

## News from the BIPM—2004

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## INTERNATIONAL REPORT

# News from the BIPM—2004

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**Introduction**

Each year, the Director of the BIPM provides a review of the activities and of the Metre Convention for readers of *Metrologia*. This year is, of course, no exception, but in introducing this review I wanted to comment first on the diversity of our activities and the pressures we are under. We were originally created to be a scientific institution with responsibility for the coherence of the world's measurement system. Initially, this focused strongly on length and mass, but over the first 30 or so years of its life BIPM's technical work grew steadily to cover temperature and electricity and photometry. Ionizing radiation and time came much later, and an activity in chemical metrology has been with us for only about five years. The scientific programme is ever-changing with large areas disappearing as BIPM's job is done, but being replaced by new projects designed to meet the needs of today's metrology community.

The BIPM is accustomed to change—something that makes it a lively and interesting place in which to work as well as keeping us on our scientific toes. Scientific work is at the heart of what we do, and gives us a technical credibility, but it is far from all we do. Progressively, General Conferences have recognized the need to respond to the metrological needs in new areas through Joint Committees or through Working Groups of existing Consultative Committees. The CIPM MRA (International Committee of Weights and Measures Mutual Recognition Arrangement) is a major activity for us as well as for national metrology institutes (NMIs) and others from the worldwide metrology community. This coordinating work of the BIPM—much appreciated, we are told, by Member States—is stretching BIPM's resources to the limit and is diverting effort away from some of the high priority technical projects voted for by the last General Conference. The next few years will be critical for us as we balance our limited resources against a large and expanding programme of work. In addition, we must soon begin preparing reports and position papers for the CIPM on our next programme of work, and budget proposals for the 23rd General Conference on Weights and Measures (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 that outstrip our current resources. I am, therefore, interested in the views and opinions from NMIs and elsewhere as we prepare for CGPM 2007.

**A review of the year**

2004 saw an increase in the activities of the BIPM in scientific terms as well as the number of meetings of Consultative Committees, Joint Committees and Workshops. This growth, fuelled substantially by the expanding work of the CIPM MRA and our collaborations with other international and intergovernmental bodies, is consistent with the orientations for our work discussed by the 22nd General Conference of Weights and Measures which I reported in the last 'News from the BIPM' (2004 *Metrologia* 41 99–108).

We are especially pleased by the progress of work in laboratory medicine under the Joint Committee for Traceability in Laboratory Medicine (JCTLM). This programme is now well on the way to creating 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, and to identifying best practice in the validation of measurement methods by competent laboratories. We were very grateful for the offer from the International Federation of Clinical Chemistry to share the costs of the JCTLM Secretariat at the BIPM, and look forward to further developments in partnership with them and the third partner in JCTLM, the International Laboratory Accreditation Conference (ILAC).

BIPM's collaboration with the accreditation community continues to develop positively. ILAC and BIPM share a common interest in, and responsibility for, the world's 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 by a National Accreditation Body (NAB) which is a signatory to the ILAC Arrangement.

The CIPM MRA and the ILAC Arrangement are complementary and mutually supportive, and their unique combination helps to provide confidence in the equivalence of SI traceable measurements worldwide. This infrastructure is increasingly recognized as providing the technical basis for consistency of measurements and their acceptance in international trade, and

its use can help reduce or eliminate Technical Barriers to Trade. These points were made strongly in a presentation to a workshop held by the World Trade Organization's Committee on Technical Barriers to Trade last June.

The Joint Committee for the Regional Metrology Organizations (RMOs) and the BIPM (the JCRB) met in May and in October 2004. At its second meeting it also held a special workshop on quality system assessment processes in the RMOs at the same time as a meeting of the Directors of NMIs from Member States of the Metre Convention and Associates of the CGPM. The JCRB has focused 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 concerned to complete this process before the deadline so as to ensure their Calibration and Measurement Capabilities (CMCs) are not removed from the Key Comparison Data Base (KCDB). 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 Directors' meeting dealt largely with matters that 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 the International Organization for Standardization (ISO). The meeting concluded with a presentation by the Secretary-General of ISO, Alan Bryden.

