

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

Supplement: Ionizing Radiation Department

(1 January 2013 – 31 December 2013)



March 2014

Bureau International des Poids et Mesures

BIPM Ionizing Radiation Department**Director: J.M. Los Arcos****(1 January 2013 to 31 December 2013)****1. X- and γ -rays (D.T. Burns, C. Kessler, S. Picard and P. Roger)****1.1 Dosimetry standards and equipment**

Following the installation of the new ^{60}Co source in the Theratron head in October 2012 and work during 2013 to ensure radiation protection, important modifications were made to the calibration bench for measurements in water and in air, including the design of a new chamber set-up for measurements in air. Beam characterization has continued, aided by the installation of a new laser system, with horizontal and vertical beam profiles measured in air and horizontal profiles in water; these data are used to evaluate correction factors for the non-uniformity of the beam. Reference air-kerma measurements have started using the new primary standard constructed for this beam. The water phantom has been installed and preliminary measurements made using the new and existing (CISbio) reference standards.

A significant development in 2013 was a change in the data acquisition software for all facilities, which until now was based on TestPoint software. New computers were installed and LabVIEW software developed for the seven measurement services – low- and medium-energy x-rays, mammography, radiotherapy-level ^{60}Co (air kerma and absorbed dose), and radioprotection-level ^{60}Co and ^{137}Cs . Validation of the changes and incorporation in the QMS documentation was completed in time for the internal audit in November 2013.

Work on the development and characterization of cavity ionization chambers continues. The standard built in 2012 for absorbed dose to water measurements in the new Theratron ^{60}Co source was tested. A study of the response of transfer chambers in the Theratron beam has started; calibration coefficients for chambers calibrated in the new beam are compared with those determined in the existing reference (CISbio) beam. Two chambers were constructed to a new design, for use as transfer standards in the determination of absorbed dose in medium-energy x-rays. The defining characteristic of these chambers is that they are waterproof and therefore do not require the use of a waterproof envelope. The first of these, with plastic walls, was characterized in ^{60}Co radiation and correction factors determined for orientation, polarity and ion recombination. The second chamber, with graphite walls, remains to be tested.

A sixth comparison was made in the series BIPM.RI(I)-K6. The BIPM equipment was shipped to the NPL (UK) in advance, with the exception of the calorimeter core and ionization chambers which were carried by hand. The comparison measurements were planned for the period 16 September to 4 October 2013 in the 6 MV, 10 MV and 25 MV beams of the Elekta accelerator at the NPL. However, a number of technical problems with the accelerator resulted in an incomplete comparison and the BIPM had to return to complete the measurements from 18 to 22 November. The codes of practice for dosimetry applied in the countries already having participated in the K6 comparison series employ a mass thickness of 10 g cm^{-2} . However, the UK currently follows a code of practice where mass-thicknesses of 5 g cm^{-2} or 7 g cm^{-2} are recommended, depending on the beam energy. For this reason, these depths have been adopted by the NPL and the BIPM has adapted its equipment to these requirements. The BIPM was already equipped for measurements at 5 g cm^{-2} as this configuration is applied for measurements in the BIPM Co-60 reference beam. In order to achieve 7 g cm^{-2} , a graphite plate of well-known density was fabricated to realize the additional mass-thickness of 2 g cm^{-2} . Furthermore, to

allow rapid and regular switching between the beam qualities, this plate was placed in a frame fixed on a sliding carriage. The mass-thickness was easily altered between 5 g cm^{-2} and 7 g cm^{-2} by sliding the frame in and out of the beam. This solution is applicable due to the cancellation of first order effects using ratios, both in the measurement routine as well as in the Monte Carlo calculations.

The preliminary results have been evaluated. Two reports of previous comparisons in the series, with the NIST (USA) and the LNE-LNHB (France) were published in 2013. The report of the comparison carried out at the ARPANSA (Australia) in 2012 is close to completion, having been delayed by the ARPANSA which discovered a problem with its primary standard after the comparison measurements. The method for establishing degrees of equivalence for the BIPM.RI(I)-K6 series, as agreed at the meeting of the CCRI in May was published in 2013. The comparison results have been analysed accordingly, are now available on the KCDB and are updated after each comparison. The calorimeter continues to be used at regular intervals in the BIPM reference ^{60}Co beam, not only for the absolute determination of absorbed dose in this beam but also for quality assurance in BIPM.RI(I)-K6.

