.5×10^{-15}.

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 TAI frequency by the primary frequency standard. We have provided an updated computation of TT(BIPM), named TT(BIPM2004), valid until August 2004. In this, we used all recently available data from the new cæsium fountains and a revised estimation of the stability of the free atomic time scale EAL on which TAI is based.

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

The BIPM Time section organizes the international network of time links. In 2004, significant improvement was made on time transfer for TAI. Ten time links obtained with dual-frequency GPS geodetic-type receivers (P3) have been introduced into TAI since 2003, and this process continues. This allows the use of three techniques for clock comparison in TAI. At present, 30 % of the links are performed with the classical GPS common-view technique based on C/A-code measurements obtained from single-channel single-frequency receivers; about 36 % of the links are obtained from observations with multichannel receivers, some of them being GPS and GLONASS dual-code dual-system ones; 10 % are calculated from observations of dual frequency GPS receivers; and 13 % are links performed with the TWSTFT technique. As a result, there has been an improvement in the accuracy for time transfer, and the whole system of time links becomes more reliable. In addition, the BIPM Time section continues to test other time and frequency comparison methods and techniques. Results of these comparisons are available on the BIPM website.

With the aim of supporting some contributing laboratories in the improvement of their contributions to TAI, GPS receivers have been sent to three time laboratories under a loan agreement.

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

i) Current work

The BIPM publishes an evaluation of the daily time differences [*UTC – GPS time*] and [*UTC – GLONASS time*] in its monthly publication *Circular T*, and routinely issues GPS and GLONASS international common-view schedules. The international network of GPS common-view links used by the BIPM follows a pattern of local stars within a continent. All GPS links are corrected for satellite positions using IGS (International GNSS Service) post-processed precise satellite ephemerides, and those performed with single-frequency receivers are corrected for ionospheric delays using IGS maps.

ii) Standards for GPS and GLONASS receivers

The Time section continues its active involvement in the work of the CCTF Working Group on Global navigation satellite systems Time Transfer Standards (CGGTTS). This has involved the ongoing development of technical guidelines for manufacturers of receivers used for timing in global

navigation satellite systems. A staff member of the BIPM provides the secretariat of the CGGTTS.

iii) Multichannel GPS time links

Twenty multichannel GPS links are used in the computation of TAI.

iv) IGS estimated ionospheric corrections

Ionospheric parameters estimated by the IGS are routinely used to correct all GPS links performed with single channel receivers for ionospheric delays in regular TAI calculations.

4.3.2 Phase and code measurements from geodetic-type receivers

It will be recalled that GPS and GLONASS time and frequency transfer may also be carried out using dual-frequency carrier-phase measurements in addition to code measurements. This technique, already in common use in the geodetic community, can be adapted to the needs of time and frequency transfer. These studies are conducted in the framework of the IGS working group on clock products, of which a physicist of the staff is a member. Studies continue at the BIPM using two Ashtech Z12-T GPS receivers, one Javad Legacy GPS/GLONASS receiver, one Septentrio PolarX receiver, and one TTS-3 GPS/GLONASS receiver (acquired in December 2004).

The method developed to perform the absolute calibration of the Ashtech Z12-T hardware delays allows us to use this receiver for differential calibrations of similar receivers worldwide. Calibration trips began in January 2001 and have continued ever since. From July 2004 to June 2005, 12 such calibrations have taken place concerning receivers in nine laboratories. The new Ashtech Z12-T serves as a local reference with which the traveling Ashtech Z12-T is compared while at the BIPM. Collaboration has been started with CNES to perform new measurements for absolute calibration of the receiver at the CNES facilities in Toulouse. Calibration of the new type of receiver Septentrio PolaRx2 is being investigated in collaboration with laboratories equipped with such receivers.

Data from geodetic-type receivers worldwide are collected for TAI computation, using procedures and software developed in collaboration with the Observatoire Royal de Belgique (ORB). As of June 2005, 17 laboratories regularly provide such P3 data. Time links computed using these data are systematically compared to other available techniques, notably for two-way time transfer. Because several time laboratories participate both to TAI with P3 data and to the IGS network, we have also compared the P3 links with

time links computed by the IGS using phase and code measurements. We have shown that the long-term stability of the P3 links is typically well below 1 ns. These time links have also been used for a dedicated exercise of comparison of cæsium fountains carried out in October-November 2004.

A 3S Navigation receiver in operation at the BIPM is used to collect data for the International GLONASS Service Pilot Project (IGLOS-PP) sponsored by the IGS, in which the BIPM participates. The objective of this project is, among others, to produce post-processed precise GLONASS satellite ephemerides.

4.3.3 Two-way time transfer

Two meetings related to TWSTFT activities have been held since October 2004. The BIPM collects two-way data from 12 operational stations and undertakes treatment of some two-way links. About ten TWSTFT links are routinely used in the computation of TAI; some others are in preparation for their introduction into TAI. The BIPM is also involved in the calibration of two-way time-transfer links by comparison with GPS. The Time section interrupted the elaboration of TWSTFT reports; instead, multi-technique comparisons are performed and published on the Internet. A staff member of the BIPM provides the secretariat for the CCTF Working Group on TWSTFT.

4.3.4 Uncertainties of TAI time links

The values of the Type A and Type B uncertainties of TAI time links are published in the *Circular T*, together with the information on the time links used in each monthly calculation. Mainly because of lack of calibration, the Type B uncertainties of GPS links can reach 30 ns. This underlines the need to complete the calibration of all TAI time links.

4.3.5 Calibration of TAI time links

The BIPM is conducting a series of calibrations of GPS time equipment located in time laboratories contributing to TAI. From July 2004 to June 2005, GPS time equipment in 17 laboratories and GPS P3 equipment in nine laboratories have been calibrated. In addition, the Time section staff is developing methods for calibration of GPS/GLONASS time receivers. The BIPM is also taking part in the organization of TWSTFT calibration trips.

4.4 **Key comparisons** (E.F. Arias and W. Lewandowski; L. Tisserand)

The key comparison in time CCTF-K2001.UTC was published for the first time in January 2005. Monthly updates are performed after the publication of *Circular T*. Timing centres in laboratories who are participants to the CIPM MRA, from Member States and Associates of the CGPM, take part in the key comparison.

4.5 **Pulsars** (G. Petit)

Collaboration is maintained with radio-astronomy groups observing pulsars and analyzing pulsar data provided that it is of interest for us; for example, to study the potential capability of millisecond pulsars as a means of sensing the very long-term stability of atomic time. The Time section provides these groups with its post-processed realization of Terrestrial Time. The collaboration continues with the Observatoire Midi-Pyrénées (OMP), Toulouse, on a programme of survey observations.

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

Uniformity in the definition of space reference systems plays an increasingly important role in basic metrology, particularly for astro-geodetic techniques that contribute to the International Earth Rotation and Reference Systems Service (IERS). Since 1 January 2001, a collaborative effort between the BIPM and the U.S. Naval Observatory (USNO) provides the Conventions of the IERS. The new edition of the *IERS Conventions* (2003), finalized in 2003, has been published in paper version. This document summarizes the models, constants and procedures used for data analysis in the IERS, and for the astrometry-geodesy community at large.

A web and ftp site for the IERS Conventions has been established at the BIPM (http://tai.bipm.org/iers/) and a user discussion forum has been set-up (http://tai.bipm.org/iers/forum/) for users to offer comments related to the future updates of the IERS Conventions. First updates of the Conventions (2003) have been posted on the website (http://tai.bipm.org/iers/convupdt). They are mostly editorial corrections and small modifications of the text. Larger modifications are currently studied with the help of an Advisory Board for the IERS Conventions updates, chaired by Jim Ray, and including representatives of all groups involved in the IERS. A special session on the IERS Conventions updates has been convened at the General Assembly of

* Until September 2004.

the European Geophysical Union in April 2005 to discuss these topics. The 39th meeting of the Directing Board of the IERS was held at the BIPM on 23 September 2004.

Activities related to the realization of reference frames for astronomy and geodesy are developed by E.F. Arias in cooperation with the IERS and with Argentine institutions.

4.7 **Other studies** (P. Wolf)

Peter Wolf is presently on secondment at the Paris Observatory (OP) and we are reporting here his contribution to their programmes.

Final results of the test of Lorentz invariance using the cryogenic sapphire oscillator at the LNE-SYRTE (OP) have been published. They improve the best previous results by about an order of magnitude. First results of the rotating Michelson-Morley experiment at the university of Western Australia were obtained, with another factor of 7 improvement. Other possibilities for testing the Lorentz invariance in the photon sector have been investigated. We have recently carried out a test of Lorentz invariance in the matter sector using Zeeman transitions in a cæsium atomic fountain clock at the LNE-SYRTE, with first results published.

Optical lattice clocks are being constructed and operated at several laboratories. They use a large number of neutral atoms (Sr, Yb, Hg, Ca) trapped in an optical potential, and are the most promising candidates for reaching 10^{-17} to 10^{-18} accuracies as they combine the advantages of single trapped ion, and freely falling neutral atom standards. We have studied methods to circumvent limitations of such clocks imposed by the intensity of the trapping laser. We show that gravity can be effectively used to reduce the intensity requirement by more than an order of magnitude. The proposed scheme is being implemented in the Sr standard of LNE-SYRTE.

4.8 **Publications, lectures, travel: Time section**

4.8.1 External publications

1. Bize S., Wolf P. *et al.*, Advances in atomic fountains, *C.R. Acad. Sci., Physique*, 2004, **5**, 829-843.
2. Bize S., Wolf P. *et al.*, Cold atom clocks and applications, *J. Phys. B*, 2005, **38**, S449–S468.
3. Foks A., Lewandowski W., Nawrocki J., Latest calibration of GLONASS P-code time receivers, *Proc. 36th PTTI*, 2004, 99-104.

4. Guinot B., Arias E.F., Atomic time-keeping since 1955 up to the present, *Metrologia*, 2005, **42**, S20-S30.
5. Lewandowski W., Cordara F., Lorini L., Pettiti V., Bauch A., Piester D., Koudelka O., A simultaneous calibration of the IEN/PTB time link by GPS CV and TWSTFT portable equipment, *Proc. 18th EFTF*, 2004 (CD-Rom).
6. Lewandowski W., 2004, International Atomic Time and time transfer, *Artificial Satellites*, **40**, 71-81.
7. Lewandowski W., Matsakis D., Panfilo G., Tavella P., First evaluation and experimental results on the determination of uncertainties in [*UTC – UTC*(*k*)], *Proc. 36th PTTI*, 2004, 243-261.
8. Marion H., Wolf P. et al., First observation of Feshbach resonances at very low magnetic field in a ^{133}Cs fountain, *Proc. 18th EFTF*, 2004 (CD-Rom).
9. McCarthy D.D., Petit G. (eds), IERS Conventions (2003), *IERS TN* 32, Verlag des Bundesamts für Kartographie und Geodäsie, 2004, 127 pp.
10. Petit G., Wolf P., Relativistic theory for time comparisons: a review, *Metrologia*, 2005, **42**, S138-S144.
11. Petit G., Stability and accuracy of geodetic GPS time links compared to two way time transfer, *Proc. ATF 2004*, 2004, 1-7.
12. Tobar M.E., Wolf P., Fowler A., Hartnett J.G., New methods of testing Lorentz violation in electrodynamics, *Phys. Rev. D*, 2005, **71**, 025004.
13. Tobar M.E., Wolf P. *et al.*, New tests of Lorentz Invariance in the Photon Sector using Precision Oscillators and Interferometers, In *CPT and Lorentz Symmetry Proc. Third Meeting, Bloomington* (V.A. Kostelecký ed.), World Scientific, 2005, 20-28.
14. Weiss M., Zhang V., Lewandowski W., Uhrich P., Valat D., 2004, NIST and OP GPS Receiver Spanning Twenty Years 1983–2003, *Proc. 18th EFTF*, 2004 (CD-Rom).
15. Wolf P., Bize S., Clairon A., Luiten A.N., Santarelli G., Tobar M.E., Improved test of Lorentz invariance in electrodynamics, *Phys. Rev. D*, 2004, **70**, 051902(R), arXiv: hep-ph/0407232.

4.8.2 BIPM publications

16. *Annual Report of the BIPM Time Section (2004)*, 2005, **17**, 94 pp.
17. *Circular T* (monthly), 7 pp.

4.8.3 Travel (conferences, lectures and presentations, visits)

E.F. Arias to:

- Paris (France), 20-22 September 2004, for the Journées Systèmes de Référence Spatio-temporels 2004, Observatoire de Paris, with two oral presentations;
- Turin (Italy), 27-29 September 2004, for the International Workshop on Galileo Time;
- Mérida (Venezuela), 22-24 November 2004, for the 3rd International ADeLA Meeting , with three oral presentations;
- Caracas (Venezuela), 25-26 November 2004, for a visit to the Observatorio de Cagigal;
- Washington DC (United States), 4-10 December 2004, for the 36th PTTI meeting to chair a session; for the meeting of the TWSTFT participating stations; for the meeting of the CCTF Working Group on the MRA and for the meeting of the CCTF Working Group on GNSS time transfer standards;
- London (United Kingdom), 14-15 February 2005, for the Royal Society Discussion Meeting on the Fundamental Constants of Physics, Precision Measurements and the Base Units of the SI;
- Moscow (Russia), 18-22 February 2005, for the 50th anniversary of VNIIFTRI and for a visit to VNIIFTRI and to the Rostekhregulirovaniye, with a conference;
- St Petersburg (Russia), 24-25 February 2005, for a visit to VNIIM;
- Vienna (Austria), 3 March and 7 June 2005, for the UN/COPUOS preparatory meetings of the International Committee on GNSS;
- Besançon (France), 20-24 March 2005, for the 19th EFTF meeting to chair a session ;
- Zaragoza (Spain), 11-13 May 2005, for the 3er Congreso Español de Metrología, with a conference;
- Bordeaux (France), 22 June 2005, for a thesis presentation at the Observatoire de Bordeaux.

Z. Jiang to:

- Tokyo (Japan), 12-17 October 2004, for the 12th meeting of the CCTF Working Group on TWSTFT;
- Beijing (China), 22-26 October 2004, for the ATF 2004/APMP 2004; and 24 October 2004, for a visit to NTSC.

W. Lewandowski to:

- Warsaw (Poland), several trips of a few days each to the Space Research Centre;
- Long Beach (California, United States), 18-25 September 2004, for the 44th meeting of the Civil GPS Service Interface Committee (chairmanship of the Timing sub-committee), and for the ION GNSS;
- Turin (Italy), 27-29 September 2004, for the International Workshop on Galileo Time, oral presentation;
- Tokyo (Japan), 12-17 October 2004, for the 12th meeting of the CCTF Working Group on TWSTFT, oral presentation;
- Washington DC (United States), 4-10 December 2004, for the meeting of the participating stations of the CCTF Working Group on TWSTFT, for the open forum on GNSS standardization organized by the CCTF sub-group on GNSS time transfer standards and for the 36th PTTI meeting with oral presentation;
- Munich (Germany), 8-11 March 2005, for the Munich Satellite Navigation Summit 2005;
- Besançon (France), 20-24 March 2005, for the 19th EFTF meeting with oral presentation;
- Paris (France), 14 April 2005, for the EUROMET meeting, with oral presentation;
- Paris (France), 12 May 2005, for "Journée nationale sur l'UTC et seconde intercalaire", with oral presentation.

G. Petit to:

- Nançay (France), 2 July 2004 and 24 March 2005, for participation in pulsar observations;
- Paris (France), 20-22 September 2004, for the Journées Systèmes de référence spatio-temporels, Observatoire de Paris, lecture on "Updating the IERS Conventions to improve reference frames";
- Beijing (China), 22-26 October 2004, for the ATF 2004, lecture on "Stability and accuracy of geodetic GPS time links compared to two way time transfer";
- Lintong (China), 29-30 October 2004, for a visit to the NTSC;
- Toulouse (France), 10-11 January 2005, for visits to the time department of CNES and to the Observatoire Midi-Pyrénées;
- Besançon (France), 21-23 March 2005, for the 19th EFTF meeting, lecture on "Long-term stability and accuracy of TAI";

- Vienna (Austria), 25-29 April 2005, for the General Assembly of the European Geophysical Union, Session Convenor, lecture on "Updating the IERS Conventions", and for a meeting of the IERS Directing Board;
- Paris (France), 22 June 2005, for a review group "Physique fondamentale" for the CNES.

P. Wolf to:

- Paris (France), 6-7 July 2004, invited to the Séminaire de prospective scientifique du CNES;
- Potsdam (Germany), 14-18 February 2005, invited to the Einstein centennial conference "Special Relativity, will it survive the next 100 years?", presentation on "Some Tests of Lorentz Invariance: Recent Experiments and Outlook for the Near Future";
- Besançon (France), 21-24 March 2005, for the 19th EFTF meeting, presentation on "Modern Rotating Michelson Morley Experiment using Cryogenic Sapphire Oscillators";
- Les Houches (France), 6-9 June 2005, for the "QED 2005" workshop, presentation on "Measuring Forces in the Casimir Regime Using Cold Atoms in an Optical Lattice".