The JCRB and Directors' meetings also endorsed the importance of a joint statement by BIPM and ILAC on the roles and responsibilities of NMIs and National Accreditation Bodies (NABs). Although the concept of accreditation initially grew from within the NMI community, various organizational and other changes may have created a separation that could lead to less collaboration and exchange of the information than is necessary to ensure an integrated approach to national metrology systems. The BIPM and ILAC are, therefore, currently developing a joint statement on the roles of NMIs and NABs and will be presenting it to the first ever meeting of RMOs and Regional Accreditation Bodies at the BIPM in March 2005. BIPM will also be working with ILAC and the International Organization of Legal Metrology (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.

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/IEC17025 system or a system based on ISO9001.

BIPM's Photometry and Radiometry group finally closed its doors in the summer 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 sections. In Ionizing Radiation, 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 some silicon spheres as part of the International Avogadro Project, and there have been a number of important publications about the FB2 balance and on air density. With colleagues in the Chemistry section and in a number of NMIs, they 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. Our colleagues in the Time section have tackled the difficult subject of uncertainty in UTC and have maintained a successful series of comparisons of GPS receivers. The Database and IT teams have improved the KCDB, have published a newsletter and have earned themselves well-deserved compliments from all over the world.

In the Publications section, the web continues to be our major vehicle for publicity. The team has developed our website, and is planning several innovations during 2005 as well as a number of major publications and reports of key conferences and meetings. *Metrologia* continues to attract new subscribers under our partnership with Institute of Physics Publishing.

On a personal front, I have spent a considerable amount of time during my first year as Director, representing the BIPM externally, in particular attending three General Assemblies of the RMOs. BIPM's first links are with the NMIs and the RMOs, and without them it clearly would be impossible to achieve our mission of worldwide consistency of measurement. I welcomed the chance to report on our work to these General Assemblies, and to make high-level contacts on behalf of Metre Convention Members and Associates.

The CIPM held its usual meeting in October and, this year, focused on our links with ILAC and OIML as well as dealing with a number of important issues that 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. The CIPM launched a number of studies and reviews that will help it formulate a response to this proposal at its next meeting. CIPM also reviewed the near-to-final draft of the 8th edition of the *SI Brochure* and commented on the supplements to the *GUM* and the next edition of the *VIM*. We expect publication of all three documents during 2005. At the CIPM we welcomed Professor Ernst Göbel in his new role as President as well as three new members, Dr Luc Erard (Bureau National de Métrologie (BNM), France), Dr Kim Carneiro (Danish Institute for Fundamental Metrology, Denmark) and Dr Hratch Semerjain (National Institute of Science and Technology (NIST), USA),

During 2004, we were pleased to welcome Costa Rica, Jamaica and Vietnam as Associates of the CGPM and all

have now signed the CIPM MRA, so bringing the number of institutes and designated organizations committed to the CIPM MRA to nearly 150.

2004 has also been a year in which several NMIs have seen turbulent times, mergers and, in the case of Australia, the creation of a new NMI from two existing organizations. Similar events are taking place in Italy and France as their national structures change. We are grateful for the support of the NMI community and the Governments of the Member States and Associates. You are our stakeholders and our ‘customers’; without you we would not survive, nor would we be able to work towards our—and your—mission. The BIPM will continue to do its best to meet the needs of the NMI community and to drive forward an active and innovative agenda for world metrology.

In what follows, the work of all the sections is reviewed in greater depth. A full report can be found in the Director’s report, which can be found on the BIPM website, [www.bipm.org](http://www.bipm.org).

### **On the relationship between national metrology institutes (NMIs) and nationally recognized accreditation bodies (NABs)**

#### *Recommendation (CI-2004)*

The International Committee for Weights and Measures, **considering that**

The 22nd General Conference on Weights and Measures, in its Resolution 11

welcomed the recent CIPM–ILAC Memorandum of Understanding between the International Committee for Weights and Measures and the International Laboratory Accreditation Cooperation (ILAC) and called upon:

- all accreditation organisations to recognise that NMIs and accredited calibration laboratories together provide an indispensable route to traceability to the SI and hence to reliability in measurements and worldwide comparability of measurement results for the whole economy and society and that they should work closely together and

recommended

- that Member Governments of the Metre Convention ensure that an appropriate relationship exists between NMIs and NABs and
- that this relationship fosters collaboration on matters concerning traceability of measurement results and ensures effective and complementary actions under the CIPM MRA and the ILAC arrangement;

#### **noting**

- that NMIs provide the essential technical information to ensure the existence of effective national measurement systems as the route to traceability to the SI
- that recent developments, including those in documentary standards, are leading to an undue separation of some NMIs and some NABs

#### **recommends**

- that NMIs and NABs work closely together to ensure that this essential technical exchange takes place; and
- that appropriate safeguards are put in place to ensure impartiality

#### **and further notes**

that nothing in this recommendation or in resolution 11 of the 22nd General Conference on Weights and Measures implies a particular model for a relationship between an NMI and an NAB.