Monte Carlo calculations for the absorbed-dose conversion from graphite to water have continued, with calculations being made for the comparisons with the ARPANSA and the NPL using photon spectra supplied by these NMIs; calculations for 6 MV were also made for METAS (Switzerland) before the comparison scheduled for March 2014 was postponed. The calculations for the NPL were for a different reference depth and required new Monte Carlo geometry codes to be constructed. A study of the effect of detector radius on the calculation of $\text{TPR}_{20,10}$ was made in collaboration with the ARPANSA. The results showed that the value used to date ($r = 22.5 \text{ mm}$) was too large; henceforth calculations will be made for $r = 10 \text{ mm}$ and $r = 3 \text{ mm}$ (simultaneously). New calculations with these smaller radii were made for all previous comparisons (NRC, PTB, NIST and LNE-LNHB) in the context of the work on W_a described below.

The project to develop an absorbed-dose standard for medium-energy x-rays, carried forward from the previous programme, has continued. The plan is to base the standard on the existing free-air chamber standard using a set of waterproof transfer standards of different wall materials and shape. As noted above, the first of these chambers, with walls of air-equivalent plastic (C552) and a waterproof outer layer of PMMA, was constructed. Following tests in x-rays, this chamber was found to have a significant leakage current. After detailed investigation, it was deduced that this leakage was due to an unexpected interaction between the C552, which has a polarizing potential of 80 V, and the outer PMMA – the same effect is not present in a graphite chamber subject to the same waterproofing. The solution was to coat the outer PMMA surfaces using a conductive graphite spray. The second chamber, with graphite walls, is ready for testing and preliminary measurements indicate that current leakage should not be a problem.

Also in the context of absorbed-dose for medium energy x-rays, the experiment to test the photon interaction cross-section data (μ -values) used by the simulation code PENELOPE continued with improved calculations. Interestingly, while the calculated values for air (μ_a), graphite (μ_c) and water (μ_w) are each lower than the corresponding measured value by 2 to 4 parts in 10^2 , each of the calculated ratios $\mu_{a,c}$ and $\mu_{a,w}$ agrees with its measured value at the level of around 5 parts in 10^3 (the statistical uncertainty), except at 100 kV where a difference of 1 to 2 parts in 10^2 is observed. This latter effect is considered to be due to μ_a because the calculated ratio $\mu_{w,c}$ agrees with the measured value within the statistical uncertainty of 4 parts in 10^3 for all energies. An improved measurement of μ_a at 100 kV is planned.

Following publication of a global analysis of the W_a -value for ^{60}Co radiation in *Metrologia* in 2012, a paper has been submitted to *Physics in Medicine and Biology* on the W_a value for accelerator photon beams. This work pulls together various elements of the BIPM work programme, including the results of the BIPM.RI(I)-K6 comparisons in the NMI accelerator beams, Monte Carlo calculations and cavity

volume measurements for ionization chambers constructed at the BIPM. The conclusion that there is no evidence for an energy variation for W_a is an important finding that will reduce the uncertainty of clinical reference dosimetry for these beams. A by-product of this work has been a new determination of the I_c -value for graphite, which is in close agreement with the value published by the BIPM in *Metrologia* in 2012. These results will be incorporated into report on Key Data which is being prepared by the International Commission on Radiation Units and Measurements (ICRU).

Primary measurements and reference chamber calibrations have continued in all of the reference x- and γ -ray beams. Comparisons and calibrations are underpinned by a significant effort in equipment calibration and maintenance, as required by the Quality System. This system, which includes new procedures and technical instructions which arose from the update of the data acquisition and storage systems, was subject to a successful internal audit in November 2013.

1.2 Dosimetry comparisons

Three comparisons were carried out in the ^{60}Co gamma radiation beam: one comparison in terms of air kerma with the LNE-LNHB and two comparisons in terms of absorbed dose to water with the LNE-LNHB and METAS. One high-energy absorbed-dose comparison was carried out in the NPL's accelerator beams, as described earlier.