4.9 Activities related to external organizations

E.F. Arias is a member of the IAU, participating in three of its working groups: on nutation, on the international celestial reference system, and on the redefinition of UTC. She is an associate member of the IERS, a member of the International Celestial Reference System Product Centre, and of the Conventions Product Centre of the IERS. She is a member of the International VLBI Service (IVS), and of its Analysis Working Group on the International Celestial Reference Frame. She is the BIPM representative at the Governing Board of the IGS. She is the BIPM representative to the Action Team on GNSS of COPUOS. She is a member of the Argentine Council of Research (CONICET) and an associated astronomer at the SYRTE, Paris Observatory. She is the corresponding member of the Bureau des Longitudes. She is the BIPM representative to the Working Party 7A of the Study Group 7 of the ITU-R, and a member of its Special Rapporteur Group on the future of UTC.

W. Lewandowski is the BIPM representative to the Civil GPS Service Interface Committee and chairman of its Timing Sub-committee. He is also a member of the Scientific Council of Space Research Centre of the Polish Academy of Sciences.

G. Petit is co-director of the Conventions Centre of the IERS and representative to the Directing Board of the IERS. He is a member of the IAU Working Group on Relativity in Celestial Mechanics, Astrometry and Metrology (RCMAM), of the IGS Working Group on clock products and of the Comité National Français de Géodésie et Géophysique.

P. Wolf is a member of the RCMAM, of the GREX (Groupe de Recherche du CNRS: Gravitation et Expériences) and the Fundamental Physics Group of the CNES.

4.10 Activities related to the work of Consultative Committees

E.F. Arias is Executive Secretary of the CCTF. She is a member of the CCTF Working Group on Two-Way Satellite Time and Frequency Transfer.

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

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

4.11 Visitors to the Time section

- Miss G. Panfilo (IEN), 1 July to 15 September, 1-15 October and 22 November to 1 December 2004.
- IERS Directing Board meeting, 23 September 2004.
- Dr D.N. Matsakis (USNO), 29 March 2005.
- Dr J. Marendic-Miljkovic (ZMDM), 13 April 2005.

5 ELECTRICITY (T.J. WITT)

5.1 Electrical potential: Josephson effect (D. Reymann and S. Solve; R. Chayramy)

5.1.1 Josephson array measurements

This year, we started a new programme to update our Josephson equipment and to develop a more portable Josephson device for on-site comparisons.

Two new probe holders for the Josephson arrays are under development, one of which is for the transportable device. These probe holders will be usable for both types of SIS and SINIS Josephson arrays. New millimetre-wave sources have been ordered. One of them is compact and programmable; it will be used for SINIS array measurements and for on-site comparisons.

A new system is being developed to measure 1.018 V Zeners using a SINIS array directly as the reference standard.

5.1.2 EUROMET Project 723: 1.09 V comparison supplementing BIPM.EM-K10.a

The report of the EUROMET comparison of Josephson standards at 1 V has been accepted by the CCEM and the results are now published in the KCDB. The BIPM measurement results were used to link this comparison to the key comparison reference value.

5.1.3 Zener diode measurements

To connect and reverse the polarity of Zener voltage standards, we use special rotary switches that feature very low residual thermal electromotive forces. We use special stepper motors to activate the rotary switches. They will be incorporated into the new fully automated measurement system that will use a SINIS array as the voltage reference.

5.2 Electrical resistance and impedance

5.2.1 Dc resistance (F. Delahaye and R. Goebel; A. Jaouen)

This year we started updating our cryogenic current comparator (CCC) equipment. A dc SQUID detector was purchased and tested. For frequencies down to, at least, 0.1 Hz, the noise level obtained with the dc SQUID is significantly lower than that of the rf SQUID used up to now as a null

detector in our CCC based resistance bridge. A new CCC coil is under construction and will be coupled to the dc SQUID.

5.2.2 Maintenance of a reference of capacitance and for capacitance calibrations (F. Delahaye and R. Goebel; R. Chayramy)

We have completed modifications to four fused silica capacitors of the AH type (two 10 pF capacitors and two 100 pF capacitors). Such commercially available capacitors feature a relatively high (about 5 pF) leakage capacitance between the capacitor "high" terminal and the grounded chassis enclosing the four capacitors. In these conditions, the realization of the two-terminal pair definition of each capacitance is imperfect and this may affect the capacitance measurements carried out with a coaxial ac bridge. The modification was suggested to us by the NPL; it involves placing additional electrostatic screens between the capacitor and the printed circuit board of the capacitor temperature controller which was originally placed too close to the capacitor terminals. The modification is relatively delicate because it requires unsoldering many connections to the capacitor unit. The four capacitors were successfully modified. The residual leakage capacitance is now negligibly small, that is, less than 0.01 pF.

All elements of a capacitance bridge for the calibration of 1 pF capacitance standards in terms of a calculable capacitor to be installed at the BIPM have been constructed. This includes a supply transformer, a main inductive divider with ratios 2.5/1 and 5/1 and a calibration transformer for calibration of the two ratios. The bridge and its voltage source are designed to operate at 250 V in the frequency range from 1000 Hz to 4000 Hz. The first tests indicate that the deviation of the ratios from nominal is of order 2 parts in 10^7 at 1600 Hz and that the ratios can be calibrated to 1 part in 10^9.

5.3 Characterization of electronic voltage standards (T.J. Witt)

We have completed our analysis of dc voltage measurement cycles that include polarity reversals and published the results (see 5.8.1, entry 2). The main results are that polarity reversals have no effect on the $1/f$ noise intrinsic to electronic voltage standards referenced to Zener diodes. A detailed model of the noise in these instruments emerges from this work. The noise is seen to include not only the $1/f$ noise component but also a surprisingly high level of intrinsic white noise. Similarly, the results of our collaboration with the NIST have been published (see 5.8.1, entry 3). The main conclusion of that work is that the results of $1/f$ noise levels measured on 25 Zeners at the NIST corroborate those obtained on 13 Zeners measured at the BIPM and put them

on a firm statistical foundation. This conclusion is that all of the Zener output voltages that we have studied are limited by $1/f$ noise that varies significantly with the technology employed in their manufacture, and that for each type of instrument the noise level varies little among individual instruments. This year, we have begun to apply the method of very low frequency variations to determine the pressure coefficients of Zeners in a way that is quite analogous to the temperature coefficient determinations by a similar method and reported here last year.

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

We are continuing our collaboration with the BIPM Chemistry section on the application of time-series analysis to repeated photo spectrometric measurements of molar concentration of ozone in nitrogen. We are close to characterizing a model which will allow the calculation of the variance of the mean of a number of repeated measurements while rigorously taking into account correlations among successive measurements.

We have applied Allan variance analysis and calculated sample autocorrelation functions for sets of repeated measurements that enter into the BIPM experimental determination of the Newtonian gravitational constant, G. Results of these analyses are being used to design the measurement routines in such a way as to repeat measurements for as long a time as the measurements remain uncorrelated and no longer.

5.5 Thermometry (S. Solve and M. Stock)

Due to the increased work load on the section, the number of thermometer calibrations for other BIPM sections had to be considerably reduced. In the future, we will calibrate only standard platinum resistance thermometers for those applications which need the highest accuracy. These calibrations are limited to the temperature range between the water triple point (~0 °C) and the gallium melting point (~30 °C). Less demanding calibrations will be performed by an accredited laboratory.

In order to maintain the quality of our primary standards, four water triple point cells and a gallium melting point apparatus have been ordered.

The draft A report of the key comparison of water triple point cells (CCT-K7), organized and carried out by the BIPM, was distributed in September 2004. However, the CCT at its meeting in June 2005 did not give approval for the final report, as additional changes were requested.

The low comparison uncertainty of 13 μK revealed significant differences between the national realizations of the water triple point. The standard deviation of the national references is 50 μK but the maximum difference between results is 171 μK. The quality of the comparison is such that it is possible to distinguish between two different populations of realizations, corresponding to two different interpretations of the realization of the water triple point. Whereas the SI definition of the kelvin does not specify the isotopic composition of the water in a water triple point cell, the *Supplementary Information for the ITS-90** states that it should have the isotopic composition of ocean water. A small number of laboratories applied corrections for the isotopic composition of their water, but most of them did not. The corresponding temperature difference is about 100 μK. As a consequence of these findings, the current documentation with respect to the kelvin and the ITS-90 was considered as not clear enough and a CCT task group was formed to propose a solution to the CCT. A clarification has been consequently added to the SI definition of the kelvin, in which the isotopic composition of the water will be explicitly stated, to appear in the 8th edition of the SI Brochure. This should reduce considerably the uncertainty related to the definition of the kelvin. The comparison is considered as a particularly successful scientific exercise since it will lead to a significant improvement for primary thermometry.

5.6 BIPM ongoing key comparisons in electricity

(F. Delahaye, D. Reymann, S. Solve and T.J. Witt; A. Jaouen)

In the ongoing BIPM key comparison programme, we have completed two new 10 V JAVS comparisons, one with the NPL (United Kingdom) in September 2004 and the other with the NRC (Canada) in October 2004.

The results, expressed as the relative difference between the values that would be attributed to the 10 V Josephson array standard by the NPL (U_{NPL}), the NRC (U_{NRC}) and its theoretical value (U_{BIPM}) are:

$(U_{\mathrm{NPL}} - U_{\mathrm{BIPM}})/U_{\mathrm{BIPM}} = -1.5 \times 10^{-10}, \qquad u_{\mathrm{c}}/U_{\mathrm{BIPM}} = 2.2 \times 10^{-10}$

$(U_{\mathrm{NRC}} - U_{\mathrm{BIPM}})/U_{\mathrm{BIPM}} = +2.8 \times 10^{-10}, \qquad u_{\mathrm{c}}/U_{\mathrm{BIPM}} = 3.1 \times 10^{-10}$

where u_{c} is the combined overall standard uncertainty.

A Zener diode bilateral comparison at 10 V with the NML (Ireland) was made in April 2005. The result of the comparison, expressed as above is:

$(U_{\mathrm{NML}} - U_{\mathrm{BIPM}})/U_{\mathrm{BIPM}} = +0.30 \times 10^{-7}, \qquad u_{\mathrm{c}}/U_{\mathrm{BIPM}} = 1.36 \times 10^{-7}.$

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* ITS-90: International Temperature Scale of 1990.

The results of these comparisons have been accepted by the CCEM for inclusion in the BIPM.EM-K10.b and -K11.b comparisons of the KCDB.

In the field of dc resistance standards, we have completed comparisons at 1 Ω and at 10 kΩ with the NML (Ireland). The results were accepted by the CCEM for inclusion in the BIPM.EM-K13.a and -K13.b comparisons of the KCDB.

In the field of capacitance standards, we have completed a comparison at 100 pF with the NML (Ireland). The results were accepted by the CCEM for inclusion in the BIPM.EM-K14.b comparison of the KCDB.

5.7 Calibrations

(F. Delahaye, D. Reymann and T.J. Witt; R. Chayramy and A. Jaouen)

This year, the Electricity section calibrated the following standards: Zener diode standards at 1.018 V and 10 V for Belgium, Bulgaria and Romania; 1 Ω resistors for Austria, Belgium, the Czech Republic, Hungary, Israel, Portugal, Slovakia and Thailand; 100 Ω resistors for Belgium; 10 kΩ resistors for Austria, Belgium, Denmark, Hungary, Portugal and Thailand; 1 pF capacitors for Brazil, South Africa and Thailand; 10 pF capacitors for Belgium, Brazil, Greece, Poland, Romania, Slovakia, Spain and Thailand; and 100 pF capacitors for Belgium, Brazil, Greece, Romania and Thailand.

5.8 Publications, lectures, travel: Electricity section

5.8.1 External publications

1. Delahaye F. and Goebel R., Evaluation of the frequency dependence of the resistance and capacitance standards of the BIPM, *IEEE Trans. Instrum. Meas.*, 2005, **54**, 533-537.
2. Witt T.J., Allan variances and spectral densities for DC voltage measurements with polarity reversals, *IEEE Trans. Instrum. Meas.*, 2005, **54**, 550-553.
3. Witt T.J. and Tang Y., Investigations of noise in measurements of electronic voltage standards, *IEEE Trans. Instrum. Meas.*, 2005, **54**, 567-570.

5.8.2 BIPM reports

4. Power O., Delahaye F., Bilateral comparison of 100 pF capacitance standards (ongoing BIPM key comparison BIPM.EM-K14.b) between

the NML, Ireland and the BIPM, January/April 2004, *Rapport BIPM*-2004/10, 7 pp.

5. Delahaye F., Power O., Jaouen A., Witt T.J., Bilateral comparison of 1 Ω standards (ongoing BIPM key comparison BIPM.EM-K13.a) between the NML (Ireland) and the BIPM, June 2004, *Rapport BIPM*-2004/13, 5 pp.
6. Delahaye F., Power O., Jaouen A., Witt T.J., Bilateral comparison of 10 kΩ standards (ongoing BIPM key comparison BIPM.EM-K13.b) between the NML (Ireland) and the BIPM, June 2004, *Rapport BIPM*-2004/14, 6 pp.
7. Reymann D., Solve S., Porter C.H., Jansen T.J.B.M., Williams J.M., Comparison of the Josephson voltage standards of the NPL and the BIPM (part of the ongoing BIPM key comparison BIPM.EM-K10.b), *Rapport BIPM*-2005/02, 10 pp.
8. Reymann D., Solve S., Wood B., Comparison of the Josephson voltage standards of the NRC and the BIPM (part of the ongoing BIPM key comparison BIPM.EM-K10.b), *Rapport BIPM*-2005/03, 14 pp.
9. Reymann D., Power O, Witt T.J., Bilateral comparison of 10 V standards between the NML (Ireland) and the BIPM, March to April 2005 (part of the ongoing BIPM key comparison BIPM.EM-K11.b), *Rapport BIPM*-2005/04, 6 pp.

5.8.3 Travel (conferences, lectures and presentations, visits)

T.J. Witt to:

- the GUM, Warsaw (Poland), 14-15 October 2004, for the 17th meeting of EUROMET contact persons in electricity and magnetism; he delivered a lecture entitled "New developments in the BIPM Electricity section";
- Beijing (China), 18-19 October 2004, for the 7th meeting of the APMP Technical Committee on Electricity and Magnetism; he delivered a lecture entitled "Summary of work in the BIPM Electricity section through October 2004" and a short report on the 17th meeting of EUROMET contact persons in electricity and magnetism held the week before;
- METAS, Bern (Switzerland), 4 November 2004, for the meeting of experts on watt balance experiments at where he gave demonstrations and delivered a lecture entitled "Demonstration of Practical Methods for Treating Serial Correlations in Experimental Observations".

F. Delahaye, R. Goebel, D. Reymann, S. Solve, M. Stock and T.J. Witt to METAS, Bern (Switzerland), 23-25 May 2005, for the EUROMET expert meeting on Quantum Electrical Metrology:

- F. Delahaye presented a lecture entitled "Introduction to coaxial bridges";
- D. Reymann and S. Solve presented a poster entitled "BIPM Josephson comparisons: what's new?".

M. Stock to:

- PTB, Berlin (Germany), 20-21 January 2005, to the workshop on new methods for determination of the Boltzmann constant;
- BEV, Vienna (Austria), 5-6 April 2005, for the meeting of EUROMET contact persons in thermometry, lecture on the comparison of water triple point cells CCT-K7.

S. Solve to PTB, Braunschweig (Germany), 4-15 April 2005, to work with R. Behr on testing and measuring arrays of Josephson Junctions.

5.9 Activities related to external organizations

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

T.J. Witt is a member of the Technical Committee for CPEM 2006.

F. Delahaye is the BIPM contact person of Working Group 2 of the Joint Committee for Guides in Metrology, JCGM (Revision of the VIM).

5.10 Activities related to the work of Consultative Committees

T.J. Witt is Executive Secretary of the CCEM, member of the WGLF and takes part in meetings of the GT-RF. He attended the meeting of the RMO technical chairpersons in electricity and magnetism.

M. Stock is Executive Secretary of the CCT and the CCPR, and a member of the CCT and CCPR working groups on key comparison, of the CCT working group on uncertainties and of the CCPR CMC Working Group.

5.11 Visitors to the Electricity section

- Dr J. Schurr (PTB), visit and discussions of the ac measurements of the quantized Hall resistance, 19-20 October 2004.
- Dr C. Apfeldorfer, Head Physical Standards Division (INPL), 24 November 2004.

- Mr G. Kyriazis (INMETRO), visit and discussions of the analysis of noise and serial correlations in electrical measurements, 18 March 2005.
- Ms L. Gomez (National Metrology Institute of Columbia), 21 March 2005.
- Mr G. Popovici, Head of Electric Quantities Laboratory (INM), 4 April 2005.
- Dr Nienfan Zhang (NIST), 20-21 June 2005.
- Dr A. Eichenberger and Mr F. Overney (METAS), 23 June 2005.
- Dr B. Wood (NRC), 27 June 2005.
- Dr W. Poirier and Dr F. Schopfer (LNE), 28 June 2005.