### **A report of BIPM’s work July 2003–July 2004**

#### *Length*

The Length section has successfully carried out two ‘campaigns’ of femtosecond comb-based laser calibrations, as a result of which we have found ways of improving the realization of the metre using traditional 633 nm lasers. The value attached by the international community to our comparison and calibration activity was evident from the enthusiastic support of the Consultative Committee for Length (CCL) for a new key comparison in the area. This has now been launched as BIPM.L-K11 and will incorporate a wider range of laser sources than before. It will also encompass comparisons carried out by the RMOs.

The major achievement during the year was undoubtedly the work, published in *Science*, on the limitations of combs in frequency comparisons and in relating optical and microwave frequencies. The paper reported that agreement between comb measurements can reach the  $10^{-19}$  level, so opening up the possibility of direct comparisons between optical and microwave clocks with measurement uncertainties that should not be dominated by the measurement process. The paper attracted considerable attention from the technical press. Our efforts to measure the 3.39  $\mu\text{m}$  methane-stabilized laser have been hampered by reference laser problems but the necessary improvements are now nearing completion and we hope to be able to report a comb-based value for the frequency within the next year.

Our development of compact lasers for use in the BIPM watt balance, calculable capacitor and gravimeter is showing very satisfactory performance and we are discussing their possible commercial exploitation.

The meeting of the CCL in September 2003 was preceded by a meeting of the Working Group on the *Mise en Pratique*, which made a partial revision of the recommended radiations list (Recommendations CCL 2a, b, c) and by a meeting of a Joint Working Group CCL/CCTF (Consultative Committee for Time and Frequency). This Joint Working Group set the criteria for radiations to be considered as secondary representations of the second and, at a later meeting, recommended a value for the microwave rubidium transition as a possible secondary representation of the second. It expects to consider more candidates, probably from the optical region, at its next meeting.

#### *Mass*

Six new prototype kilograms (Nos 86 to 91) have been manufactured and their mass stability has been studied over

several months. This work at last removes the backlog of longstanding orders for new prototypes. We continue to support the worldwide effort to redetermine the Avogadro constant. In addition, staff resources from the Mass section have been redirected to the BIPM watt balance project. We have carried out calibrations of four national prototype kilograms and have introduced a new calibration service for the volume magnetic susceptibility of artifacts used with the BIPM susceptometer. In the midst of these activities, we have introduced a Quality System for all calibration services and have undergone a successful peer review.

### Time

The automated calculation procedure applied for International Atomic Time (TAI) has shortened the delay in the publication of *Circular T* and has rendered the complete process more reliable. Starting in March 2004, the Type A and Type B uncertainties of TAI time links are published in *Circular T*. The medium-term stability of TAI, expressed in terms of an Allan deviation, is estimated to be about  $0.6 \times 10^{-15}$  for averaging times of 20 d to 40 d. The accuracy of TAI is based on the data from nine primary frequency standards that include, at present, five caesium fountains (IEN CSF1, BNM-SYRTE FOM, BNM-SYRTE FO2, NIST-F1 and PTB CSF1). The scale unit of TAI has been estimated to match the SI second to within  $2 \times 10^{-15}$  since July 2003. An important part of the activity of the section deals with studies of time and frequency comparison using navigation satellite systems. The network of international time links, which classically relied only on the Global Positioning System (GPS) common-view technique based on C/A-code measurements obtained from one-channel receivers, has been enriched with the addition of new techniques of clock comparison. As a conclusion of the pilot experiment to test the use in TAI links of dual-frequency P-code measurements from geodetic type GPS receivers, four of these links have been incorporated into TAI. The number of GPS multi-channel receivers has increased in the past year, and the TWSTFT (two-way satellite time and frequency transfer) observations in Europe and North America are now performed on a daily and sometimes sub-daily frequency. Calibration programmes of GPS receivers have been organized and run by the section, with almost 50% of the receivers participating in TAI having been 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 (United States) jointly provide the Conventions Product Centre of the International Earth Rotation Service (IERS) with the responsibility for establishing conventions for space-time reference systems; the 'IERS Conventions (2003)' have been published. Other research subjects are pulsars, future clocks in space and atom interferometry.