Eleven comparison reports were published in the *Metrologia Technical Supplement*, three reports for the LNE-LNHB, two reports for the NMIJ (Japan), two for the NIST and one each for the GUM (Poland), the ININ (Mexico), the VNIIM (Russian Federation) and the IAEA.

The Summary comparison report for the K5 Cs-137 air-kerma key comparison and the report on degrees of equivalence for the K6 high-energy x-ray beam key comparison were also published in the *Metrologia Technical Supplement*.

1.3 Characterizations of national standards for dosimetry

Forty-two characterizations of national standards were carried out; five in low-energy x-rays for the NMISA (South Africa), NRPA (Norway) and the IAEA, one in mammography x-rays for the NRPA, nine in medium-energy x-rays for the NMISA, the CRRD (Argentina), the NRPA, the IAEA and the LNMRI (Brazil), twenty four in ^{60}Co for the NMISA, the CRRD, the GUM, the NRPA, the IAEA and the LNMRI and three in ^{137}Cs for the NMISA and the NRPA.

The IAEA/WHO dosimetry assurance programme continues to be supported by biannual reference irradiations, which in 2013 involved one series of irradiations for the radiotherapy level in the ^{60}Co beam and one for the radiation-protection level in the ^{137}Cs beam.

2. Radionuclides (J.M. Los Arcos, S. Courte, C. Michotte, M. Nonis and G. Ratel)

2.1 International Reference System (SIR) for γ -ray emitting radionuclides

2.1.1 SIR submissions in 2013

During 2013, the BIPM received seven ampoules filled with seven different radionuclides from four laboratories (i.e. one ampoule each containing ^{57}Co (RC), ^{59}Fe (LNE-LNHB), ^{109}Cd (LNE-LNHB), ^{137}Cs (RC), $^{166\text{m}}\text{Ho}$ (PTB), ^{177}Lu (IFIN) and ^{222}Rn (LNE-LNHB). All the submissions had been made to generate equivalence values in the associated ongoing BIPM key comparisons BIPM.RI(II)-K1.

Measurements of ^{222}Rn , which is a radioactive gas with a short half-life ($T_{1/2} = 3.8235 \text{ d}$, $u = 0.0003 \text{ d}$), were repeated to try and remove a systematic bias detected in the activity determination of this gas. Analysis is presently ongoing.

For the first time the ININ tried to submit three ampoules filled with radioactive solutions of ^{60}Co , ^{137}Cs and ^{241}Am but unfortunately the parcel did not reach the BIPM due to transportation or customs formalities which are being investigated.

Three further ampoules containing ^{14}C , ^{134}Cs and ^{137}Cs from the NRC are expected to be sent before the end of 2013.

2.1.2 SIR Reports and quality assurance

Updated reports of three comparisons were published in the *Metrologia Technical Supplements* covering ^{64}Cu , ^{134}Cs , ^{137}Cs including the linked [COOMET.RI\(II\)-K2.Cs-137](#) comparison. One other report is in circulation. All results prior to 2009 have now been published in the *Metrologia Technical Supplement* except for one which is still to be received from the NMI concerned. To date, all the Draft A reports have been circulated except for 4 results (^{51}Cr , ^{111}Ag , ^{125}Sb , ^{222}Rn) that are still to be received from the NMIs concerned.

There are 40 SIR results awaiting publication in the KCDB and every effort will be made to ensure that reports are published as quickly as possible, particularly when NMIs make submissions that are to replace outdated results already removed from the KCDB.

All the SIR measurements are covered by the BIPM Quality Management System and an internal audit, including the extension to short-lived radionuclides, was carried out on 28 November 2013 by the BIPM Quality, Health and Safety Manager, Mr C. Maggi.

A hand and foot contamination detector has been ordered in response to a recommendation made by the external auditor, Prof. Dr F.O. Bochud from the IRA-METAS (Switzerland), during the last external audit carried out on 21 September 2012. In compliance with the BIPM QMS Manual, an internal audit was carried out in 2013.