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

6.1 X- and γ-rays
(P.J. Allisy-Roberts, D.T. Burns, C. Kessler and S. Picard; P. Roger)

6.1.1 Dosimetry standards and equipment

Monte Carlo calculations of correction factors for the ^{60}Co air kerma standard are now complete. The results were presented to the CCRI and at the BIPM Workshop on Uncertainties in Dosimetry. The latter event was attended by 25 external experts from 18 national laboratories. A paper on the new air kerma evaluation has been submitted for publication in *Physics in Medicine and Biology*. The combined change to the standard is 0.46 %, arising mainly from the correction for the axial non-uniformity of the radiation field. As discussed and agreed by the CCRI, the change will be implemented following publication of the paper, but not before 2007.

Monte Carlo simulations have also been used to calculate the low-energy x-ray spectra at the BIPM. These have been compared with spectra measured using the new Compton spectrometer system as well as with spectra determined previously using the NMi spectrometer. Agreement at 50 kV is excellent and is reasonably good at 30 kV. However, at 10 kV the Compton spectrometer is in poor agreement with the NMi spectrometer. Monte Carlo calculations at 10 kV should help to explain this discrepancy.

Work towards a graphite calorimeter standard has progressed. Preliminary measurements have been made of the specific heat capacity of two graphite samples, with a statistical uncertainty of about 6×10^{-4}. Systematic effects dominate the uncertainties and efforts to understand and reduce these have required improvements to the temperature isolation of the apparatus. Several methods to analyse the data have been tested and a new method based on an empirical model of the system has been developed. Following an interruption due to equipment failure, a study of the specific heat capacity of a group of graphite samples is underway.

Following the change of medium-energy x-ray tube, the CCRI reference radiation qualities were re-established through the measurement of half-value layers and reference chamber calibration coefficients. The new qualities have higher air kerma rates for which the ion recombination corrections for the primary standard were re-measured.

Measurements using different field sizes in low-energy x-rays have shown the need to define and correct for the field size during comparisons and calibrations. A similar study will be made for medium-energy x-rays. New reference anode currents were established following the systematic decrease in tube output at 10 kV, thought initially to be due to the accumulation of deposits inside the tube window. The air-attenuation coefficient at 10 kV was re-measured and shown to be unaffected by this process.

Measurements of the horizontal and vertical beam profiles were made in air following the repair of the 250 TBq ^{60}Co source exposure mechanism. Horizontal beam profiles in water were also measured for both the 250 TBq and 170 TBq sources. The two sources have been used in parallel during comparisons and calibrations. After correcting for known effects, a residual difference of around 0.1 % is observed for calibration coefficients in the two beams. This is currently under study. Appropriate phantoms and experimental benches were constructed for the new beam.

A prototype graphite cavity chamber standard has been assembled and tested. The results are in reasonable agreement with the existing standard, although further work is required on the accurate determination of the chamber volume.

Primary measurements and reference chamber calibrations have continued in all of the reference x- and γ-ray beams and for the new mammographic radiation qualities. Calibrations and comparisons are underpinned by a significant effort in equipment calibration and maintenance, as required by the BIPM Quality System.

The report of a CCRI comparison of dosimeters for industrial radiation processing at very high absorbed doses (kGy), piloted by the BIPM, has been submitted for publication in *Radiation Physics and Chemistry*.

6.1.2 Dosimetry comparisons

Air kerma comparisons in low-energy x-rays with the NMIJ (Japan), and in ^{60}Co γ-rays with the ENEA (Italy) and the ITN (Portugal) were carried out in November 2004, December 2004 and June 2005, respectively. Reports of previous comparisons of air kerma in medium-energy x-rays with the NIST (United States), in ^{60}Co with the LNMRI (Brazil) and the NMIJ (Japan) in ^{137}Cs, and absorbed dose to water with the LNE-LNHB (France) have been published. The summary report for all previous absorbed dose to water comparisons has also been published with the results presented in the KCDB following the approval of the CCRI. A draft B summary report of all previous air kerma comparisons in ^{60}Co is in preparation prior to approval for publication by the CCRI(I). A number of related comparison reports for the BARC (India), LNE-LNHB (France), NIM (China), NPL (United Kingdom) and the PTB (Germany) are also in preparation. The report for the ENEA (Italy) is close to publication.

Following the agreement of the CCRI(I) in May 2005 on new values for correction factors, based on Monte Carlo calculations particularly for the axial non-uniformity in the ^{60}Co gamma beam, a new value for the BIPM air kerma evaluation will be published and adopted at a date to be agreed, probably 1 July 2007.

Reports of previous x-ray comparisons with the ARPANSA (Australia), BEV (Austria), NIM (China), NMi (Netherlands) and the NMIJ (Japan) are in preparation. These comparison reports evaluate degrees of equivalence and the results will be included in the KCDB once they have been approved by the CCRI.

The four transfer chambers for the high-energy absorbed-dose CCRI key comparison continue to be measured periodically in the BIPM ^{60}Co beam.

6.1.3 Calibration of national standards for dosimetry

The revised BIPM report of measurement conditions for dosimetry calibrations has been published to include the changes in the x-ray standards that were published previously. An internal audit of the calibration services was completed in August 2004. No non-compliances were recorded.

A total of three series of calibrations of national standards were made in low- and medium-energy x-rays for the IAEA, the LNE-LNHB (France) and the CSIR-NML (South Africa).

Thirteen calibrations of national standards were carried out in the BIPM gamma-ray beams in terms variously of air kerma, absorbed dose to water and ambient dose equivalent, as requested by the CSIR-NML (South Africa) IAEA and the ITN (Portugal).

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

6.2 Radionuclides

(C. Michotte and G. Ratel; S. Courte and M. Nonis)

6.2.1 International key comparisons of activity measurements

The CCRI(II) recently endorsed a ten-year plan for international activity comparisons, for which the BIPM is the pilot laboratory, to enable NMIs to support their measurement claims. Of the 19 such comparisons that have been completed, the results of ten are published in the KCDB, four comparisons are at the draft B report stage and the remaining five more recent comparisons are at the draft A report stage.

The seven most recent comparisons were the subject of a workshop held at the BIPM in November 2004. Twenty-five participants from 18 laboratories contributed to make this a success.

To accommodate the additional workload of the comparison programme the radiochemical laboratory has been updated; a new balance has been purchased and the balance room is being re-equipped with a new air-conditioning system to replace the original that was installed over thirty years ago. The effects of the changes on the mass measurements are being studied. The adoption of a new security system for all chemicals at the BIPM has been beneficial but required a considerable administrative workload to set up for the section.

6.2.2 Comparison of activity measurements of a ^{241}Am solution

Some laboratories detected the presence of impurities in the solution of ^{241}Am distributed by the NPL and supplementary measurements have been requested from the laboratories by the KCWG in order to determine and correct for the impurity level to assure the outcome of this comparison.

The draft A will be amended appropriately once these results have been received and then distributed to the participants.

6.2.3 Comparison of activity measurements of a ^{65}Zn solution

A solution of $ZnCl_2$ in hydrochloric acid 0.5 mol dm^{-3} was prepared by the IRMM and 23 ampoules were then sent to the BIPM for measurements in the SIR ionization chambers. Nineteen ampoules were then sent to the participants. The solution was free of impurity. Several different measurement techniques have been used, the most popular ones using coincidence counting with proportional counters working at atmospheric pressure. Twenty-seven results were submitted to the BIPM showing a spread of ± 2 % if one result, considered as an outlier, is excluded from the data set. The draft A is nearly finished and should be distributed this summer to the participants.

6.2.4 Comparison of activity measurements of a ^{125}I solution

The comparison of activity measurement of a solution of ^{125}I is now finished. The draft A has been completed and will be distributed to the 22 participants before the end of June 2005. Thirty-five results which had been obtained using 20 different methods were communicated to the BIPM. Most of the results are in reasonably good agreement although six showed unexplained large discrepancies.

6.2.5 Comparison of activity measurements of a ^{32}P solution

The solution of ^{32}P, for the additional measurements recommended by the CCRI(II) to identify the discrepancies found by three participants in the recently completed comparison of this radionuclide, was dispatched at the end of January 2005 by the PTB. The participants in this extension include these three laboratories, three linking laboratories to the previous comparison and five new participants: the BARC, BIPM, LNE-LNHB, LNMRI, CSIR-NML, IRA (Switzerland), IRMM, NIST, NMIJ, PTB and the RC (Poland). The dead-line for submitting the results has been postponed to the end of June 2005 at the request and with the agreement of the participants to allow more time for the experimental methods. The draft A will then be prepared.

6.2.6 Comparison of activity measurements of a ^{54}Mn solution

The draft A report has been distributed to the 23 participants and corrections and improvements received from them are being incorporated into the draft B report that is in preparation.

6.2.7 Comparison of activity measurements of a ^{90}Y solution

The results of the comparison have been published on the web.

6.2.8 International reference system (SIR) for gamma-ray emitting radionuclides

During 2004, the BIPM received 20 ampoules from nine laboratories: the BARC, the CIEMAT, the IRMM (two ampoules for two different radionuclides), the NIST, the NMIJ (seven ampoules for three different radionuclides), the NPL, the OMH and the PTB (four ampoules filled with three different radionuclides) and the RC. Twelve different radionuclides were measured producing 18 new results for ^{18}F, ^{22}Na, ^{51}Cr (two results), ^{57}Co, ^{60}Co, ^{85}Sr, ^{109}Cd (two results), ^{131}I, ^{134}Cs (four results), ^{137}Cs (two results), ^{139}Ce and ^{153}Sm. Since the beginning of the SIR in 1976, 872 ampoules have been measured, which corresponds to a total of 634 independent results for 62 different radionuclides.

In addition, five ampoules prepared by the NPL for the international comparison of ^{125}I have been measured in the SIR ionization chambers with the aim of providing a direct and robust link of the individual results of the ^{125}I CCRI(II) comparison to the KCRV for this radionuclide. Unfortunately, the activity submitted was too low for this to be achieved.

The new SIR measurement system is being tested in parallel with the previous system to validate the experimental set-up and the acquisition software. Until the beginning of 2005, the second SIR chamber has only been checked by measuring the reference ^{226}Ra sources. Measurements of the SIR ampoules are now being carried out in this ionization chamber so that, in the future, both chambers will be fully characterized and calibrated.

Twelve ongoing BIPM comparison reports have been published in the KCDB during the last twelve months, including links for CCRI(II) or RMO comparisons in four cases. A further draft B report is in circulation and four others are in preparation.

The project in collaboration with the NPL on the determination of a mathematical solution to the SIR photon and electron efficiency curves as a function of energy is at the end. The mathematical model includes the correction for impurities in each individual SIR measurement and a calculation of the beta spectrum shapes. The uncertainties and correlations are treated in detail. The results are under analysis and the curves compare favourably with preliminary Monte-Carlo simulations from the IRA and with

the previously published curve which was updated using the same SIR results and nuclear data as for the new curves.

The measurement of a series of ^{85}Kr gas ampoules containing about the same activity but with internal Kr pressure ranging from 800 hPa to 5000 hPa demonstrated a linear dependence of the ^{85}Kr equivalent activity to Kr gas pressure of -45.5 kBq/hPa. This negative dependence is related to the bremsstrahlung produced by the ^{85}Kr beta particles in the Kr gas. This study now enables the SIR participants to submit ^{85}Kr ampoules filled at the pressure of their choice as a correction factor can now be applied. However, the difference in the ^{85}Kr SIR results between the two participants remains and additional investigations are planned before the start of the international comparison now scheduled for 2006. A similar study will need to be carried out for ^{133}Xe gas.

Various liquid scintillation preparations are being studied to identify the best solution appropriate for the extension of the SIR to beta and alpha emitters.

6.2.9 Gamma spectrometry

Impurity checks have been made for ^{18}F, ^{57}Co and ^{90}Sr submitted to the SIR. No significant impurity was identified in any of these ampoules nor in those submitted for the ^{32}P activity comparison of the CCRI(II). The ^{153}Sm ampoule from the ANSTO was also measured and this identified a ^{156}Eu impurity not notified by that laboratory. This enabled a reduction in the discrepancy of the ANSTO SIR result compared to the KCRV.

6.3 Publications, lectures, travel: Ionizing Radiation section

6.3.1 External publications

1. Allisy-Roberts P.J., Radiation quantities and units – understanding the sievert, *J. Radiol. Prot.*, 2005, **25**, 97-100.
2. Allisy-Roberts P.J., Burns D.T., Summary of the BIPM.RI(I)-K4 comparison for absorbed dose to water in ^{60}Co gamma radiation, *Metrologia*, 2005, **42**, *Tech. Suppl.*, 06002.
3. Allisy-Roberts P.J., Burns D.T., Kessler K., Delaunay F., Leroy E., Comparison of the standards for absorbed dose to water of the BNM-LNHB and the BIPM for ^{60}Co γ rays, *Metrologia*, 2005, **42**, *Tech. Suppl.*, 06006.
4. Burns D.T., O'Brien M., Lamperti P., Boutillon M., Comparison of the NIST and BIPM medium-energy x-ray air-kerma measurements, *J. Res.*

Natl. Inst. Stand. Technol., 2003, **108**, 383-389. http://www.nist.gov/jres

5. Ratel G., Evaluation of the uncertainty of the degree of equivalence, *Metrologia*, 2005, **42**, 140-144.
6. Ratel G., Michotte C., BIPM comparison BIPM.RI(II)-K1.Xe-133 of activity measurements of the radionuclide ^{133}Xe, *Metrologia*, 2004, **41**, *Tech. Suppl.*, 06011.
7. Ratel G., Michotte C., BIPM comparison BIPM.RI(II)-K1.Sm-153 of activity measurements of the radionuclide ^{153}Sm, *Metrologia*, 2004, **41**, *Tech. Suppl.*, 06012.
8. Ratel G., Michotte C., BIPM comparison BIPM.RI(II)-K1.Ir-192 of the activity measurements of the radionuclide ^{192}Ir and links for the international comparison CCRI(II)-K2.Ir-192, *Metrologia*, 2004, **41**, *Tech. Suppl.*, 06013.
9. Ratel G., Michotte C., BIPM comparison BIPM.RI(II)-K1.Zn-65 of activity measurements of the radionuclide ^{65}Zn, *Metrologia*, 2004, **41**, *Tech. Suppl.*, 06014.
10. Ratel G., Michotte C., BIPM comparison BIPM.RI(II)-K1.Tl-201 of activity measurements of the radionuclide ^{201}Tl, *Metrologia*, 2004, **41**, *Tech. Suppl.*, 06015.
11. Ratel G., Michotte C., Coursol N., Morel J., BIPM comparison BIPM.RI(II)-K1.Yb-169 of activity measurements of the radionuclide ^{169}Yb and links for the 1997 regional comparison EUROMET.RI(II)-K2.Yb-169, *Metrologia*, 2004, **41**, *Tech. Suppl.*, 06017.
12. Ratel G., Michotte C., García-Toraño E., Los Arcos J.-M., Update of the BIPM comparison BIPM.RI(II)-K1.F-18 of activity measurements of the radionuclide ^{18}F to include the CIEMAT, *Metrologia*, 2004, **41**, *Tech. Suppl.*, 06016.
13. Ratel G., Michotte C., Hino Y., BIPM comparison BIPM.RI(II)-K1.Y-88 of activity measurements of the radionuclide ^{88}Y and links for the 2000 regional comparison APMP.RI(II)-K2.Y-88, *Metrologia*, 2004, **41**, *Tech. Suppl.*, 06010.
14. Ratel G., Michotte C., Kossert K., Janssen H., Activity measurements of the radionuclide ^{131}I for the PTB, Germany in the ongoing comparison BIPM.RI(II)-K1.I-131, *Metrologia*, 2005, **42**, *Tech. Suppl.*, 06004.
15. Ratel G., Michotte C., Nathuram R., Shaha V.V., Activity measurements of the radionuclide ^{22}Na for the BARC, India in the ongoing comparison BIPM.RI(II)-K1.Na-22, *Metrologia*, 2005, **42**, *Tech. Suppl.*, 06005.

16. von Martens H., Elster C., Link A., Wöger W., Allisy P.J., Linking the results of the regional key comparison APMP.AUV.V-K1 to those of the CIPM key comparison CCAUV.V-K1, *Metrologia*, 2004, **41**, *Tech. Suppl.*, 09002.

17. Zimmerman B.E., Ratel G., Report of the CIPM Key Comparison CCRI(II)-K2.Y-90, *Metrologia*, 2005, **42**, *Tech. Suppl.*, 06001.

6.3.2 BIPM reports

18. Allisy-Roberts P.J., Kessler C., Mello da Silva C.N., Comparison of the standards for air kerma of the LNMRI/IRD and the BIPM for ^{60}Co γ rays, *Rapport BIPM*-2005/01, 6 pp.

19. Allisy-Roberts P.J., Burns D.T., Kessler C., Measuring conditions used for the calibration of ionization chambers at the BIPM, *Rapport BIPM*-2004/17, 20 pp.

20. Allisy-Roberts P.J., Burns D.T., Takata N., Koyama Y., Kurosawa T., Comparison of the standards for air kerma of the NMIJ and the BIPM for ^{60}Co γ rays, *Rapport BIPM*-2004/11, 12 pp.