As a part of the activities of the Conventions Product Centre of the IERS, a position of visiting scientist for one year has been provided at the BIPM. Dr Jim Ray (US National Geodetic Survey) benefited from this position from 1 September 2003 until September 2004.

### Electricity

This has been an eventful year for the Electricity section, especially with the arrival in the section of three colleagues from the Photometry and Radiometry section and the beginning of two major projects, the watt balance and the calculable capacitor, described in another section of this report. Another important event was the successful establishment of the Quality System that included external audits by some of the world's foremost experts in the fields of voltage, resistance and capacitance metrology. As an aid for setting priorities in the work of the section, we have circulated a questionnaire to NMIs concerning their intention to participate in possible future BIPM direct comparisons of Josephson standards. Of the 36 specialists polled, 34 responded to the questionnaire and 32 expressed a wish to participate in a BIPM comparison. These results show a remarkable level of interest in this BIPM activity. Highlights of the technical activities of the year include the successful testing of the programmable array given to us by the Physikalisch-Technische Bundesanstalt (PTB). We compared voltages of two segments of this array with themselves as well as the voltage across all segments with an array of SIS junctions and found no significant differences to within a standard uncertainty of 0.1 nV. Also, in the area of voltage metrology we participated in a EUROMET comparison of Josephson standards at 1.09 V and obtained agreement within 0.07 nV with a standard uncertainty of 0.16 nV. This provides a solid link between the ongoing BIPM key comparisons of Josephson standards and the EUROMET comparison results. In the area of impedance metrology, we have made advances in realizing and testing series and parallel combinations of quantum Hall effect devices.

The Electricity section has also developed a method of extending the frequency range of our most accurate capacitance measurements to cover the interval from 500 Hz to 6000 Hz through the use of a quadrature bridge containing resistors of known frequency dependence and using divider ratios between 1/4 and 4/1. Our investigations of noise in dc measurements clearly demonstrate that polarity reversal does not affect 1/f noise. We have also verified the accuracy of our calculations of the spectral density and Allan variance from noise voltage measurements by showing that the spectral density agrees to within a few per cent with the Nyquist expression for thermal noise in a room temperature resistor. Our collaboration with the NIST now includes the characterization of the noise in measurements of 25 Zener-based voltage standards with an array of Josephson junctions and a digital voltmeter. The results agree with a noise model containing two spectral terms, white and 1/f noise, and confirm trends observed in some earlier BIPM work that indicate significant lower noise in certain Zeners. We have had some interesting results using a new scheme to deduce temperature coefficients of Zeners using very low-frequency temperature modulation.

The activities of the section now cover the work on thermometry that was transferred from Photometry and Radiometry. The measurements for the Consultative Committee for Thermometry (CCT) key comparison of water triple point cells were finished in July 2003, with the exception of one additional cell which was provided later as a replacement for a cell with unsatisfactory behavior. In total, 20 laboratories participated in this comparison, underlining

the great importance of the water triple point as defining the SI unit of temperature, the kelvin. The results of this new comparison (CCT-K7) are of a much better quality than those of the previous comparison as we have made substantial improvements to our instrumentation. The report is currently in preparation.

The cooperative project with the NMIJ/AIST on the thermodynamic temperature determination of metal–carbon eutectic alloys was limited to one year as a consequence of the closure of the Radiometry and Photometry section. Metal–carbon eutectics are candidates for high-temperature fixed points in a future temperature scale. In spite of the short time, the feasibility of all necessary steps of the project was demonstrated. A new technique for the characterization of optical defects of the imaging system was developed.

### *Ionizing radiation*

We have replaced the medium-energy x-ray tube after 30 years' service and the reference beams are being re-established. New high-voltage dividers have been constructed and installed on both x-ray facilities. A Compton x-ray spectrometer is being set up to confirm simulated mammography spectra prior to the completion of two comparisons. Verification of the correction factors (experimental and calculated) for the 250 TBq  $^{60}\text{Co}$  beam is progressing and a new water phantom has been constructed. The accurate measurement of specific heat capacity is underway for the core of the new graphite calorimeter standard for absorbed dose. Following the implementation of Monte Carlo calculated correction factors for the BIPM x-ray air kerma standards, the results for 23 comparisons are now published in the KCDB. Two new dosimetry comparisons have been made and 32 national secondary standards have been calibrated.