2.2 Gamma spectrometry

Routine measurements of potential impurities in SIR ampoules are made using the Ge(Li) and HPGe spectrometers. The Ge(Li) preamplifier failed in July 2013 and attempts to repair it have been unsuccessful to date. The service for measuring activity of impurities in SIR ampoules, when required and following the protocol CCRI(II)/01-01, has thus been temporarily suspended. The service could be restarted when the Ge(Li) is repaired or the HPGe calibrated. However, no time was available to analyse the calibration measurements of the HPGe and the BIPM Ionizing Radiation Department is offering an NMI secondment to collaborate on this project.

The impurity $^{177\text{m}}\text{Lu}$ was identified as expected in the ^{177}Lu submitted to the SIR by the IFIN-HH (Romania). The analysis of these measurements made with the HPGe detector is ongoing. Measurements of several swabs for a leakage test of an SIR ampoule of ^{68}Ge were carried out.

2.3 Extension of the SIR to short-lived radionuclides

The BIPM report which describes the SIRT in detail and the tests made during its development has been finalized and submitted for publication.

The BIPM.RI(II)-K4.Tc-99m ($T_{1/2} = 6.0$ h) key comparison using the SIR Transfer Instrument (SIRTI) is running at a rate of two comparisons per year: the LNMRI-IRD (Brazil) and the IFIN-HH participated in 2013. The results of the comparisons in China, Argentina and Brazil have been published. The VNIIM is the next planned participant. The SIRTI has remained very stable since 2007 even though it is regularly transported around the world, showing a relative standard deviation of 6×10^{-5} for the counting rate of the ^{94}Nb reference source.

The extension of the SIRTI to measure ^{18}F ($T_{1/2} = 1.8$ h) is in development. Stability and reproducibility tests were carried out successfully. Further tests of the electronics are planned before calibration against the SIR. Monte Carlo simulations of the SIRTI response to ^{18}F agree with preliminary measurements within 4×10^{-3} in relative terms. A trial comparison at a European NMI which has already participated in the SIR will be organized. NMIs that expressed an interest in the ^{18}F comparison are the ENEA-INMRI (Italy), NIST, NIM (China), ANSTO (Australia), CNEA (Argentina), IFIN-HH, LNMRI-IRD and the VNIIM.

2.4 Extension of the SIR to pure beta emitters

The analysis of the comparison initiated by the Working Group for the extension of the SIR to the measurement of pure beta emitters has continued. Results obtained for the submissions by the eight participating laboratories (ENEA (Italy), IRMM (EU), LNE-LNHB, NIST, NMISA, NPL, PTB (Germany) and POLATOM RC (Poland)) with the BIPM TDCR system have been evaluated and compared with those obtained with the same technique at the LNE-LNHB.

The results of these measurements were presented together with those obtained using the universal efficiency curves (UEC) during the CCRI(II) meeting held at the BIPM in May 2013 and at the ICRM 2013 Conference held in Antwerp, Belgium, on 17-21 June 2013.

A larger scale exercise involving 19 interested NMIs and the radionuclides ^3H , ^{14}C , ^{55}Fe and ^{63}Ni , was approved by the CCRI(II) in May 2013.

3. Thermometry (S. Picard, M. Nonis)

The Ionizing Radiation Department provides internal calibration services for thermometry at the BIPM, under the BIPM Quality Management System. In June 2012, the BIPM was invited by the Consultative Committee for Thermometry (CCT) to take part in the CCT-K9 comparison which was already under way and piloted by the NIST. For this purpose, the second part of the comparison measurements were carried out at the BIPM in April 2013 after being returned from the NIST.

In 2013, eighteen SPRTs and eight commercial laboratory thermometers belonging to the Electricity, Mass, Time and Ionizing Radiation Departments were calibrated.

4. Publications

External publications

1. Allisy-Roberts P.J., Kessler C., Burns D.T., Summary of the BIPM.RI(I)-K5 comparison for air kerma in ^{137}Cs gamma radiation, Metrologia, 2013, 50, Tech. Suppl., 06001.