21. Allisy-Roberts P.J., Burns D.T., Takata N., Koyama Y., Kurosawa T., Comparison of the standards for air kerma of the NMIJ and the BIPM for ^{137}Cs γ rays, *Rapport BIPM*-2004/12, 8 pp.

22. Michotte C., Note on the decay correction required for a radionuclide ^{N}X in presence of its metastable state ^{N}X^{m}, *Rapport BIPM*-2004/15, 3 pp.

The BIPM has also published *Monographie 5* in two volumes and has made available on the website electronic versions of all the earlier Monographies.

6.3.3 Travel (conferences, lectures and presentations, visits)

P.J. Allisy-Roberts to:

- CNAM, 22 September 2004, for the 35th anniversary of the BNM (since February 2005, the LNE replaced the former BNM, France); 5 April 2005, to attend the Journée des métrologues;
- London (United Kingdom), 13 October 2004, to attend the Ionizing Radiation Health and Safety Forum; 19 October 2004, 13 January and 19 April 2005 for the editorial board of the *Journal of Radiological Protection*; 14-15 February 2005 to attend the Royal Society Scientific Discussion meeting on "The fundamental constants of physics, precision measurements and the base units of the SI";

- Coventry (United Kingdom), 21-22 October 2004, for the DTI Measurement Advisory Committee (MAC);
- LNE (France), 11 January 2005, for the editorial board of the *Revue française de métrologie*;
- NPL (United Kingdom), 23-25 February 2005, to chair the MAC working groups on acoustics and on ionizing radiation; 16 March 2005 to attend the DTI International Programme meeting;
- York (United Kingdom), 14-15 March 2005, for the DTI Measurement Advisory Committee (MAC);
- Cardiff (United Kingdom), 15 June 2005, to participate in an international conference on radiation protection.

D.T. Burns to:

- Arlington, Virginia (United States), 6–10 September 2004, to attend the meeting of the Main Commission of the ICRU;
- LNE (Paris), 27–29 September 2004, as the BIPM representative at the EUROMET Ionizing Radiation Contact Person and Workshop meeting.

C. Michotte to:

- Geel (Belgium), 15-19 November 2004, to participate in the VERMI Young Researchers' Workshop on secondary standardization methods (together with S. Courte) and to give a lecture on the determination of the photon efficiency curve of an ionization chamber using an iterative method;
- ININ (Mexico), 4–13 April 2005, for technology transfer in the field of gamma spectrometry.

S. Picard to LNE (Trappes), 10 February 2005, to visit Mr B. Hay (together with D.T. Burns and P. Roger).

G. Ratel to:

- Paris (France), 18 November 2004, to attend the meeting of the Société française de radioprotection on "Les nouvelles orientations en radiobiologie et radiopathologie";
- Rungis (France), 9-10 December 2004, to attend the "Quatrièmes rencontres des personnes compétentes en radioprotection".

6.4 Activities related to external organizations

P.J. Allisy-Roberts is the member of the MAC for ionizing radiation and acoustics and is a scientific member of the UK Ionising Radiation Health and Safety Forum. She is also a member of an ICRU Report Committee, the

BIPM representative on the IAEA SSDL Scientific Committee, a member of the editorial board of the *Journal of Radiation Protection* and a referee for *Physics in Medicine and Biology* (PMB), the *British Journal of Radiology* and the *Bulletin du BNM.*

D.T. Burns is the BIPM representative at the ICRU and a member of the ICRU Committee on Fundamental Quantities and Units. He is the BIPM contact person at EUROMET for ionizing radiation and radioactivity. He is a referee for PMB and for *Medical Physics*.

G. Ratel is the BIPM representative at the International Committee for Radionuclide Metrology (ICRM).

C. Michotte is the BIPM contact person and rapporteur for Working Group 1 of the JCGM that met in November 2004 and in February 2005.

6.5 Activities related to the work of Consultative Committees

P.J. Allisy-Roberts is Executive Secretary of the CCRI and its three Sections, all of which met in May 2005 and of the CCAUV which met in September 2004. She attended the CCAUV and CCRI RMO working groups, both of which met in September 2004.

She and D.T. Burns are members of the CCRI(I) working groups on metrological equivalence (key comparisons), on air kerma correction factors for cavity chambers, and brachytherapy standards.

P.J. Allisy-Roberts, C. Michotte and G. Ratel are members of the CCRI(II) working groups on key comparisons and short-lived radionuclides.

G. Ratel is a member of the CCRI(II) working groups on the extension of the SIR to beta emitters and on measurement uncertainties.

The BIPM hosted a Workshop on Activity Comparisons on behalf of the CCRI(II) in November 2004, at which G. Ratel gave presentations and C. Michotte reported the recommendations (also to the CCRI(II)), and a Workshop on Dosimetry Uncertainties on behalf of the CCRI(I) in May 2005 at which P.J. Allisy, D.T. Burns, C. Kessler and S. Picard gave presentations and the results of which were reported to the CCRI(I). The participants at each workshop requested that the BIPM organize further workshops in 2006 and 2007 respectively.

6.6 Visitors to the Ionizing Radiation section

- Prof. M. Cox and Mr A. Pearce (NPL), 27 July 2004 and 14 September 2004.
- Dr N. Coursol (LNE-LNHB), 19 August 2004.
- Mr J.T. Cessna and Dr M. Schultz (NIST), 1 September 2004.
- Dr N. Takata (NMIJ), 20 September 2004.
- Dr A. Nohtomi (NMIJ), 25 October 2004.
- Prof. M. Cox, Mr S. Judge and Mr A. Pearce (NPL), 16 December 2004.
- Dr P. Cassette (LNE-LNHB), 18 January 2005.
- Mrs M. Moune (LNE-LNHB), 26 January 2005.
- Dr M.P. Toni (ENEA), 11 March 2005.
- Dr T. Altzitzoglou (IRMM), 22 March 2005.

6.7 Guest workers

- Dr T. Kurosawa and Dr A. Nohtomi (NMIJ), 15-22 November 2004.
- Mrs Li Mo (ANSTO), 22 November 2004 – 25 February 2005.
- Dr M. Bovi (ENEA), 13-17 December 2004.
- Mr L. Czap (IAEA), 13-17 June 2005.
- Dr J.V.S. Cardoso (ITN), 20-24 June 2005.

7 CHEMISTRY (R.I. WIELGOSZ)

7.1 Gas metrology programme
(R.I. Wielgosz, M. Esler and J. Viallon; P. Moussay)

7.1.1 Ozone photometer comparison programme (J. Viallon; P. Moussay)

Measurements for the ozone (ambient level) comparison (CCQM-P28), coordinated by the BIPM, were completed in March 2005. This comparison has allowed the degree of equivalence of 23 reference standards to be determined in relation to the BIPM maintained standards. During the final period of the comparison, July 2004 to March 2005, eight laboratories visited the BIPM to participate in the comparison. The first draft of the pilot study report was circulated to participants in April 2005. A two day workshop,

with forty participants, was held at the BIPM in April 2005 to discuss the results of the comparison. A final version of the pilot study report will be available in October 2005, as well as a new protocol for the on-going key comparison (BIPM.QM-K1).

7.1.2 Statistical treatment of comparison results

The collaboration with Dr W. Bremser of BAM on the statistical treatment of ozone comparison data, initiated in January 2004, is continuing. The focus of this collaborative project is the use of a generalized least-squares method to compare the measurement results of two ozone photometers. Dr W. Bremser has developed a programme (OzonE) dedicated to the treatment of ozone comparison data. The software allows correlations between the measurement results to be taken into consideration, and includes a new feature to treat direct comparisons as well as comparisons performed *via* a transfer standard. Tests performed at the BAM and BIPM with real comparison data have confirmed the choice of 12 sampling points, as used in the CCQM-P28 comparison, to be a good compromise between reduced measurement uncertainty and the time needed to perform a comparison.

7.1.3 Study of systematic biases and measurement uncertainty in Standard Reference Photometers (SRPs)

The study of systematic biases and measurement uncertainty in SRPs, started in 2004, was completed in February 2005. Extensive measurements of the gas temperature in the SRP cells have been performed. The measurements confirmed the existence of a temperature difference of 2 °C to 3 °C between the ends of the cells, depending on the SRP model. Furthermore, the instrument's original temperature probe has been found to have a measurement bias of 0.3 °C due to a self-heating process. Extensive comparisons performed on the five SRPs maintained at the BIPM have shown a 0.4 % bias on the SRP measurement results due to the actual temperature effects. A method for removing this bias has been developed at the BIPM, and will be applied to all SRPs used in future ozone comparisons. A second major bias of 0.5 % in the SRP measurement results had been demonstrated resulting from the optical design of the instrument. Corrections and their related uncertainties are being addressed, and a new uncertainty budget for the instrument will be published. A feasibility study has demonstrated the advantage of introducing a laser-based light source into the SRP, and a programme to develop a candidate primary ozone photometer based on a laser light source has been initiated. Studies will be performed

with a frequency-doubled argon laser. This follows an extensive period of tests with a solid-state (Ytterbium:YAG) laser, which was unable to meet the technical specification required for the system.

7.2 Primary NO_2 gas standard facility (M. Esler; P. Moussay)

A primary gas standard facility for the dynamic preparation of nitrogen dioxide gas standards in the range (0.5 – 10) μmol/mol, based on a magnetic suspension balance system, was constructed in 2003-2004. Full software control and automation of the facility, as well as testing of the system to ensure it met stability requirements have been completed during 2004-2005. A multiple gas mixture sampling module for this facility is currently under construction which will allow static gravimetric NO_2 gas reference mixtures (prepared in cylinders) to be compared with the facility's dynamically generated reference mixtures. The facility will be used to assign values of NO_2 amount fractions to mixtures held in cylinders and test their stability. The new module will automatically process up to 15 cylinders simultaneously. The completed facility will initially serve as a primary reference for NO_2 mass fraction measurements for the gas-phase titration facility, and as a facility for the comparison of NO_2 standards.

7.3 Gas-phase titration facility (M. Esler)

A gas-phase titration (GPT) facility as an alternative, potentially primary method for ozone concentration measurements was constructed in 2003-2004, and has been modified and its performance improved during this period. The system employs the mass-flow-controlled dynamic dilution of high-concentration nitrogen monoxide (NO) gas standards. Changes in NO concentration are monitored with a chemiluminescence analyzer and compared with the loss of ozone determined from UV absorption. The first iteration of the GPT facility relied on calibrated mass flow controllers (MFCs) for the measurement of gas flow, limiting the measurement uncertainty of the system to >1 %. In 2004-2005, a second version was constructed using molbloc/molbox technology for gas flow measurements, allowing the overall measurement uncertainty to be improved significantly to, approximately, 0.3 %. The system has been fully automated. The BIPM participated in the CCQM-P28 study using the redesigned system, producing a result consistent with that of an independently developed GPT facility (NIES, Japan), but biased with respect to the ozone photometer measurements. The source of this bias will be investigated in the future programme. The development of the BIPM GPT facility has revealed

chemical interference effects in the measurement of nitrogen monoxide by chemiluminescence detection. The source of the interference has been identified by FTIR analysis and removed (see section 8.1.5).

7.4 **NO gas standard comparison facility** (M. Esler; P. Moussay)

In 2003-2004, a facility for the comparison of NO gas standards with nominal amount fractions of (30-70) μmol/mol was constructed. During 2004-2005, this facility was used to compare and value assign of NO gas standards required for the GPT facility. The data has been analyzed using time series analysis (Allan variance) and Generalized Least Squares (GLS) regression. This has made it possible to analyze NO gas standards with a measurement uncertainty equivalent to the gravimetric uncertainty of their preparation (0.05 % relative), using two independent analysis principles: UV spectrophotometry and chemiluminescence. Additionally, two independent suites of gravimetric primary reference NO/N_2 gas mixtures purchased from two NMIs have been compared at the BIPM. Comparison of these two suites over time has revealed that the reference mixtures from one of the NMIs were unstable. The results of these initial studies have been presented to the CCQM GAWG, and a BIPM coordinated comparison of gravimetric nitrogen monoxide reference mixtures from different NMIs was proposed and approved. Commencing in October 2005, the BIPM will coordinate the pilot study CCQM-P73, on the comparison of gravimetric NO mixtures sourced from 12 NMIs. The initial NO facility is capable of processing 15 cylinders simultaneously. This has been complemented by a second unit capable of sampling 30 cylinders. Software for the automation of both the 15-port and the 30-port units has been written and tested.

7.5 **FTIR facility** (M. Esler; P. Moussay)

A remotely operated and programmable filter wheel has been constructed and installed in the FTIR spectrometer's sample compartment. The wheel carries a selection of infrared bandpass filters, each of which optimizes the signal to noise ratio for a different part of the infrared spectrum, leading to an improvement in the uncertainty of gas analysis by FTIR.

The FTIR facility was interfaced to a commercial nitrogen oxide analyzer and used to investigate the gas phase chemistry of NO detection by chemiluminescence. This investigation was undertaken to identify the source of anomalous behavior of the commercial NO analyzer in certain configurations, which may lead to measurement errors. The source of the anomaly has been identified and further action is being considered.

7.6 **Composition of air** (M. Esler and R.I. Wielgosz)

In 2003-2004, at the request of the CCM and CCQM, the KRISS undertook a re-determination of the mole fraction of argon in air in order to resolve the discrepancy in methods for the determination of air density in mass metrology. Two papers reporting the details of the argon measurement and its consequences for mass metrology were published in *Metrologia*, 2005, **41**, 387-395 and 396-400. The KRISS argon result has recently been corroborated by independent studies at the LNE. These results will be the subject of a recommendation by the CCM to the CIPM to revise the air density formula.

7.7 **Organic analysis programme** (R. Josephs, S. Westwood and R.I. Wielgosz; A. Daireaux)

The availability of reliable methodologies for the characterization of pure materials is essential for the establishment of a system of SI-traceable chemical measurement results. In the area of organic analysis, purity is most usefully described in terms of mass fraction of the component of interest present in the material. This can be determined either by approaches which measure the mass fraction or mole fraction of the main component directly or by "indirect" approaches, which identify and estimate the mass fraction of the individual impurities and/or distinct classes of impurities present in the material and, by subtraction, provide a measure for the main component of the material.

Implementation of a BIPM work programme in the field of organic pure substances has commenced with the recruitment of Dr S. Westwood, Dr R. Josephs and Mrs A. Daireaux, and laboratory facilities to support ongoing activities in this area have been established. The long-term aim of the programme is to enable the BIPM to engage in and support the CCQM international programme of purity assessment comparisons and contribute to the development of robust approaches and methodologies for the determination of purity. This will require the extension of the CCQM-P20 series of comparisons for purity determination, the use of BIPM laboratory facilities to support these activities, and the establishment of international liaisons to support and promote the programme. The programme will thereby ensure that the international comparisons of the CCQM provide agreed and documented methodologies for purity determination, and demonstrate the measurement capabilities of laboratories providing services in this area. The programme will not require the BIPM to produce reference materials.

In prioritizing its programme, the BIPM has considered the needs for organic pure substances that are required for establishing reference measurement systems for laboratory medicine. Taking into account the current interests of the CCQM and the JCTLM in the ongoing requirements of laboratory medicine, purity assessment studies of therapeutic drugs and non-peptide hormones were selected as the source of specific analytes for the continuation of the CCQM-P20 series of comparisons. Theophylline and digoxin have been identified as suitable materials for the initial studies. Their analysis will contribute in a complementary manner to the overall technical aims of the CCQM-P20 study. They are also important analytes in their own right for which no pure substance certified reference materials (CRMs) are currently available. Investigations of the extension of the comparison to include clinically-important steroid hormones such as progesterone, β-estradiol and testosterone will also be undertaken.

7.8 Establishment of organic analysis laboratory facilities

The organic analysis programme within the Chemistry section is developing a facility to undertake purity assessments using robust procedures for the identification and summation of impurities. This general approach will be supported by direct assay techniques where they are applicable. To deliver the measurement capability required for the programme, infrastructure for analysis by liquid chromatography with mass spectrometry (LC/MS), gas chromatography with mass spectrometry (GC/MS), gas chromatography with a flame ionization detector (GC/FID) and differential scanning calorimetry (DSC), supplemented by Karl Fischer titration and thermogravimetric analysis has been or are being installed and tested at the BIPM. Facilities for the safe handling, processing and ongoing storage of materials under investigation are being completed. The facilities will be supported by external collaborations for specialized services such as elemental microanalysis and nuclear magnetic resonance (NMR).

7.8.1 Coordination of CCQM-P20

A BIPM work proposal was presented at the CCQM Organic Analysis Working Group meeting in October 2004 and further discussed further in April 2005. Agreement has been reached for BIPM to proceed as the co-coordinating laboratory for subsequent rounds of the CCQM-P20 series of comparisons. Two comparisons were approved: CCQM-P20.e for theophylline; and -P20.f for digoxin.

The overall aim of the series of studies is to evaluate the scope, applicability and limitations of various methodologies to assess the purity of organic materials. This will allow a comprehensive series of guidelines to be developed for the design of purity assessment plans appropriate for a given organic compound or compound chemical class for use in a given measurement application. Additionally, these studies allow NMIs to assess their capabilities to characterize the purity of their own materials, including the quantification of specific impurities, and to determine the contribution that different sources of material can have on the degree of equivalence determined in CCQM comparisons. The BIPM programme will allow NMIs with specific CMC claims for the provision of organic pure substance Certified Reference Materials (CRMs) to demonstrate their purity assignment capabilities.