We have successfully implemented the quality system for calibrations and an external expert has audited this. In the radionuclide field, six key comparisons are underway with measurements just beginning for the  $^{125}\text{I}$  comparison, reports being written for the  $^{241}\text{Am}$ ,  $^{54}\text{Mn}$  and  $^{65}\text{Zn}$  comparisons, and draft reports already circulating for the  $^{192}\text{Ir}$  and  $^{90}\text{Y}$  comparisons. The BIPM radionuclide measurement facilities, particularly the electronics, are being updated to cope with this increased workload. In addition to several CCRI(II) comparison ampoules, six laboratories have submitted eight different radionuclides to the International Reference System (SIR) this year. In the last twelve months, a further 31 SIR comparison reports have been published in the KCDB. In addition to the reports in progress for the remaining eight ongoing comparisons, a further two new radionuclide comparisons and ten updates are in progress. Collaboration continues with the NPL on the SIR efficiency curves to improve the mathematical model and reduce the uncertainties. Impurity activity levels were measured using the BIPM Ge(Li) gamma spectrometer for seven radionuclides submitted for various comparisons.

### *Chemistry*

The last General Conference endorsed the priority we attach to chemistry and two additional staff have been recruited, although they will join us just after the end of the formal

period covered by this report. Their main area of activity will be in organic chemistry as part of the pure material reviews endorsed by the Consultative Committee for Amount of Substance (CCQM).

Until recently, therefore, the main focus of the section's work has been on gases. This has proved to be remarkably successful and good progress has been made with a relatively small team. The BIPM is coordinating the ozone reference standard comparison (CCQM-P28). Fourteen laboratories have participated in the comparison since July 2003, and a further 13 laboratories are expected to participate. An informal comparison of the newly acquired ozone reference standard of the Istituto di Metrologia G Colonnetti with the BIPM-SRP27 reference standard has also been performed. A collaboration with the Bundesanstalt für Materialforschung und –prüfung has been initiated to develop the use of a generalized least-squares method to develop expressions for the degree of equivalence of ozone reference standards.

The construction of BIPM-SRP33, in collaboration with the NIST, was completed at the BIPM in July 2003. The instrument has been used to investigate possible sources of bias in standard reference photometer (SRP) measurements. The accuracy of the temperature measurement in the SRP has been evaluated, and biases that were found have been removed by the development and installation of a temperature control unit to equilibrate gas cell temperatures within the instrument. We have also investigated the pressure difference in the gas cells of SRPs and the effect of optical design on the optical path length. Modified optical window holders have been designed and constructed, allowing confirmation of the effect of multiple reflections within the gas cells. A feasibility study on the incorporation of a laser-based light source into the SRP has been completed.

A primary gas standard facility for the dynamic preparation of nitrogen dioxide gas standards is being developed. The new system has been tested, and analysis of the Allan variance of time series measurements has confirmed that it now meets the required stability specifications. The completed facility will ultimately act as a primary reference for  $\text{NO}_2$  mass fraction measurements for gas-phase titration.

A gas-phase titration (GPT) facility as a second potentially primary method for ozone concentration measurements has been constructed. Four molblocs have been purchased and are being integrated into the system to allow real-time measurement of gas flow at considerably reduced uncertainty. Validation of the facility is currently underway. It is planned that the redesigned facility will participate in CCQM-P28.

A facility for the comparison of NO gas standards with nominal amount fractions of  $50\ \mu\text{mol/mol}$  has been established. It has been demonstrated that NO gas standards can be analysed with a measurement uncertainty that is of the same order of magnitude as the uncertainty in their value determined from their gravimetric preparation. The completed facility will be used to ensure that the measurements of the amount fraction of NO in the GPT system are traceable to primary gravimetric gas standards. The BIPM has recently proposed a CCQM pilot study for the comparison of NO gravimetric mixtures using the NO facility.

The KRISS together with the Chemistry and Mass sections have published two papers in *Metrologia* describing

the measurement of argon mole fractions in air and their importance to mass metrology ('A redetermination of the argon content of air for buoyancy corrections in mass standard comparisons' by S Y Park, J S Kim, J B Lee, M B Esler, R S Davis and R I Wielgosz 2004 *Metrologia* **41** 387–395; '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' by A Picard, H Fang and M Gläser 2004 *Metrologia* **41** 396–400).