2. Andreo P., Wulff J., Burns D.T., Palmans H., Consistency in reference radiotherapy dosimetry: resolution of an apparent conundrum when ^{60}Co is the reference quality for charged-particle and photon beams, *Phys. Med. Biol.*, 2013, **58**, 6593-6621.
3. Burns D.T., Kessler C., Knyziak A.B., Key comparison BIPM.RI(I)-K3 of the air-kerma standards of the GUM, Poland and the BIPM in medium-energy x-rays, *Metrologia*, 2013, **50**, Tech. Suppl., 06003.
4. Kessler C., *Développement et mise en place au BIPM d'un système international de comparaison et d'étalonnage pour la dosimétrie en mammographie*, Ph.D. thesis (LNE-INM/Cnam, La Plaine-Saint-Denis), 2013, 151 pp.
5. Kessler C., Allisy-Roberts P.J., Minniti R., Comparison of the standards for air kerma of the NIST and the BIPM for ^{60}Co gamma radiation, *Metrologia*, 2013, **50**, Tech. Suppl., 06002.
6. Kessler C., Alvarez Romero J.T., Tovar-Muñoz V.M., Key comparison BIPM.RI(I)-K1 of the air-kerma standards of the ININ, Mexico and the BIPM in ^{60}Co gamma radiation, *Metrologia*, 2013, **50**, Tech. Suppl., 06017.
7. Kessler C., Burns D.T., Czap L., Csete I., Gomola I., Comparison of the air kerma standards of the IAEA and the BIPM in mammography x-rays, *Metrologia*, 2013, **50**, Tech. Suppl., 06005.
8. Kessler C., Burns D.T., Delaunay F., Donois M., Key comparison BIPM.RI(I)-K1 of the air-kerma standards of the LNE-LNHB, France and the BIPM in ^{60}Co gamma radiation, *Metrologia*, 2013, **50**, Tech. Suppl., 06018.
9. Kessler C., Burns D.T., Delaunay F., Donois M., Key comparison BIPM.RI(I)-K4 of the absorbed dose to water standards of the LNE-LNHB, France and the BIPM in ^{60}Co gamma radiation, *Metrologia*, 2013, **50**, Tech. Suppl., 06019.
10. Kessler C., Burns D.T., Oborin A.V., Villevalde A.Y., Key comparison BIPM.RI(I)-K7 of the air-kerma standards of the VNIIM, Russian Federation and the BIPM in mammography x-rays, *Metrologia*, 2013, **50**, Tech. Suppl., 06013.
11. Kessler C., Saito N., Kurosawa T., Key comparison BIPM.RI(I)-K1 of the air kerma standards of the NMIJ, Japan and the BIPM in ^{60}Co gamma radiation, *Metrologia*, 2013, **50**, Tech. Suppl., 06006.
12. Kessler C., Saito N., Kurosawa T., Key comparison BIPM.RI(I)-K5 of the air kerma standards of the NMIJ, Japan and the BIPM in ^{137}Cs gamma radiation, *Metrologia*, 2013, **50**, Tech. Suppl., 06007.
13. Michotte C., Nonis M., Liang J.C., Chen J., Liu H.R., Zhang M., Zhao Q., Yang Y.D., Activity measurements of the radionuclide $^{99\text{m}}\text{Tc}$ for the NIM, China in the ongoing comparison BIPM.RI(II)-K4.Tc-99m, *Metrologia*, 2013, **50**, Tech. Suppl., 06010.
14. Michotte C., Ratel G., Courte S., Kharitonov I. A., Zanevsky A. V., Sahagia M., van Wyngaardt W. M., van Staden M. J., Lubbe J., Simpson B. R. S., Maringer F. J. and Brettner-Messler R., Update of the BIPM comparison BIPM.RI(II)-K1.Cs-137 of activity measurements of the radionuclide ^{137}Cs to include the 2007 results of the VNIIM (Russia), the 2009 result of the IFIN-HH (Romania), the 2010 result of the NMISA (South Africa) and the 2011 result of the BEV (Austria), *Metrologia*, 2013, **50**, Tech. Suppl., 06014.
15. Michotte C., Ratel G., Courte S., Maringer F.J., Caffari Y., van Wyngaardt W.M., Update of the BIPM comparison BIPM.RI(II)-K1.Cs-134 of activity measurements of the radionuclide ^{134}Cs to

include the 2008 results of the BEV (Austria), the 2009 result of the IRA (Switzerland) and the 2010 results of the NMISA (South Africa), Metrologia, 2013, 50, Tech. Suppl., 06009.