7.8.2 External collaborations

The BIPM is developing international liaisons with interested NMIs to support and promote its programme. Active collaborations have been established with LGC in the studies related to theophylline and digoxin, and with NMIJ in the area of steroid hormones.

A collaboration with the LGC as part of the BIPM programme of purity assessment of selected organic pure substances, linked to the CCQM series of organic substance purity comparisons, was initiated in 2004. Within the context of this collaboration, R. Josephs was seconded to the LGC for November 2004 and February 2005 to produce several batches of test materials for therapeutic monitored drugs (theophylline, theobromine and caffeine). The test materials are being used by the BIPM to develop and assess different purity determination techniques and methodologies. During the first part of the secondment, batches of pure and gravimetrically spiked materials were prepared, bottled and tested for homogeneity by liquid chromatography with UV diode array detection (LC-DAD). The second part of the secondment concentrated on further measurements with the LC-DAD system, and liquid chromatography with a tandem mass spectrometry (LC-MS/MS) system. This work allowed the performance characteristics of the techniques to be assessed. In addition, the applicability of gas chromatography with flame ionization detection (GC-FID) using cooled on-column injection was evaluated for the compounds of interest.

Theophylline and digoxin materials, which are candidate materials for the CCQM-P20 comparisons, have been prepared by the LGC and will be transferred to the BIPM in June and July 2005, respectively.

A collaboration on purity measurement method development of steroid hormone materials was initiated with NMIJ in 2004. The NMIJ has obtained 200 g batches of testosterone, progesterone and β-estradiol materials. The materials will be used for method development and are candidate samples for the CCQM comparison programme. Initial analyses of the materials have been performed at the NMIJ. Dr Ihara (NMIJ) has undertaken, and will continue to undertake, a number of secondment periods at the BIPM to aid in the purity method development programme.

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

R.I. Wielgosz is Secretary of the Joint Committee for Traceability in Laboratory Medicine, and a member of its review team on Quality Systems and Implementation.

The second meeting of the Executive Committee of the JCTLM was held at the BIPM in December 2004 and was followed by meetings with JCTLM Working Group 1 Review Team Leaders, JCTLM Members and Stakeholders, and a workshop on Reference Measurement Systems for Biologicals. A quality manual outlining the procedures used to review materials and methods for publication in the JCTLM database has been published. We are preparing to convert the published JCTLM lists of materials and methods into a web-based searchable database. The technical specifications of the database design have been completed, and construction of the database will start at the end of the year.

A second JCTLM list of "higher order reference materials and measurement procedures" has been published on the BIPM website. This second list refers to reference materials that are value-assigned using an internationally agreed-upon protocol (e.g. reference materials for blood typing, coagulation factors, microbial serology, nucleic acids and some proteins). The values of the measurands in the reference materials on this list are not SI-traceable and/or no internationally-recognized reference measurement procedures exist. The list also contains a group of purified substances that due to the absence of reference measurement procedures should not be directly used for calibration unless commutability is established.

A meeting of JCTLM WG 2 Chairs was held in March 2005 at the BIPM, to develop the procedures to be used in the evaluation of reference measurement services provided for laboratory medicine.

7.10 Activities related to the work of Consultative Committees

R.I. Wielgosz is the Executive Secretary of the CCQM. The CCQM held its 11th meeting at the BIPM (14-15 April 2005), and was preceded by meetings of its working groups.

M. Esler is a member of the CCQM Working Group on Gas Analysis.

J. Viallon is a member of the CCQM Gas Analysis and Surface Analysis Working Groups.

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

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

7.10.1 CCQM related workshops

The following CCQM workshops were organized at the BIPM:

- CCQM Focus Group Meeting on Reference Measurement Systems for Food Analysis, 13 September 2004.
- CCQM-P28 Workshop – Ozone, ambient level, 7-8 April 2005.
- CCQM Workshop on higher-order measurement methods for physiologically-significant molecules, 13 April 2005.

7.10.2 CCQM comparisons coordinated by the BIPM

The BIPM is the coordinating laboratory for following CCQM comparisons:

- CCQM-P28 – Ozone, ambient level.
- BIPM.QM-K1 – Ozone, ambient level.
- CCQM-P73 – Nitrogen monoxide in nitrogen, preparative capabilities.
- CCQM-P20.e – Theophylline, purity analysis series.
- CCQM-P20.f – Digoxin, purity analysis series.

7.11 Activities related to external organizations

R.I. Wielgosz is the BIPM representative to the World Meteorological Organization (WMO), the World Health Organization (WHO) and the CODEX Alimentarius Commission. He is a member of the editorial board of *Accreditation and Quality Assurance*.

S. Westwood is the BIPM and CCQM representative at ISO REMCO.

7.12 Publications, lectures, travel: Chemistry section

7.12.1 External publications

1. Park S.Y., Kim J.S., Lee J.B., Esler M.B., Davis R.S., Wielgosz R.I., A redetermination of the argon content of air for buoyancy corrections in mass standard comparisons, *Metrologia*, 2004, **41**, 387-395.
2. Cozzolino D., Esler M.B., Dambergs R.G., Cynkar W.U., Boehm D.R., Francis I.L., Gishen M., Prediction of color and pH in grapes using diode array spectrophotometer (400-1100 nm), *J. Near Infrared Spectrosc.*, 2004, **12**, 105-111.
3. Dambergs B., Esler M.B., Gishen M., Analysis of beverages and brewing products, In *Near-infrared Spectroscopy in Agriculture* (Roberts C.A, Workman J. Jr, Reeves J.B. III eds.), Agronomy Series, Am. Soc. Agron., Crop Sci. Soc. Am., Soil Sci. Soc. Am., 2004, **44**, 465-485.
4. Wielgosz R.I., Quality Assurance/Primary Standards, *Encyclopedia of Analytical Science*, Elsevier, Second Edition, 2005, 419-426.

7.12.2 BIPM publications

5. Viallon J., Moussay P., Wielgosz R.I., Novak J., Vokoun M., Comparison of ozone reference standards of the CHMI and the BIPM, *Rapport BIPM*-2005/05, 12 pp.

7.12.3 Travel (conferences, lectures and presentations, visits)

R.I. Wielgosz to:

- AACC meeting, Los Angeles (United States), 23-28 July 2004, to participate in JCTLM WG1 and WG2 meetings and the AACC Industrial Meeting;
- IAEA, Vienna (Austria), 25-27 August 2004, to present a paper on the CIPM MRA and chair a session at the International Symposium on Quality Assurance for Analytical Methods in Isotope Hydrology;
- WHO, Geneva (Switzerland), 30 September – 1 October 2004, to participate in a WHO informal consultation on the recommendations for the preparation, characterization and establishment of WHO international standards and other biological reference materials;

- NRCCRM, Beijing (China), 17-22 October 2004, to attend CCQM-GAWG and OAWG and give a presentation on the BIPM Metrology in Chemistry Programme at the Beijing International Symposium on Metrology in Chemistry;
- CMS-ITRI, Hsinchu (Taiwan), 25-26 October 2004, to visit CMS laboratories and give a presentation on the BIPM/CCQM Metrology in Chemistry Programmes;
- NIST, Gaithersburg (United States), 25-28 January 2005, to participate in the JCTLM Working Group 1 meetings on the JCTLM quality manual and visit the Biotechnology Division;
- London (United Kingdom), 9-11 February 2005, to LGC/NPL and NIBSC to discuss the CCQM Bioanalysis Programme;
- CEM, Madrid (Spain), 16-18 February 2005, to attend the EUROMET Metchem plenary and Gas Analysis Working Group meeting and present the BIPM Organic Analysis programme and JCTLM activities;
- AOAC Europe/Eurachem, Brussels (Belgium), 3-4 March 2005, to attend the 3rd AOAC Europe - Eurachem Symposium on legal limits on the road to food safety: establishing sound criteria for compliance decisions, with R. Josephs;
- WMO, Geneva (Switzerland), 14-16 March 2005, to participate in the WMO-GAW 2005 meeting, and give a presentation on the BIPM activities in ground-level ozone standard comparisons;
- Effectech Ltd, Utoxeter (United Kingdom), 22 March 2005, to inaugurate new laboratories;
- Budapest (Hungary) 1-4 April 2005, to represent the BIPM at the International Agency Meeting (for organizations working in the field of analysis and sampling of food) and the CODEX Committee on Methods of Analysis and Sampling (CCMAS);
- CODEX Alimentarius, The Hague (Netherlands), 25-27 April 2005, to represent the BIPM in the CODEX Committee on Food Additives and Contaminants (CCFAC) of the joint FAO/WHO food standards programme, with R. Josephs;
- IMGC, Turin (Italy), 28 April 2005, to present the CCQM Programme for Chemical Metrology at a workshop on Metrology in Chemistry;
- IRMM, Geel (Belgium) 19 May 2005, to discuss the future BIPM Metrology in Chemistry Programme;
- NIST, Gaithersburg (United States), 23, 26 and 27 May 2005, to participate in the JCTLM Working Group 1 meetings on the JCTLM

quality manual and visit the CSTL to discuss the future BIPM Metrology in Chemistry Programme;

- NIH, Bethesda (United States), 24-25 May 2005, to participate in the Standardization of Genomic Amplification Techniques (SoGAT) meeting and give a presentation on the "JCTLM approach to higher order standards".

M. Esler to:

- NMi VSL, Delft (Netherlands), 21-22 July 2004, to visit laboratory and discuss gas metrology issues;
- Amsterdam (Netherlands), 6-8 October 2004, to present a poster on "Value assignment of gas CRMs; minimizing analytical uncertainty", at NEN 3rd Gas Analysis Symposium;
- NRCCRM, Beijing (China), 17-23 October 2004, to attend CCQM-GAWG and Beijing International Symposium on Metrology in Chemistry.

J. Viallon to:

- École des Mines de Paris (France), 30 September 2004, to attend the meeting "Journée Technique du Collège Français de Métrologie sur les Mesures d'Humidité dans les Gaz";
- CEA (France), 15-19 November 2004, for training as a laser safety officer;
- Lyon (France), 20-23 June 2005, to present a paper on "An international network for ground-level ozone reference standard comparisons" at the 12th International Congress of Metrology.

S. Westwood to:

- NRCCRM, Beijing (China), 19-22 October 2004, to attend the Metrology in Chemistry Symposium and represent BIPM at the CCQM Organic Analysis Working Group meeting;
- LNE, Paris (France), 3 November 2004, to discuss the BIPM Organic Analysis Programme;
- LGC, Teddington (United Kingdom), 16-17 November 2004, to review progress in the BIPM/LGC collaboration on Primary Calibrators for Laboratory Medicine;
- ISO, Geneva (Switzerland), 18-21 April 2005, to represent BIPM and CCQM at the annual ISO REMCO meeting.

R. Josephs to:

- LGC, Teddington (United Kingdom), 8 November 2004 - 3 December 2004, seconded to the LGC within the framework of the BIPM/LGC collaboration on Primary Calibrators for Laboratory Medicine for the development of purity methodology (1st secondment); 17 January 2005 – 5 February 2005 (2nd secondment);
- CODEX Alimentarius, Budapest (Hungary), 4-8 April 2005, to represent the BIPM in the CCMAS of the joint FAO/WHO food standards programme.

7.13 Visitors to the Chemistry section

- Dr H. Tanimoto, Dr H. Mukai and Mr S. Hashimoto (NIES), 26-30 July 2004.
- Dr J. Novák and Mr M. Vokoun (CHMI), 20-24 September 2004.
- Ms M. J. van Rensburg (CSIR-NML), 27 September – 1 October 2004.
- Mr H. P. Ahleson (NERI), 22-26 November 2004.
- Mr L. Marsteen and Mr N. Ladegård (NILU), 29 November – 3 December 2004.
- Dr W. Bremser (BAM), 2-3 December 2004.
- Mr M. Van Rijn (NMi VSL), 11-13 January 2005.
- Dr M. P. Sassi and Mr E. Malgeri (IMGC), 24-26 January 2005.
- Dr O. Rabin (WADA), 23 June 2005.

7.14 Guest worker

- Dr T. Ihara (NMIJ), 6-10 June 2005

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

8.1 Information registered in the KCDB (S. Maniguet and C. Thomas)

Appendix B of the database now covers 623 key and supplementary comparisons conducted under the auspices of the CIPM or of RMOs. These

include 500 key comparisons, 176 of which have had their results published onto the KCDB by 1 June 2005. The ongoing BIPM key comparisons in electricity are regularly updated with the results of new bilateral comparisons carried out between the BIPM and some NMIs. Since October 2002, results have been approved and published for 56 of the 59 ongoing BIPM key comparisons on radionuclide activity conducted within the framework of the SIR. We have also registered a new BIPM key comparison, BIPM.L-K11, of primary wavelength standards.

The results of 27 RMO key comparisons (nine conducted by APMP and 18 by EUROMET) are linked to those of the corresponding Consultative Committee (CC) key comparisons; the full sets of degrees of equivalence are published in the KCDB. The same type of linkage has also been carried out for 13 CC key comparisons, among which nine are key comparisons of radionuclide activity conducted under the auspices of Section II of the CCRI, and linked to the corresponding ongoing BIPM SIR key comparisons. The four others are bilateral key comparisons subsequent to full-scale CC key comparisons; their results were added on the appropriate graphs of equivalence. New results approved by CCs are still communicated to the BIPM for publication *via* the KCDB at an average rate of about one per week.

Appendix C contained some 17 500 calibration and measurement capabilities (the CMCs) at the beginning of June 2005, covering all fields of metrology. The total number of uncertainty values that are displayed is, however, much larger (around 35 000) thanks to the presentation under the form of tables. Big sets of CMCs, especially those covering ionizing radiation from all regions, and those corresponding to the update of APMP and COOMET claims in electricity and magnetism, were posted during this year in Appendix C. In addition, we undertake a daily update to respond to small corrections (mainly editorial), minor changes (increase of uncertainty values, reduction of the measurement ranges, etc.), and deletion of some CMCs (services that are no longer offered to clients, or that are not covered by an appropriate Quality System).

8.2 Analysis of the results of key comparisons published in the KCDB (C. Thomas)

A detailed analysis of the methods used to derive the key comparison reference value and to compute the linkage between the results of key comparisons of the same "family" (CIPM and RMO key comparisons with similar protocols) was carried out starting from those results that are effectively published in Appendix B.

Among the 176 key comparisons having final report posted in the KCDB Appendix B, 136 are placed at the centre of a family (50 % of which are BIPM ongoing key comparisons), and the other 40 are linked comparisons. The measurements are generally obtained for several nominal values of the measurand or of an influence parameter, leading to a total of about 360 sets of results interpreted in terms of equivalence.

Diverse methods are used for the computation of the key comparison reference values: arithmetic mean, 40 % (percentages estimated over the 360 sets of results); weighted mean, 18 %; weighted mean with maximum weight, 6 %; median, 2 %; known values (values of international standards maintained by the BIPM and global values known *a priori*, such as a ratio equal to 1 for example), 7 %; and individual reference value (for example, the case of the gravimetric value of each sample distributed in some of the chemistry key comparisons), 27 %.

The linked results expand those of the corresponding central key comparisons in order to form 25 duos, three trios, and three quartets. The linkages reported in Appendix B are generally deduced from a case-by-case examination of the particular situation. The different methods used are related to the techniques put in place to conduct the comparisons and to the manner in which the key comparison reference values are computed. For instance, the linkage is direct when individual or global reference values are known a priori. In the case of radioactivity measurements, the linkage is based on the measurement in the SIR of some of the ampoules distributed in CCRI and RMO key comparisons. When a statistical treatment of results of common participants is carried out, it always relies on the repeatability of the corresponding measurements.

8.3 The KCDB and the BIPM Quality System

(S. Maniguet and C. Thomas)

The work of the KCDB is detailed in nine procedures that successfully passed the BIPM Quality System internal review on 31 May 2005 for the second consecutive year. Seven of these procedures describe the technical aspects of the entry of information into the databases of the KCDB; they are kept in restricted access for certain BIPM members only, and are saved on CDs placed in individual offices. The two additional procedures deal with the formal authorization processes needed before publishing data on the web; they are initially available on the BIPM Intranet but may eventually be made available publically.

8.4 Visits to the KCDB website and publicizing the KCDB
(S. Maniguet and C. Thomas)

The number of external connections to the KCDB website has increased by 35 % over the period August 2004 – March 2005, reaching 8600 visits in March 2005. This trend is equally shared between Appendix B and Appendix C.

We try to publicize the KCDB as often as we can through, for example, the distribution of copies of the KCDB leaflet, and the presentation of the KCDB website at workshops and congresses.

The first issue of the *KCDB Newsletter* was sent to about 1000 e-mail addresses on 16 June 2004 and made available from the KCDB website, with the firm intention of issuing such Newsletters twice a year, in June and in December. Indeed, issues 2 and 3 were launched on 7 December 2004 and 14 June 2005, respectively. The KCDB Newsletter provides an ideal place for the communication of matters relevant to the CIPM MRA, the JCRB, and any other news concerning the content of Appendices B and C.