A detailed BIPM work programme in the field of organic pure substances was presented to the CCQM Working Group on Organic Analysis in September 2003 and the CCQM in April 2004.

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. The BIPM has prioritized the requirements in laboratory medicine for pure clinically relevant analytes, which would be required for the establishment of reference measurement systems. The initial period of the programme will focus on the comparison of purity assessments of clinically relevant steroids and therapeutic monitored drugs. The BIPM has established collaborative projects with the Laboratory of the Government Chemist and the NMIJ/AIST to coordinate these comparisons.

The Chemistry section provides the secretariat for the JCTLM. The first meeting of the JCTLM Executive Committee was held at the BIPM, and a JCTLM list of 'higher order reference materials and measurement procedures' has been published on the BIPM's website.

### *Special projects*

Two new projects have been launched with the approval of the General Conference and the CIPM. These are essential to maintain the BIPM as a dynamic organization meeting the changing needs of world metrology. In deciding to start this work, we were able to make a long-term commitment to maintain a calculable capacitor and decided that the time was right for BIPM to embark on a watt balance needed to monitor the international kilogram prototype.

*Calculable capacitor.* This is a cooperative project with the NML-CSIRO and aims at the development of a new advanced version of the calculable capacitor. Two calculable capacitors based on advanced design techniques and improved technology will be constructed by October 2006, with the objective of an uncertainty of 1 part in  $10^8$ . The BIPM workshop has fabricated a measurement jig which will serve to test the quality of the electrode rods of the capacitors fabricated by the NML-CSIRO. Their straightness is fundamental for successful operation of the instruments. BIPM will also contribute an improved interferometer for the measurement of the effective length of the electrodes. We will also develop software for the calculation of the interference patterns in a multi-beam interferometer and for simulation of the effects of misalignments of the optical components. We also plan to include one of BIPM's compact iodine-stabilized modulation-free Nd:YVO<sub>4</sub>/KTP lasers in the optical system.

*Watt balance.* BIPM's approach to the watt balance differs from those in other NMIs as we propose to make simultaneous measurements of the moving and static parts of the classic watt balance, and also to operate with a cryogenic technique that will help reduce some of the errors found in other approaches. We have started to use finite-element analysis to study different forms of the magnetic circuit. A closed, symmetric system with the magnets and the air gap inside the circuit presents several advantages: screening from external magnetic fields, high uniformity of the flux density in the air gap and compact design. We are currently working with a commercial company on the fabrication of the system. Alignment is a critical factor in all watt balances and we are paying close attention to techniques to align the magnet with respect to the local gravitational acceleration and to align the coil with respect to the magnet. Two systems to generate the relative movement of the coil and the magnet were studied: in one case, the magnetic circuit is moved and in the other case the coil. As we plan to carry out the weighing mode and the moving mode simultaneously, we have to move the coil through the magnet while a current is flowing. This entailed an estimation of the effect of eddy currents. At cryogenic temperatures, the related forces are significant but should cancel over a whole cycle of measurement. We have verified that for certain varieties of SmCo magnets the temperature coefficient is very small. This opens up an opportunity for the construction of the magnetic circuit with a much lower temperature coefficient than in existing experiments.

### *Publications and information technology*

The arrangements with IOPP to manage much of the production process for *Metrologia* continue to work well and we now also have a planned programme of special issues reaching out for the next three years. The main event of the year was, however, the launch of the new BIPM website. We have already had a very positive response to the new version and the links provided to the various databases managed by the BIPM. As with many other organizations, the website is our main interface with external users, and we have taken full advantage of the functionality to use it for all papers related to meetings and to the publication of the relevant reports.

In Information Technology, the main server was replaced last year and now offers better performance. In addition, we have introduced a more sophisticated firewall system and enhanced virus protection.

### *The BIPM key comparison database, KCDB*

The work on the KCDB continues as before with the regular updating of Appendix B with reports of key and supplementary comparisons. Some 570 comparisons are now in the database and approximately one new comparison report arrives each week.

The CMC data in Appendix C continue to expand and we are continually checking input data against the JCRB rules and procedures. Modifications to the way in which electricity CMCs were specified have resulted in a simpler and more compact way of specifying uncertainties and the information behind the CMC statement. A particularly important task will be to make sure that CMCs arrive with a statement that they

comply with Quality Systems reviewed by the relevant RMO committee. This assumes greater importance now that the CIPM MRA transition period is at an end.