16. Michotte C., Ratel G., Courte S., Sochorová J., Auerbach P., Keightley J., Johansson L., Bakhshandear E., Cassette P., Moune M., Capogni M. and De Felice P., Update of the BIPM comparison BIPM.RI(II)-K1.Cu-64 of activity measurements of the radionuclide ^{64}Cu to include the 2009 results of the CMI-IIR (Czech Rep.) and the NPL (UK), the 2010 result of the LNE-LNHB (France) and the 2011 result of the ENEA-INMRI (Italy), Metrologia, 2013, 50, Tech. Suppl., 06021.
17. Picard S., Burns D.T., Roger P., Bateman F.B., Tosh R.E., Chen-Mayer H., Key comparison BIPM.RI(I)-K6 of the standards for absorbed dose to water of the NIST, USA and the BIPM in accelerator photon beams, Metrologia, 2013, 50, Tech. Suppl., 06004.
18. Picard S., Burns D.T., Roger P., Delaunay F., Gouriou J., Le Roy M., Ostrowsky A., Sommier L., Vermesse D., Key comparison BIPM.RI(I)-K6 of the standards for absorbed dose to water of the LNE-LNHB, France and the BIPM in accelerator photon beams, Metrologia, 2013, 50, Tech. Suppl., 06015.
19. Picard S., Burns D.T., Los Arcos J.M., Establishment of degrees of equivalence of national primary standards for absorbed dose to water in accelerator photon beams, Metrologia, 2013, 50, Tech. Suppl., 06016.
20. Michotte., Nonis M., Arenillas P., Cerutti G., da Silva C. J., Lima da Cruz P. A., Moreira D. S., Iwahara A., Delgado J. U., Poledna R., da Silva R. L., de Oliveira A. E. and dos Santos Gomes R., Activity measurements of the radionuclide $^{99\text{m}}\text{Tc}$ for the CNEA, Argentina and the LNMRI/IRD, Brazil in the ongoing comparison BIPM.RI(II)-K4.Tc-99m, Metrologia, 2013, 50, Tech. Suppl., 06023.

BIPM publications

1. C. Michotte, M. Monis, C. Bobin, T. Altizoglou, G. Sibbens, The SIRTI : a new tool developed at the BIPM for comparing activity measurements of short-lived radionuclides world-wide, Rapport BIPM-2013/02, 24pp.

5. Activities related to the work of Consultative Committees

J.M. Los Arcos is the Executive Secretary of the CCRI, *ex-officio* member of all CCRI working groups and Coordinator of the CCRI(II) Working Group on the Extension of the SIR to beta-emitters using liquid scintillation (ESWG(II)). During 2013 there were meetings of the CCRI, its three sections, CCRI(I), CCRI(II) and CCRI(III), as well as the ADWG(I), KCWG(II), BqWG(II), TIWG(II), ESWG(II) and KCWG(III).

D.T. Burns is a member of the CCRI(I) Key Comparisons Working Group (KCWG(I)), Accelerator Dosimetry Working Group (ADWG(I)) and Brachytherapy Standards Working Group (BSWG(I)). He is also a member of an *ad hoc* group evaluating the effect of excess charge on the value for W_{air} . Since 2009 he has been *rapporteur* at annual meetings of the CCRI.

C. Kessler is the Coordinator of the CCRI(I) Brachytherapy Standards Working Group (BSWG(I)).

C. Michotte is the coordinator of the CCRI(II) Transfer Instrument Working Group (TIWG(II)), which met in October 2013, and a member of the Key Comparisons Working Group (KCWG(II)) which met in May and October 2013.