8.5 Travel (conferences, lectures and presentations, visits)

C. Thomas to:

- the Institut de France, Paris (France), 25 October 2004, 24 January 2005, 21 March 2005 and 23 May 2005, for meetings of the Working Group of the Académie des Sciences "Unités de base et constantes fondamentales";
- London (United Kingdom), 14-15 February 2005, to attend the Royal Society Scientific Discussion meeting on "The fundamental constants of physics, precision measurements and the base units of the SI";
- Reading (United Kingdom), 16-17 February 2005, for the editing meeting of the draft 8th edition of the SI Brochure with I.M. Mills, T.J. Quinn, B.N. Taylor and A.J. Thor;
- Minsk (Belarus), 10-12 May 2005, to present the BIPM key comparison database at the BIPM-JCRB-COOMET Workshop on the CIPM MRA, and to attend part of the 14th JCRB meeting;
- Tsububa (Japan), 16 May 2005 and 18-20 May 2005, to attend the NMIJ-BIPM Workshop on the Impact of Information Technology in Metrology;
- Tokyo (Japan), 17 May 2005, to attend a symposium organized at the occasion of the World Metrology Day;

- Lyon (France), 21 June 2005, to present the BIPM key comparison database at the 12th International Metrology Congress.

8.6 Activities related to external organizations

On 1 January 2005, C. Thomas became a member of the "Cabinet scientifique des Secrétaires perpétuels de l'Académie des Sciences de Paris". In this context, she acts as the Scientific Secretary of the Working Group of the Académie des Sciences "Unités de base et constantes fondamentales".

8.7 Activities related to the work of Consultative Committees

C. Thomas is the Executive Secretary of the CCU.

C. Thomas attended the following meetings:

- CCRI Working Group on CMCs, 23-24 September 2004;
- 4th CCAUV, 27-28 September 2004;
- CCAUV Working Group on CMCs, 29 September 2004;
- 13th JCRB (in part), 30 September 2004;
- Director's Meeting, 1 October 2004;
- 93rd CIPM (in part), 7 October 2004;
- CCEM working groups, 14-16 March 2005;
- 24th CCEM, 17-18 March 2005;
- 11th CCQM, 14-15 April 2005;
- 9th CCM and some of the CCM working groups, 25-28 April 2005;
- Sections II and III of the 19th CCRI (in part), 23-26 May 2005;
- 23rd CCT, 9-10 June 2005;
- 17th CCU, 29-30 June and 1 July 2005.

C. Thomas also participated in a number of internal meetings concerning the BIPM's comments to the draft 3rd edition of the *International Vocabulary of Basic and General Terms in Metrology*, the VIM, 10-14 January 2005.

S. Maniguet attended the following meetings:

- JCTLM, 13-15 December 2004;
- 11th CCQM and CCQM Workshop, 13-15 April 2005.

8.8 Publications

8.8.1 External publications

1. Thomas C., The BIPM key comparison database, *12th International Metrology Congress*, June 2005 (CD-Rom).
2. Thomas C., The BIPM key comparison database (KCDB): linkage of key comparison results, *NMIJ-BIPM Workshop on the Impact of Information Technology in Metrology*, May 2005 (to be available from the BIPM website in September 2005).
3. Thomas C., The BIPM key comparison database (KCDB): technical aspects and data management, *NMIJ-BIPM Workshop on the Impact of Information Technology in Metrology*, May 2005 (to be available from the BIPM website in September 2005).

8.8.2 BIPM reports

4. Thomas C., The BIPM key comparison database (KCDB): linkage of key comparison results, *Rapport BIPM*-2005/06, 2005, 10 pp.
5. Thomas C., The BIPM key comparison database (KCDB): technical aspects and data management, *Rapport BIPM*-2005/07, 2005, 7 pp.

8.9 Visitors to the KCDB

- Dr L. Érard (LNE), 3 March 2005.
- Dr C. Rhone (CROSQ) and Dr D. Lalla-Rodrigues (ABBS), 9 March 2005.

9 THE JOINT COMMITTEE OF THE REGIONAL METROLOGY ORGANIZATIONS AND THE BIPM, JCRB (I. CASTELAZO)

9.1 The JCRB empowers RMO TC/WG chairs

At its 13th meeting, held in Paris on 29 September 2004, the JCRB approved a modification in its procedures allowing the RMO Technical Committee/Working Group (TC/WG) chairs to interact directly with the BIPM during the review of inter-regional CMC. In the previous scheme,

TC/WG chairs were required to communicate with each other through the RMO representatives and the JCRB Executive Secretary. This modification allows them to post, send comments and approve CMC submissions directly, using the facilities of a new interactive website that keeps all parties informed at every step in the process. The benefits expected from this new procedure include an improved awareness and interest in the MRA process on the part of the TC/WG chairs and a reduction of the time needed to complete the reviews of CMCs.

9.2 Fast-track approval of CMCs

A fast-track procedure to approve and publish, in special circumstances, CMCs in Appendix C was approved by the JCRB in September 2004. The normal procedure calls for a formal review period which must be recorded in the website, after which a set of revised CMCs is posted for approval. The JCRB recognises that CC and RMO working groups in several areas carry out this review outside of the formal process. In these cases, when the CMCs are submitted to the BIPM there is already an inter-regional consensus. Consequently, these CMCs are posted in the JCRB website only to record the formal approval of the reviewing RMOs, thus reducing the time elapsed from submission to publication.

9.3 End of the transition period

At the 14th meeting of the JCRB, held in Minsk (Belarus), in May 2005, the RMOs concluded the last action remaining from the transition period of the CIPM MRA. The RMOs presented their review of the NMI Quality Systems supporting the CMCs published in Appendix C, and presented a list of services that were to be temporarily deleted because the MRA Quality System requirements had not yet been satisfied. It was agreed that those CMCs could be reinstated as soon as the RMOs verify that a fully implemented Quality System is in place.

After this action, the CIPM MRA enters a new phase where it can be confidently stated that the list 17 000 CMCs published in Appendix C fully satisfy the requirements originally established in 1999.

9.4 Inter-regional review procedures

JCRB procedures have been revised with the objective of improving the efficiency of the review process, and assuring that CMC declarations are uniform and technically correct. A time limit was included in the procedure

for the approval of posted CMCs, after which they will be published in Appendix C in the absence of objections and if, at least, one RMO indicates its consent.

A document was approved at the 11th meeting of the JCRB which clarifies the chain of responsibility to ensure that CMC claims made by an NMI are consistent with the results obtained in key and supplementary comparisons. The instructions for drawing up CMC Excel files now include a procedure for specifying the range and uncertainty of CMCs and forbid any form of ambiguous declaration.

9.5 New Executive Secretary

On 27 May 2005, Dr Ismael Castelazo concluded his tenure as Executive Secretary of the JCRB and returned to CENAM, Queretaro, Mexico. Dr Pedro Espina, on secondment from the NIST, started working as the designated Executive Secretary on 4 April 2005 and was able to work alongside Dr Castelazo for almost two months before taking over as the new Executive Secretary.

9.6 Publications, travel: JCRB

9.6.1 New JCRB documents

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

1. Subsequent bilateral key-comparison flowchart.
2. JCRB CMC-review procedures.

9.6.2 Revised JCRB documents

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

1. Revised rules of procedure for CMC entry into Appendix C.
2. Criteria for acceptance of data for Appendix C.

9.6.3 Travel (conferences, lectures and presentations, visits)

I. Castelazo to:

- Berlin (Germany), 25-29 October 2004, for the OIML Forum: Metrology – Trade facilitator, 12th Legal Metrology Conference and 39th CIML Meeting;

- BIPM, 7-8 March 2005, for the BIPM/ILAC Workshop;
- BIPM, 10 March 2005, for the BIPM/OIML/ILAC meeting.

I. Castelazo and P. Espina to Minsk (Belarus), 11-12 May 2005, for the 14th JCRB meeting and the COOMET International Workshop on the "Role of MRA CIPM in international cooperation in the field of metrology and in supporting trade and economical interrelations".

9.7 Activities related to the work of Consultative Committees

I. Castelazo attended the following meetings:

- CCRI RMO Working Group on CMCs, 23 September 2004;
- CCEM 5th RMO Electricity and Magnetism Technical Committee/ Working Group Chairpersons Meeting, 16 March 2005.

I. Castelazo and P. Espina attended the following meetings:

- CCQM Working Group on CMCs, 7-8 April 2005;
- CCM Working Group on CMCs, 27 April 2005.

9.8 Visitors to the JCRB

- Dr M.C. César Cajica (CENAM), 22-26 November 2005.
- Drs C. Rhone, D. Lalla Rodrigues and H. Edmonson (CARICOM), 9 April 2005.
- Mr L. Gómez (Superintendencia de Industria y Comercio, Colombia), 24 April 2005.

10 QUALITY SYSTEM AND LIAISONS TO ISO AND ILAC (R. KÖHLER)

10.1 Liaisons to ISO and ILAC (R. Köhler)

The BIPM Quality System (QS) required to comply with ISO/IEC 17025 is fully operational for almost all services which issue internal or external calibration certificates. Two more services will be added before the end of 2005. The publication of data in the KCDB is also covered by an ISO 9000 compatible QS. Other services, such as administration and the workshop

have procedures according to ISO 9000, but have not yet been formally audited.

For Health and Safety, intrinsically linked to the BIPM QS, internal checks have been carried out. The workshop environment was audited by a specialized outside company.

ILAC and the BIPM continue their cooperation and the common statement explaining the respective roles and responsibilities is in the final draft state and will be distributed in the near future. We also hosted a meeting between the Regional Metrology Organizations and the Regional Accreditation Bodies to discuss matters of mutual interest in March 2005.

A tripartite meeting between the BIPM, ILAC and OIML also took place.

Participation in ISO working groups concerning the ISO 17000, important for the work at the BIPM and its stakeholders, continues and the BIPM participation and input is well recognized.

10.2 Travel (conferences, lectures and presentations, visits)

R. Köhler to:

- Salt Lake City (United States), 12-15 July 2004, for the NCSLI meeting with a lecture on "Improving worldwide traceability and acceptance of measurements carried out within the CIPM MRA and the ILAC Arrangement";
- ISO Central Secretariat, Geneva (Switzerland), 21-22 July 2004 and 4-5 April 2005, for an ISO WG 23 meeting, and 29 July 2004, for an ISO WG 18 meeting;
- Ljubljana (Slovenia), 13-15 September 2004, for a Metronet conference with a lecture on "The BIPM key comparison database";
- Cape Town (South Africa), 8-11 October 2004, for the ILAC General Assembly;
- NEN, Delft (Netherlands), 5-6 November 2004, for an ISO WG 23 meeting;
- Amsterdam (Netherlands), 8-10 November 2004, for the ISO CASCO General Assembly giving a short update on BIPM activities;
- Kuala Lumpur (Malaysia), 29 November – 3 December 2004, for ISO TC 176 meetings;
- NMIJ, Tsukuba (Japan), 16-20 May 2005, for the third workshop on the evaluation of key comparisons, for the International Symposium on Measurement Standards in Japan 2005, held at the Tokyo International

Exchange Center, 17 May 2005, with a presentation "Challenges faced by IT-oriented next-generation metrology", and the NMIJ/BIPM workshop on the impact of information technology on metrology with a presentation "ISO/IEC 17025 and remote calibration, are they compatible?";

- Lyon (France), 18-20 June 2005, for the CIML meeting giving an update on the BIPM and the CIPM MRA activities.

11 SPECIAL PROJECTS (M. STOCK)

11.1 Calculable capacitor (F. Delahaye, R. Goebel, J. Sanjaime, M. Stock, L.F. Vitushkin and T.J. Witt)

The collaborative work with the NMIA (Australia) on the development of two calculable capacitors, capable of achieving relative uncertainties of the order of 10^{-8}, has continued according to the project plan.

The BIPM workshop made the parts for the lower guard assembly, according to the drawings provided by NMIA. This included the manufacturing of a complex parallel motion spring, which was made using the recently acquired electrical discharge machine. At the end of April 2005, we have received the drawings for the assembly and alignment tools for the lower guard assembly. The NRC (Canada) has recently signed a bilateral contract with the NMIA to obtain the critical components of the calculable capacitor, of which we will also provide a number.

The system for measuring the straightness of the electrode bars, built in the BIPM workshop during the last year, is now in regular use at the NMIA.

All elements of a capacitance bridge for the calibration of 1 pF capacitance standards in terms of the calculable capacitor have been constructed. This includes a supplying transformer, a main inductive divider and a calibration transformer. The bridge and its voltage source are designed to operate at 250 V in the frequency range from 1 kHz to 4 kHz. First tests indicate that the deviation of the ratios from nominal are of order of 2 parts in 10^7 at 1600 Hz, and that the ratios can be calibrated to 1 part in 10^9.

A green Nd:YVO_4/KTP/I_2 laser for the interferometer, needed to measure the separation of the guard electrodes, has been modified and now works with a

higher modulation frequency of 10 kHz. The basic specifications have been verified. One additional laser is currently being built.

Colleagues from NMIA propose a Fabry-Perot interferometer with a special design which will reduce the diffraction correction. The mirrors in both electrodes are spherical, with curvatures matching those of the wave fronts at their respective positions. We plan a simple experimental set-up to test this design, as well as some other configurations.

The first version of the software for the calculation of the wave front propagation in a real multiple beam interferometer, developed at the Polytechnical University of St Petersburg and the State University of St Petersburg is currently being tested and improved. This software will allow us to simulate the interference pattern of the interferometer, and to estimate the related uncertainty contribution, which will be one of the major uncertainties of the calculable capacitor.

11.2 Watt balance

(R.S. Davis, F. Delahaye, H. Fang, A. Picard, T.J. Quinn, D. Reymann, S. Solve, M. Stock, L.F. Vitushkin and T.J. Witt)

During the period of this report, our work has concentrated on the conception of the magnetic circuit and the balance suspension. Recently, work on the constant current source and the interferometry has begun.

The magnetic circuit will produce a horizontal radial field which leads to the vertical magnetic force on the coil, necessary to compensate the gravitational force on the mass. We have chosen a geometry for the magnetic circuit which differs from that used in existing experiments. The main innovations are the high symmetry of the circuit, which should lead to a very uniform field profile in the air gap and the good screening of the air gap against external fields by the closed iron yoke.

For a feasibility study of such a system and for optimization of the design parameters, we have started a collaboration with an engineering company, specializing in the design of electromagnetic systems. The results of the finite-element-calculations made at the BIPM were confirmed by more sophisticated calculations. It is relatively simple to obtain a flux density of at least 0.5 T in the 13 mm-wide air gap. The form of the pole pieces was optimized to obtain a very high uniformity of the field in the air gap. This is essential for our plans to undertake the weighing and moving mode operation simultaneously. The effects of a magnetic hysteresis due to the reversal of current in the coil have been estimated and shown to be negligible at the

required uncertainty level. No fundamental difficulties questioning the feasibility were identified.

We have recently started the second phase of the study, which includes the influence of mechanical imperfections on the magnetic properties. The next step would then be to design the magnetic circuit for fabrication. The magnet will not arrive at the BIPM before mid-2006. We have therefore started to build a less sophisticated magnet system with the help of the BIPM workshop. This simplified model should allow us to carry out initial investigations of the alignment, and of the behaviour of the induced voltage and the force in our watt balance design. The main parts of the iron yoke have been manufactured, we are currently waiting for the test magnets to arrive.

The parts for the balance suspension, including an electrostatic motor for the coil displacement have been designed and were built in the workshop. The parts are currently being assembled. The suspension contains many CuBe-flexure strips to avoid any friction. The system contains parallel horizontal electrode plates which generate a vertical force if a high voltage is applied. Position-sensitive detectors (PSDs) will be used together with laser diodes to analyze the motion of the system. A numerical servo control of the velocity of a test coil will be developed by using the PSDs and high voltage amplifiers.

To generate the magnetic force, a constant current needs to be supplied to the coil. The value of the current will be measured but needs to be as stable as possible. We expect the room temperature experiment to work at an uncertainty level of 10^{-5} to 10^{-6}. The current source should have a comparable stability. A self-made current source used previously for the calibration of Zener diodes was successfully modified and shown to provide a current of 1 mA, which according to initial tests is stable within 1 part in 10^7. We have plans to improve the source by replacing its voltage reference by a Zener standard.

The accuracy of the room temperature experiment will be limited by the temperature coefficient of the electrical resistance of the coil and by the temperature stability of the magnetic circuit. We plan to use, in addition to the moving coil, an identical but fixed coil, which will allow us to follow the variations of the resistance with temperature.

An overview of existing interferometric techniques was undertaken to select a system for the velocity and position measurement. A Michelson interferometer is better suited for fringe interpolation than a Fabry-Perot instrument. A heterodyne interferometer provides an ac signal with better

signal-to-noise ratio than a homodyne system. We have therefore ordered a commercial heterodyne Michelson interferometer.