The KCDB is aimed at external users in NMIs, companies and regulators and so requires continual modification to reflect the needs of users. No major restructuring was needed in 2003–2004; however, several small but significant modifications were needed to increase the functionality and utility of the site for users and those in the RMOs who are responsible for CMC submissions. The internal processes have also been formalized in procedures within the BIPM Quality System, and the KCDB recently passed the internal review.

We are now beginning to promote the KCDB to new users. At the moment, such activity is relatively low key, but several presentations have been made at relevant meetings, and we launched a web-based *KCDB Newsletter* in June 2004.

#### *Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB)*

From its first meeting in 2003, the JCRB has paid particular attention to actions related to the end of the CIPM MRA transition period. RMOs were asked to submit a report on their review and acceptance of Quality Systems in participating NMIs, by 5 April 2004. Discussions on these reports at the 12th meeting of the JCRB, held in Querétaro (Mexico), in May 2004, resulted in a deadline of 31 December 2004 for completion of all Quality System implementations. After this date, all published CMCs that are not supported by a Quality System reviewed and accepted by its RMO and the JCRB will be deleted from Appendix C. A workshop is being planned for 30 September 2004, where the BIPM will present its Quality System and RMOs will make presentations on their procedures to review the Quality Systems of their member NMIs.

With the CMC submissions in thermometry and time and frequency currently undergoing inter-regional reviews, all metrology areas are now participating in the MRA. It is foreseen that after the May 2005 meeting the JCRB activities will become more routine and it may be necessary to reassess the convenience of meeting twice a year.

#### *Quality system*

The first milestone for the introduction of a Quality System compatible with ISO/IEC 17025 has been achieved as planned at the end of 2003 and all measurement services that issue a calibration certificate, including supporting measurement services, have now been internally audited and peer reviewed. In 2004, the KCDB and the Time section were added to the system. The calculation of TAI and the distribution of a stable reference frequency were both successfully audited internally and externally, whereas the KCDB has only been subject to an internal audit. The second round for the yearly internal audits has started.

The 2003 management review gave rise to some action points but concluded that so far the introduction of the system had been very successful.

#### *Liaison with ILAC and ISO*

During the last year, it has become evident that we need to maintain a closer liaison with ILAC and ISO. In particular, we have begun an open exchange of information with ISO and now are represented at the major meetings of the REMCO and CASCO committees. The BIPM now also takes a more active role in a number of ISO working groups, namely on vocabulary, quality in metrology and accreditation issues. The aim is to represent the Metre Convention's position *vis-à-vis* ISO activity, and to alert NMIs and others on any work at ISO that may have an impact on them or the activities of the Convention.

We have also set up a formal joint working group with ILAC in support of the BIPM-ILAC Memorandum of Understanding. The group met in March 2004 at the BIPM. As a result, both organizations will prepare a joint paper on fundamental issues concerning traceability to the SI, and the national and regional roles and responsibilities of NMIs and NABs, reflecting changes in these roles that arise especially from economic pressures. This close collaboration between the two organizations is aimed at dealing with a number of practical issues aimed at improving the effectiveness and transparency of 'national measurement systems', which combine the responsibilities of NMIs and accredited laboratories.

#### **Publications**

During the period July 2003–June 2004 the following have been published:

- *Director's Report on the Activity and Management of the BIPM (2003)*, 2004, **4**, 239 pp.
- *International Committee for Weights and Measures, 92nd meeting (2003)*, 2004, **71**, 157 pp.
- *Annual Report of the BIPM Time Section (2003)*, 2004, **16**, 89 pp.
- *Circular T* (monthly), 7 pp.
- *Metrologia*, issues **40** (4–6) and **41** (1–3).

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 in their original language on the BIPM website. Full bilingual printed versions in French and English no longer appear.

Staff members have published some 70 articles in scientific journals (including 37 reports of key comparisons published in the Technical Supplement of *Metrologia*) and have written 12 BIPM reports; a complete list of these publications may be found in the *Director's Report on the Activity and Management of the BIPM (2004)*, published in January 2005. Copies of these documents may be obtained upon application to the Director, BIPM, Pavillon de Breteuil, F-92312 Sèvres Cedex, France.

#### **BIPM homepage on the worldwide web**

The BIPM homepage can be found at [www.bipm.org](http://www.bipm.org).