G. Ratel is a member of the CCRI(II) Working Group on the Extension of the SIR to beta-emitters using liquid scintillation (ESWG(II)), which met on May 2013 and for which he was the *rapporteur*, the KCWG(II) and the Working Group on the Realization of the becquerel (BqWG(II)), which met in May and October 2013, and the Transfer Instrument Working Group (TIWG(II)) which met in October 2013.

S. Picard is Executive Secretary of the Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV), which held its 9th meeting on 29 to 31 October 2013. She is a member of the CCAUV Working Group for RMO Coordination (CCAUV-RMOWG), the CCAUV Working Group on Strategic Planning (CCAUV-SPWG) and the CCAUV Working Group for Key Comparisons (CCAUV-KCWG), which met on 28-29 October 2013. She is the Interim Acting Executive Secretary of the Consultative Committee for Thermometry (CCT).

6. Activities related to external organizations

J.M. Los Arcos evaluates scientific projects for the Spanish National Evaluation and Foresight Agency (ANEP) and is a technical auditor for the Spanish accreditation body.

D.T. Burns is a Fellow of the Institute of Physics (FInstP) in the UK and elected Commissioner of the ICRU. He is a member of the ICRU Committee on Fundamental Quantities and Units and of the ICRU Report Committee on Key Data for Dosimetry. He is Commission Sponsor for three reports (Key Data for Dosimetry, Operational Quantities for Radiation Protection, and Small and Non-Standard Fields). He is the BIPM representative on the IAEA Secondary Standards Dosimetry Laboratory (SSDL) Scientific Committee.

C. Michotte is the contact person at the BIPM and *rapporteur* for the JCGM-WG1 meetings in May and December 2013.

G. Ratel is the BIPM representative on the International Committee for Radionuclide Metrology (ICRM) and is the President of the ICRM Nominating Committee. He was a member of the Scientific Committee for the 19th International Conference on Radionuclide Metrology and its Applications (ICRM 2013), which was held in Antwerp (Belgium) on 17-21 June 2013. He refereed seven papers presented at the ICRM 2013, and papers for the journals *ARI*, *Cal Lab Magazine*, *NSCLI* and *Metrologia*.

7. Travel (conferences, lectures and presentations, visits)

D.T. Burns to:

- Teddington (UK), 16-20 September 2013, to participate in the BIPM.RI(I)-K6 comparison of absorbed dose to water in accelerator beams with the NPL.
- Paris (France), 8 October 2013, to participate in the 16th International Congress of Metrology and to present a poster entitled "The BIPM Calorimetric Standard for Accelerator Dosimetry".
- Paris (France), 2-4 December 2013, to participate in a meeting of the ICRU Report Committee on Operational Quantities for Radiation Protection, held at the LNE.

S. Picard to:

- St Denis (France), 19 February 2013, to visit the thermometry department of the LNE/INM-Cnam.
- Berlin (Germany), 12 March 2013, to attend the CCT/TG-SI progress meeting at the PTB on the

determination of the Boltzmann constant.

- Berlin (Germany), 13 March 2013, to visit the laboratory on dielectric constant gas thermometry at the PTB.
- Prague (Czech Republic), 10 April 2013, to attend the EURAMET TC-T workshop on thermophysical properties.
- Prague (Czech Republic), 10-12 April 2013, to attend the EURAMET TC-T meeting and to present news from the BIPM and the CCT.
- Teddington (UK), 17 September to 2 October and 18 to 22 November 2013, to carry out the BIPM.RI(I)-K6 comparison of absorbed dose to water in accelerator beams with the NPL.
- Teddington (UK), 30 September 2013, to visit the ultrasound, acoustics and underwater acoustics laboratories at the NPL.
- Teddington (UK), 1 October 2013, to visit the thermometry laboratories at the NPL.
- Paris (France), 8 October 2013, to participate in the International Congress of Metrology in Paris and to give a poster presentation entitled "The BIPM Calorimetric Standard for Accelerator Dosimetry".
- Paris (France), 15 November 2013, to attend an award ceremony at the LNE.
- Teddington (UK), 19 November 2013, to visit the humidity laboratories at the NPL.