11.3 Travel (conferences, lectures and presentations, visits): Special projects

R.S. Davis, H. Fang, A. Picard, M. Stock and T.J. Witt to METAS, Bern (Switzerland), 4-5 November 2004, to participate at the "Watt Balances Technical Meeting". M. Stock presented "The BIPM watt balance", A. Picard "Alignment procedure for the BIPM watt balance" and "Sorption artefacts for Avogadro project and watt balance experiment", T.J. Witt "Demonstration of methods for treating serial correlations in experimental observations" and H. Fang "Water vapour adsorption on mass standards measured by ellipsometry".

H. Fang, A. Picard and M. Stock to the University of St Quentin, 15 December 2004, to attend at a presentation of a PhD thesis entitled "Mesure et contrôle de position et de vitesse à l'échelle nanométrique : application à la balance du watt" by Darine Haddad.

A. Picard to METAS, Bern (Switzerland), 19-20 May 2005, for technical discussions on the METAS watt balance and to give a talk on "Water vapour sorption study: application in the Avogadro project".

11.4 Visitors: Special projects

- Dr J. Fiander and Dr G. Small (NMIA), 12-13 July 2004, for discussions related to our collaboration on the calculable capacitor.
- Mr F. Daninos (La Recherche), 6 August 2004, to explore the possibility of an article on watt balances written by the BIPM watt balance team.
- Mr P. Dent (Electron Energy Corporation), 3 September 2004, for discussion on magnets for the watt balance.
- Mr D. Nettleton (NPL), 7 September 2004, to discuss his ideas of a new type of watt balance.
- Dr B. Inglis (NMIA), 18 March 2005, during the CCEM, for discussion on progress with the calculable capacitor project.
- Dr A. Eichenberger (METAS), 23 June 2005, for discussion on the BIPM watt balance.
- Dr B. Wood (NRC), 27 June 2005, for discussion on the calculable capacitor.

12 PUBLICATIONS AND INFORMATION TECHNOLOGY (J. WILLIAMS)

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

Since July 2004 the following have been published:

- *Director's Report on the Activity and Management of the BIPM (2004)*, 2005, **5**, 295 pp.

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

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

12.2 *Metrologia* (J.R. Miles and J. Williams; D. Saillard)

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

The technical details of the production of *Metrologia* between the BIPM and IOPP are continuing to work well. The journal appears on time and we benefit from the extensive marketing network of IOPP to assist in maintaining the subscriptions levels of the journal at a time when subscription levels are falling for the majority of technical scientific journals. Special issues of the *Metrologia* are still organized by an invited specialist editor in cooperation with the editor at the BIPM. Over the period of this report, there have been two special issues of *Metrologia*: one on Charge and the other to celebrate the 50th anniversary of Atomic Time keeping.

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

A recent project has been the digitization of the whole archive of *Metrologia*. This process of digitization was undertaken by IOPP on our behalf, and was completed at the end of 2004. IOPP is marketing this *Metrologia* Archive as part of the archive of papers published in their journals on behalf of the BIPM.

Impact factor (IF) = (number of citations in the current year to papers published in previous two years / number of papers published in previous two years)

Year	2000	2001	2002	2003	2004
IF	0.820	0.945	0.842	0.983	1.314

The impact factor is moving in the right direction. It is likely that the impact factor will further increase as a paper published in *Metrologia* at the beginning of 2005 (Redefinition of the kilogram: a decision whose time has come – I.M. Mills *et al*., *Metrologia*, **42**, 71-80) gained extensive media coverage. It is important for us to achieve and maintain an impact factor above 1.0 as this is typically the cut-off value that librarians and subscriptions managers look at when they are seeking which journals with low impact factor to cut from their budgets.

Institutional subscriptions have been falling regularly, this decline is to be regretted, however, the fact that the journal is now distributed in a pack with other IOPP titles means that it is now more widely available. Typically, a pack subscription would be a library (not necessarily in a metrology institute) and readers in that library will now find *Metrologia* on the shelves, whereas the library would previously probably not have considered taking out an institutional subscription. In this way, we are using the pack subscription route offered by IOPP as a communication tool to make *Metrologia* and metrology more widely available to the scientific and technical community.

The *Technical Supplement to Metrologia* is growing, with 36 abstracts published in 2004, 10 already online in 2005 with many more in the pipeline. It was noted that at a recent chemistry conference, some attendees commented that they liked the *Technical Supplement* even though they didn't publish in *Metrologia*.

The following are Accept-to-Web publication (AW) and Accept-to-Print publication (AP) times for *Metrologia*. The figures have been compiled from the monthly production reports. They demonstrate that the editorial and publication processes involving BIPM and IOPP are working well.

	AW	AP
2004 (volume 41)	41 days	111 days
2005 (volume 42 – to date)	31 days	70 days

12.3 **Information Technology** (L. Le Mée and J.R. Miles; G. Petitgand)

The BIPM website (www.bipm.org) continues to evolve as the BIPM's primary means of communication and as the world's most comprehensive metrology portal. The front page of the website was redesigned in March 2005 to speed up access to selected areas of the site and to increase the visibility of the KCDB and JCTLM-database areas. A new section on "databases" was also added, giving access to the KCDB and JCTLM-database and a compilation of the various "search" facilities available on the site. A study on search engines is under way, and we hope to install a new improved search engine towards the end of 2006.

Following a decision of the CCL, the *Mise en Pratique* for the definition of the metre is now published and updated on the BIPM website. The text formerly printed in *Metrologia* has therefore been adapted and updated, and published on the website as a collection of wavelength-specific files available at http://www.bipm.org/en/publications/mep.html. The CCT documents on the ITS-90, and the abstracts of all BIPM Reports, can also be found under http://www.bipm.org/en/publications/.

At the request of CCT Working Group 8 on CMCs in the field of thermometry, 2005 has also seen the introduction of a BIPM Discussion Forum, http://forum.bipm.org/. The success of this forum has quickly led to its adoption by other groups, and there are now over sixty registered users in five different subject areas. The forum facilitates discussions between scientists spread around the world, provides an archive of their discussions, and serves as a reference source for important documents.

The working documents of the Consultative Committees and Working Groups now occupy almost 2 Gbytes of disk space. After committee meetings, an increasing number of these documents are being made available in "open access" areas. The work published by members of the Committees continues to be highlighted through bibliography pages.

More country-specific information has been published about the Member States (under http://www.bipm.org/en/convention/member_states/), and figures illustrating some of the technical partnerships between the BIPM and the Member States have been introduced at http://www.bipm.org/en/bipm/comparisons/. More information of a historical nature is also being collated. Recent additions include photographs of the Curies visiting the BIPM in the early 1900s (under http://www.bipm.org/en/si/history-si/radioactivity/famille_curie.html), short biographies of some former members of the CIPM (under http://www.bipm.org/en/committees/cipm/former_members.html), and infor-

mation relating to the International Metre Commission, the precursor of the Metre Convention (http://www.bipm.org/en/ si/history-si/commission.html).

To better publicize the work of the BIPM, the annual *Director's Report* is also available on the website.

The IT group of the BIPM put in place this year the hardware and software of a new automated backup system. The hardware for this system comprises a backup onto tape (a tape library), which permits us to hold about 2 Tbytes of data. The software associated with this system functions in a client/server mode permitting us to backup data situated on different servers.

This year saw the replacement by the IT group of the central server of the BIPM's Intranet server and its main database, which had been in use since 2000. The new server has a larger memory, offers a better performance and allows better management of the database. Another change is that an important part of the software hosted on the new server is Open Source; that is, software that is freely available.

The BIPM continues to be assaulted by ever increasing amounts of unsolicited emails (SPAM e-mails). At present about 75 % of the, on average, 1200 e-mails that arrive at the BIPM each day are SPAM. Consequently, the IT group has reinforced the sophisticated 'firewall' protection against SPAM, and also installed a centralized system to search for and eliminate messages which contain "IT viruses" and mails which contain rude words or words which are habitually associated with SPAM. This firewall protection has been installed on both portable and on non-portable computers used by members of the BIPM.

In addition, the IT group has developed and has put in place a number of Intranet and Internet applications, presenting new ideas and opportunities for improvement to the service offered to BIPM staff, members of Consultative Committees, to outside visitors, and those seeking to learn more about metrology and the work of the BIPM. A considerable amount of work has been put into developing systems for the management and control of working documents. The IT group was involved in replacing several of the optical fibre links which serve as conduits for rapid data transfer around the site of the BIPM, and in the installation of wireless Internet access on the site of the BIPM.

Finally, the IT group has been involved in the purchase, installation, administration and maintenance of about 170 office- or laboratory-based computers, and a dozen networked printers.

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

J. Williams to:

- London (United Kingdom), 14-15 February 2005, to attend the Royal Society Scientific Discussion meeting on "The fundamental constants of physics, precision measurements and the base units of the SI"; 19-21 April 2005, to the 4th CCM International Conference on Pressure Metrology from Ultra-High Vacuum to Very High Pressure;
- Reading (United Kingdom), 12 May 2005, to visit Prof. I.M. Mills.

J.R. Miles to:

- London (United Kingdom), 10 November 2004, to the ESPERE Users Group meeting;
- London (United Kingdom), 2-3 December 2004, to the Online conference;
- Reading (United Kingdom), 18 April 2005, to visit Prof. I.M. Mills.

J.R. Miles and J. Williams to London (United Kingdom), 19 April 2005, to the IOPP Partners Meeting.

12.5 Visitors: Publications and Information Technology section

- Mrs M. Jost, on a number of occasions.
- Mr F. Khababa, student at the École des Hautes Études en Sciences Sociales, 25 May-22 July 2005.

With L. Le Mée and C. Thomas:

- Mrs C. Iooss (CEA), 30 May 2005.
- Mr J.-P. Favrot and Mr S. Py (Verity), 6 June 2005.
- Ms C. Offredo (Exalead), 13 June 2005.

13 MEETINGS AND LECTURES AT THE BIPM

13.1 Meetings

The following meetings were held at the BIPM:

- The CCQM Working Group on Food Analysis met on 13 September 2004.
- The CCRI II Working Group on Key Comparisons met on 21 September 2004, followed by the CCRI II Working Group on Uncertainties on 22 September, by the CCRI RMO Working Group on CMCs on 23 September, and by the CCRI RMO Working Group on 24 September.
- The CCAUV met on 27-28 September 2004.
- The JCRB RMO Workshop met on 29 September 2004 and the 13th JCRB on 30 September.
- The Directors meeting was held on 30 September – 1 October 2004.
- Working Group 1 (GUM) of the Joint Committee for Guides in Metrology (JCGM) met on 8-10 November 2004 and on 14-18 February 2005, and Working Group 2 (VIM) on 21-25 February 2005 and 30 May-3 June 2005.
- The BIPM and ILAC met on 12 November 2004.
- The CCRI Workshop on Key Comparisons met on 25-26 November 2004.
- The JCTLM met on 13-15 December 2004.
- The CCRI Working Group on Key Comparisons met on 10 February 2005, followed the CCRI Working Group on Uncertainties on 11 February.
- A Joint meeting of the CIPM/ILAC/OIML Working Group was held on 10-11 March 2005, preceded by a BIPM/ILAC Workshop on 7-8 March.
- The CCEM met on 17-18 March 2005, preceded by its workings groups on 14-16 March.
- The CCRI Working Group on the Extension of the SIR to β-emitters Using Liquid Scintillation met on 21-22 March 2005.
- The JCTLM Working Group 2 Chairmen met on 31 March 2005.
- The CCQM met on 14-15 April 2005; it was preceded by meetings of its working groups from 7-13 April.
- The CCM met on 28-29 April 2005; it was preceded by meetings of its working groups from 25-27 April.
- The CCRI met on 27 May 2005; it was preceded by a workshop on key comparisons on 17 May and by meetings of its three sections from 18-26 May 2005.

- The CCT met on 9-10 June 2005; it was preceded by meetings of its working groups from 6-8 June.
- The CCU met on 29-30 June and 1 July 2005.

13.2 External Seminars

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

- K.W.D. Ledingham (Strathclyde University, United Kingdom): The development of and perspective for high power laser production of radionuclides for positron-emission tomography, 24 May 2005.
- L. Pitre (LNE-INM): "Le thermomètre acoustique sphérique : *vers la fin des échelles de température* ?", 15 June 2005.
- N. F. Zhang (NIST): Statistical analysis on uncertainty for autocorrelated measurements, 20 June 2005.
- T. Fortier (Los Alamos Laboratory and NIST): Cutting edge combs for optical frequency measurements and comparisons, 27 June 2005.

13.3 Internal Seminars

- L.-S. Ma and L. Robertsson: Optical comb comparisons and optical frequency measurements, 25 January 2005.
- T.J. Quinn: Redefinition of the kilogram, a decision whose time has come, 24 March 2005.
- H. Fang and A. Picard: Water vapour sorption study, application in the Avogadro project, 19 April 2005.
- D. Burns and S. Picard: Towards an absorbed-dose calorimeter: measurement of the specific heat capacity of graphite, 10 May 2005.
- H. Fang, A. Picard, D. Reymann and M. Stock: The BIPM watt balance, 16 June 2005.
- G. Petit: GPS time transfer, 15 years of progress, 21 June 2005.

14 CERTIFICATES AND NOTES OF STUDY

In the period from 1 July 2004 to 30 June 2005, 99 Certificates and 5 Notes of Study were delivered.

For a list of Certificates and Notes see pages 128-134.

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

15.1 Accounts

Details of the accounts for 2004 may be found in the "Rapport annuel aux Gouvernements des Hautes parties contractantes sur la situation administrative et financière du Bureau International des Poids et Mesures". An abstract of Tables taken from this report may be found on pages 135-141.

The headings for the tables may be translated as follows:

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

Two additional tables detail the payments made against budget in 2004 and the balance sheet at 31 December 2004. This is done under the headings:

Détail des dépenses budgétaires	**Statement of budgetary expenditure**
Bilan au 31 décembre 2004	**Balance at 31 December 2004**

It should be noted that in all tables, since 2002, the unit of currency is the euro, according to Resolution 13 of the 21st General Conference.

15.2 Staff

15.2.1 Appointments

- Dr Ralf D. Josephs, born 9 February 1970 in Dortmund (Germany), German nationality, previously scientific officer at the Institute for Reference Materials and Measurements in Geel (Belgium), was engaged as *chimiste* in the Chemistry section from 1 August 2004.
- Dr Steven W. Westwood, born 6 October 1959 in Sydney (Australia), Australian nationality, previously team leader at the Australian Government Analytical Laboratories in Pymble (Australia), was engaged as *chimiste* in the Chemistry section from 1 September 2004.
- Mrs Adeline Daireaux, born 27 July 1979 in Cherbourg (France), French nationality, previously technician in a French private company, was engaged as *technicien* in the Chemistry section from 13 June 2005.

15.2.2 Promotions and change of grade

- Dr David Burns*, *physicien* in the Ionizing Radiation section, was promoted *physicien principal* from 1 January 2005.
- Dr Steven W. Westwood*, *chimiste* in the Chemistry section, was promoted *chimiste principal* from 1 January 2005.
- Mr André Zongo, *agent d'entretien,* was promoted *jardinier* from 1 January 2005.

* These promotions resulted from a vote of the CIPM during its 93rd meeting in October 2004.

15.2.3 Changes of post and transfer to a permanent post

- Mrs Maria J. Fernandes, contractual employee since 2 February 2004, was confirmed on 1 January 2005 as *agent d'entretien*.
- Mrs Arminda Da Ponte, contractual employee since 16 June 2004, was confirmed on 1 January 2005 as *agent d'entretien*.
- Since January 2004, Dr H. Fang, *physicien* in the Mass section, has been assigned to the watt balance project (Electricity section/Special projects) for 50 % of her time.
- Since January 2004, Mr A. Picard, *physicien principal* in the Mass section, has been assigned to the watt balance project (Electricity section/Special projects) for 80 % of his time.

15.2.4 Research Fellows

- Dr Massimo Zucco, Research Fellow in the Length section from 9 September 2002, has had his fellowship extended until 31 December 2005.

15.2.5 Departures

- Mrs Rosa Prieto, *agent d'entretien*, retired on 31 July 2004 after 20 years of service.
- Mrs Marie-Josette Coarasa, *technicien métrologiste* in the Mass section, retired on 31 December 2004 after nearly 35 years of service.

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

15.3 Buildings

15.3.1 Grand Pavillon

- Painting of the floor of the corridor in the basement.
- Replacement of the floor-covering of the staircase between the ground floor and the basement.
- Replacement of the electric board of the staff canteen.

15.3.2 Petit Pavillon

- Redecoration of the visitor's apartment including the replacement of the electric board.

15.3.3 Observatoire

- Refurbishment of room 10 for the installation of a laboratory for the chemistry section.
- Replacement of electric boards of rooms 6, 7, 14, 114 and of the vault.
- Installation of a false ceiling in the corridor at the first floor.

15.3.4 Ionizing Radiation building

- Replacement of air-conditioning equipment in room 21.
- Installation of air-conditioning equipment in room 12.

15.3.5 Nouveau Pavillon

- Replacement of light fittings in the meeting room at level -2.

15.3.6 Pavillon du Mail

- Installation of air-conditioning equipment in the gravimetry room.

15.3.7 Outbuildings and park

- Partial repair of a pedestrian path and of a staircase.
- Construction of two platforms for gravimetrical measurements.
- Motorization of the entrance gate.
- Repair of part of the boundary fence.