G. Ratel to:

- Barcelona, (Spain) 18-22 March 2013, to attend the LSC 2013 conference and to co-chair the session "Radionuclide Metrology using LSC".
- Antwerp, (Belgium) 17-21 June 2013, to attend the 19th International Conference on Radionuclide Metrology and its Applications, ICRM 2013, and to chair the sessions "Aspects of International Metrology" and "Intercomparisons".
- Paris, (France) 8 October 2013, to attend the 16th International Congress of Metrology to give a talk entitled "Some thoughts about the extension of the International Reference System (SIR) to β emitters".
- LNE-LNHB, Saclay (France) 21 November 2013, to attend as an examiner the defence of the "*Habilitation à diriger les recherches*" of Marie-Noëlle Amiot.
- LNE-LNHB, Saclay (France) 5 December 2013, to attend the "*Journées Utilisateurs LNHB*" to make a presentation entitled "*Système International de Référence*".

G. Ratel and C. Michotte to:

- Antwerp (Belgium), 17-21 June 2013, to attend the 19th International Conference on Radionuclide Metrology and its Applications, where G. Ratel made an oral presentation entitled "Pilot study organized in view of using liquid scintillation to extend the SIR to pure beta emitters" and chaired the sessions "Aspects of International Metrology" and "Intercomparisons".

C. Michotte to:

- NPL, Teddington (UK), 7-8 November 2013, to attend a meeting to celebrate the 20th Anniversary of the GUM.
- Bucharest (Romania), 18-22 November 2013, to carry out an activity comparison of ^{99m}Tc (BIPM.RI(II)-K4.Tc-99m) at the IFIN-HH using the SIR Transfer Instrument.

C. Michotte and M. Nonis to:

- Rio de Janeiro (Brazil), 1-8 July 2013, to carry out an activity comparison of ^{99m}Tc (BIPM.RI(II)-K4.Tc-99m) at the LNMRI-IRD using the SIR Transfer Instrument.

8. Visitors

A number of delegations from different countries or organizations visited the Ionizing Radiation Department in 2013:

- M. Gröning, Laboratory Head, Terrestrial Environment Laboratory, Department of Nuclear Sciences and Applications, IAEA, 1 March 2013;
- J. Stenger, PTB Board and EURAMET EMRP Chair, 12 June 2013;
- Delegation from the 102nd meeting of the CIPM: B. Bowsher, H.S. Brandi, K. Carneiro, K.H. Chung, Y. Duan, L. Énard, B. Inglis, R. Kaarls, W. Louw, J.W. McLaren, W.E. May, H. Nava Jaimes, H. Uğur, J. Ullrich, T. Usuda, J. Valdés, T.J. Quinn (Emeritus Director), P. Richard (President of the CCM) A.J. Wallard (Emeritus Director), 20 June 2013;
- L. Pereira Neves and A.P. Perini (IPEN, Brazil), 2 July 2013;
- Saudi Arabia: Mr Khalid Al-Dawood, Supervisor of Time and Frequency Laboratory, Metrology and Quality Organization (SASO), Mr Ahmed Hamed Aljawana, Time and Frequency Laboratory, Metrology and Quality Organization (SASO), Prof. Ramiz Hamid, Head of Time, Frequency and Wavelength Laboratory (TÜBİTAK - UME, Turkey) and Chair of EURAMET Technical Committee for Time and Frequency, 3 October 2013;
- Bangladesh Delegation: Mr Muhammad Musharraf Hossain Bhuiyan, Cabinet Secretary, Mr Mohammad Moinuddin Abdullah, Ministry of Industries, Mr Md Abu Abdullah, Director General, Bangladesh Accreditation Board (BAB), Mr Iqramul Haque, Director General, Bangladesh Standards and Testing Institution, Mr Md Lutfor Rahman Tarafder, Joint Chief, Ministry of Industries and Project director, BQI-BEST, Dr Franz Hengstberger, Technical Advisor, BQI-BEST, 11 October 2013.

9. Guest workers

- H. Bjerke (NRPA, Norway), 16 September 2013,
- L. Czap (IAEA), 14-18 October 2013,
- P. Rosado (LNMRI, Brazil), 21-31 October 2013.