15.4 Travel: Finance, administration and general services section

B. Perent to:

- London (United Kingdom), 30 June – 1 July 2004, for a meeting of the bureau of the CIPM;
- London (United Kingdom), 21-22 April 2005, to attend a meeting on privileges and immunities in international organizations organized by the International Institute of Administrative Sciences.

16 SECRETARIAT (F. JOLY)

The workload on the Secretariat continues to increase with the rising number of meetings held at the BIPM (about 10 % more than last year), essentially Consultative Committees and Working Groups (these being held in different places at the same time, in particular for the CCM, CCQM and the CCT).

In order to cope with the organization of these meetings, and the evolution of administrative work, the Secretariat is continuing to develop its knowledge of IT tools, so that our most important documents for Consultative Committees or for communications with Member States and NMI Directors can be accessed from the BIPM's website.

17 WORKSHOP AND SITE MAINTENANCE (J. SANJAIME)

The BIPM workshop provides an essential and much-valued contribution to our work programme. Many of the activities of the workshop are mentioned in the reports of the individual sections, but the core mission of the workshop is to support the technical programme with the construction of specialized apparatus and, where necessary, when NMIs and others bring items to the BIPM for calibration. In this latter case, ancillary equipment if often needed at short notice in response to any problems that may arise or to make repairs

if equipment is damaged in transit, so that the calibration may proceed smoothly. The availability of a rapid response is critical to the efficiency of the BIPM's services to NMI staff who may only be able to visit the BIPM for fixed, short periods of time.

The workshop carries out high-precision mechanical work for the scientific sections of the BIPM. Among recent projects we mention in particular:

- Continuing work on the calculable capacitor, in collaboration with the NMIA (Australia), fabrication of components;
- fabrication of a variety of pieces for the use of the various scientific sections;
- watt balance, fabrication and testing of components.

In addition, the workshop is the only source of platinum-iridium prototype kilograms, which are made exclusively for the Metre Convention and which makes use of the specialized equipment and unique experience of the workshop staff.

LIST OF ACRONYMS USED IN THE PRESENT VOLUME

1 Acronyms for laboratories, committees and conferences*

AAAC	Association of Accrediting Agencies of Canada
ABBS	Antigua and Barbuda Bureau of Standards (Antigua and Barbuda)
ADeLA	Dynamical Astronomy in Latin America/Astronomía Dinámica en Latino América
AIST*	National Institute of Advanced Industrial Science and Technology, see NMIJ/AIST
ANSTO	Australian Nuclear Science and Technology Organization, Menai (Australia)
AOAC	Association of Analytical Communities
APMP	Asia/Pacific Metrology Programme
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency, Sydney and Melbourne (Australia)
ATF	Accelerator Test Facility, Upton (United States)
BAM	Bundesanstalt für Materialforschung und -prüfung, Berlin (Germany)
BARC	Bhabha Atomic Research Centre, Trombay (India)
BelGIM	Belarussian State Institute for Metrology, Minsk (Belarus)
BEV	Bundesamt für Eich- und Vermessungswesen, Vienna (Austria)
BIPM	International Bureau of Weights and Measures/ Bureau International des Poids et Mesures
BNM*	Bureau National de Métrologie, Paris (France), see LNE
BRGM	Bureau de Recherches Géologiques et Minières, Paris (France)
CARICOM	Carribean Community
CC	Consultative Committee of the CIPM
CCAUV	Consultative Committee for Acoustics, Ultrasound and Vibration/Comité Consultatif de l'Acoustique, des Ultrasons et des Vibrations
CCEM	Consultative Committee for Electricity and Magnetism/ Comité Consultatif d'Électricité et Magnétisme
CCFAC	CODEX Committee on Food Additives and Contaminants

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

CCL	Consultative Committee for Length/ Comité Consultatif des Longueurs
CCM	Consultative Committee for Mass and Related Quantities/ Comité Consultatif pour la Masse et les Grandeurs Apparentées
CCMAS	CODEX Committee on Methods of Analysis and Sampling
CCPR	Consultative Committee for Photometry and Radiometry/ Comité Consultatif de Photométrie et Radiométrie
CCQM	Consultative Committee for Amount of Substance: Metrology in Chemistry/Comité Consultatif pour la Quantité de Matière : Métrologie en Chimie
CCRI	Consultative Committee for Ionizing Radiation/ Comité Consultatif des Rayonnements Ionisants
CCT	Consultative Committee for Thermometry/ Comité Consultatif de Thermométrie
CCTF	Consultative Committee for Time and Frequency/ Comité Consultatif du Temps et des Fréquences
CCU	Consultative Committee for Units/ Comité Consultatif des Unités
CEA	Commissariat à l'Énergie Atomique, Saclay (France)
CEM	Centro Español de Metrología, Madrid (Spain)
CENAM	Centro Nacional de Metrología, Mexico (Mexico)
CETIAT	Technical Centre for the Heating, Ventilation and Air Conditioning Industries/Centre Technique des Industries Aérauliques et Thermiques, Villeurbanne (France)
CGGTTS	CCTF Group on GPS Time-Transfer Standards
CGPM	General Conference on Weights and Measures/ Conférence Générale des Poids et Mesures
CHMI	Czech Hydrometeorological Institute, Prague (Czech Republic)
CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, Madrid (Spain)
CIML	International Committee of Legal Metrology/ Comité International de Métrologie Légale
CIPM	International Committee for Weights and Measures/ Comité International des Poids et Mesures
CLEO	Conference on Lasers and Electro Optics
CMS-ITRI	Centre for Measurement Standards of the Industrial Technology Research Institute (Chinese Taipei)
CNAM*	Conservatoire National des Arts et Métiers, Paris (France), see LNE

CNES	Centre National d'Études Spatiales, Toulouse (France)
CNRS	Centre National de la Recherche Scientifique, Paris (France)
CONICET	Argentine Council of Research
COOMET	Cooperation in Metrology among the Central European Countries
COPUOS	Committee on the Peaceful Uses of Outer Space of the United Nations
CPEM	Conference on Precision Electromagnetic Measurements
CROSQ	CARICOM Regional Organization for Standards and Quality
CSIR-NML	Council for Scientific and Industrial Research, National Measurement Laboratory, Pretoria (South Africa)
CSTL	Chemical Science and Technology Laboratory, NIST, Gaithersburg (United Sates), see NIST
DFM	Danish Institute of Fundamental Metrology, Lyngby (Denmark)
DTI	Department of Trade and Industry (United Kingdom)
ECNU	East China Normal University, Shanghai (China)
EFTF	European Frequency and Time Forum
EIM	Hellenic Institute of Metrology, Athens (Greece)
ENEA	Ente per le Nuove Tecnologie, l'Energia e l'Ambiente, Rome (Italy)
ESA	European Space Agency
EUROMET	European Collaboration in Measurement Standards
FAO	Food and Agricultural Organization of the United Nations
GAWG	CCQM Working Group on Gas Analysis
GREX	Groupe de Recherche du CNRS: Gravitation et Expériences
GT-RF	CCEM Working Group on Radiofrequency Quantities
GUM	Central Office of Measures/ Glówny Urzad Miar, Warsaw (Poland)
IAC	International Avogadro Coordination Committee
IAEA	International Atomic Energy Agency
IAG	International Association of Geodesy
IAU	International Astronomical Union
ICAG	International Conference of Absolute Gravimeters
ICRM	International Committee for Radionuclide Metrology
ICRU	International Commission on Radiation Units and Measurements
IEC	International Electrotechnical Commission

IEEE	Institute of Electrical and Electronics Engineers, Piscataway, NJ (United States)
IEN	Istituto Elettrotecnico Nazionale Galileo Ferraris, Turin (Italy)
IERS	International Earth Rotation and Reference Systems Service
IFCC	International Federation of Clinical Chemistry and Laboratory Medicine
IGLOS-PP	International GLONASS Service Pilot Project
IGN	Institut Géographique National, Saint-Mandé (France)
IGS	International GNSS Service
IKZ	Institute of Crystal Growth/Institüt fur Kristallzüchtung, Berlin (Germany)
ILAC	International Laboratory Accreditation Cooperation
IMEKO	International Measurement Confederation
IMGC	Istituto di Metrologia G. Colonnetti, Turin (Italy)
INETI	Instituto Nacional de Engenharia e Technologia Industrial, Lisbon (Portugal)
ININ	Instituto Nacional de Investigaciones Nucleares, Mexico (Mexico)
INM*	Institut National de Métrologie, see LNE-INM
INM	National Institute of Metrology, Bucharest (Romania)
INMETRO	Instituto Nacional de Metrologia, Normalizaçao e Qualidade Industrial, Rio de Janeiro (Brazil)
INPL	National Physical Laboratory of Israel, Jerusalem (Israel)
ION	Institute of Navigation, Alexandria, VA (United States)
IOP	Institute of Physics, London (United Kingdom)
IOPP	Institute of Physics Publishing, London (United Kingdom)
IPGP	Institut de Physique du Globe de Paris, Paris (France)
IRA	Institut de Radiophysique Appliquée, Lausanne (Switzerland)
IRD*	see LNMRI
IRD	Institut de Recherche pour le Développement, Paris (France)
IRMM	Institute for Reference Materials and Measurements, European Commission
ISO	International Organization for Standardization
ISO CASCO	International Organization for Standardization, Conformity Assessment Committee
ISO REMCO	International Organization for Standardization, Committee on Reference Materials
ITN	Instituto Tecnológico e Nuclear, Sacavém (Portugal)

ITU	International Telecommunication Union
IUPAC	International Union of Pure and Applied Chemistry
IUPAP	International Union of Pure and Applied Physics
IVS	International VLBI Service
JCGM	Joint Committee for Guides in Metrology
JCRB	Joint Committee of the Regional Metrology Organizations and the BIPM
JCTLM	Joint Committee for Traceability in Laboratory Medicine
JILA	Joint Institute for Laboratory Astrophysics, Boulder, CO (United States)
KCWG	Key Comparison Working Group
KRISS	Korea Research Institute of Standards and Science, Daejeon (Rep. of Korea)
LGC	Laboratory of the Government Chemist, Teddington (United Kingdom)
LNE	(former BNM) Laboratoire National de Métrologie et d'Essais, Paris (France)
LNE-CNAM	Bureau National de Métrologie, Conservatoire National des Arts et Métiers, Paris (France)
LNE-INM	Bureau National de Métrologie, Institut National de Métrologie, Paris (France)
LNE-LNHB	Bureau National de Métrologie, Laboratoire National Henri Becquerel, Gif-sur-Yvette (France)
LNE-SYRTE	Bureau National de Métrologie, Systèmes de Référence Temps Espace, Paris (France)
LNHB*	Laboratoire National Henri Becquerel, see LNE
LNMRI	Laboratório Nacional de Metrologia das Radiaçoes Ionizantes, Rio de Janeiro (Brazil)
LNMRI/IRD	Laboratório Nacional de Metrologia das Radiaçoes Ionizantes, Instituto de Radioproteção e Dosimetria, Rio de Janeiro (Brazil)
MAC	UK Department of Trade and Industry Measurement Advisory Committee
METAS	Swiss Federal Office for Metrology and Accreditation (Switzerland), renamed Federal Office of Metrology
MRA	Mutual Recognition Arrangement
MST	Foundation for the Promotion of Material Science and Technology of Japan (Japan)
NAB	National Accreditation Body
NCM	National Centre of Metrology, Sofia (Bulgaria)

NCSLI	National Conference of Standards Laboratories, Boulder, CO (United States)
NEN	Nederlands Normalisatie-Instituut, Delft (Netherlands)
NERI	National Environmental Research Institute, Roskilde (Denmark)
NEWRAD	New Developments and Applications in Optical Radiometry Conference
NIBSC	National Institute for Biological Standards and Control, London (United Kingdom)
NIES	National Institute for Environmental Studies, Tsukuba, Ibaraki (Japan)
NIH	National Institutes of Health, Bethesda (United States)
NILU	Norwegian Institute for Air Research, Kjeller (Norway)
NIM	National Institute of Metrology, Beijing (China)
NIMT	National Institute of Metrology, Bangkok (Thailand)
NIST	National Institute of Standards and Technology, Gaithersburg, MD (United States)
NMi VSL	Nederlands Meetinstituut, Van Swinden Laboratorium, Delft (Netherlands)
NMI	National Metrology Institute
NMIA	National Measurement Institute, Australia, Lindfield (Australia)
NMIJ/AIST	National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology, Tsukuba (Japan)
NML	National Metrology Laboratory, Dublin (Ireland)
NPL	National Physical Laboratory, Teddington (United Kingdom)
NRC	National Research Council of Canada, Ottawa (Canada)
NRCCRM	National Research Centre for Certified Reference Materials, Beijing (China)
NTSC	National Time Service Centre, Lintong (China)
OAWG	CCQM Working Group on Organic Analysis
OIML	International Organization of Legal Metrology/ Organisation Internationale de Métrologie Légale
OMH	Országos Mérésügyi Hivatal/National Office of Measures, Budapest (Hungary)
OMP	Observatoire Midi-Pyrénées, Toulouse (France)
OP	Observatoire de Paris (France)
ORB	Observatoire Royal de Belgique, Brussels (Belgium)

PTB	Physikalisch-Technische Bundesanstalt, Braunschweig and Berlin (Germany)
PTTI	Precise Time and Time Interval Applications and Planning Meeting
RC	Radioisotope Centre, Otwock (Poland)
RCMAM	IAU Working Group on Relativity in Celestial Mechanics, Astrometry and Metrology
RMO	Regional Metrology Organization
SCL	Standards and Calibration Laboratory (Hong Kong)
SIM	Sistema Interamericano de Metrología
SMD	Service de la Métrologie, Brussels (Belgium)
SMU	Slovenský Metrologický Ústav/Slovak Institute of Metrology, Bratislava (Slovakia)
SP	SP Sveriges Provnings- och Forskningsinstitut/Swedish National Testing and Research Institute, Borås (Sweden)
SPRING	Standards, Productivity and Innovation Board, Singapore (Singapore)
SSDL	Secondary Standards Dosimetry Laboratories
SYRTE*	Bureau National de Métrologie, Systèmes de Référence Temps Espace, see LNE
TC	Technical Committee
UN	United Nations
USNO	U.S. Naval Observatory, Washington DC (United States)
VERMI	Virtual European Radionuclide Metrology Institute
VNIIFTRI	All-Russian Research Institute for Physical, Technical and Radiophysical Measurements, Rostekhregulirovaniye of Russia, Moscow (Russian Fed.)
VNIIM	D.I. Mendeleyev Institute for Metrology, Rostekhregulirovaniye of Russia, St Petersburg (Russian Fed.)
VSL*	Van Swinden Laboratorium, see NMi VSL
WADA	World Anti-Doping Agency
WG	Working Group
WGAC	CCM Working Group on the Avogadro Constant
WGLF	CCEM Working Group on Low-frequency Quantities
WHO	World Health Organization
WMO	World Meteorological Organization
WMO-GAW	World Meteorological Organization, Global Atmospheric Watch Programme, Geneva (Switzerland)
ZMDM	Bureau of Measures and Precious Metals, Belgrad (Serbia and Montenegro)

2 Acronyms for scientific terms

CCC	Cryogenic Current Comparator
CMC	Calibration and Measurement Capabilities
CRM	Certified Reference Material
DAD	Diode Array Detection
DSC	Differential Scanning Calorimetry
EAL	Free Atomic Time Scale/Échelle Atomique Libre
FID	Flame Ionization Detector
FTIR	Fourier Transform Infrared Technique
GC	Gas Chromatography
GLONASS	Global Navigation Satellite System
GLS	Generalized Least Square
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GPT	Gas-phase Titration
GUM	Guide to the Expression of Uncertainty in Measurement
IT	Information Technology
ITS-90	International Temperature Scale of 1990
JAVS	Josephson Array Voltage Standard
KCDB	BIPM Key Comparison Database
KCRV	Key Comparison Reference value
LC	Liquid Chromatography
LC-DAD	Liquid chromatography with UV diode array detection
MeP	*Mise en Pratique*
MFC	Mass Flow Controller
MS	Mass Spectrometry
NMR	Nuclear Magnetic Resonance
PRT	Platinum Resistance Thermometer
PSD	Position-sensitive Detector
QED	Quantum Electronic Device
QMS	Quality Management System
QS	Quality System
SI	International System of Units/Système International d'Unités
SINIS	Superconductor-insulator-normal metal-insulator-superconductor
SIR	International Reference System for gamma-ray emitting radionuclides/Système International de Référence pour les mesures d'activité d'émetteurs de rayonnement gamma
SIS	Superconductor-insulator-superconductor
SQUID	Superconducting Quantum Interference Device

SRP	Standard Reference Photometer
TA	Atomic Time/Temps Atomique
TAI	International Atomic Time/Temps Atomique International
TT	Terrestrial Time
TTL	Transistor-transistor Logic
TWSTFT	Two-way Satellite Time and Frequency Transfer
UTC	Coordinated Universal Time
UV	Ultraviolet
VIM	International Vocabulary of Basic and General Terms in Metrology
VLBI	Very Long Baseline Interferometry
YAG	Yttrium Aluminium Garnet

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