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

Supplement: Ionizing Radiation Department

(1 January 2014 – 31 December 2014)

March 2015

Bureau International des Poids et Mesures

BIPM Ionizing Radiation Department

Director: J.M. Los Arcos

(1 January 2014 to 31 December 2014)

1. X- and γ-rays (D.T. Burns, C. Kessler, S. Picard and P. Roger)

1.1 Dosimetry standards and equipment

The project to develop an absorbed-dose standard for medium-energy x-rays, based on the existing standard for air kerma, has made significant progress. A system for raising and lowering a small water phantom has been developed to allow ionization chambers in water to be set up accurately and rapidly. The transfer standards constructed at the BIPM have been measured in air and in this new water-phantom arrangement over the range of x-ray energies. Corresponding Monte Carlo calculations of the relative response of the chambers under these conditions continue; the first indications are that the target standard uncertainty of 1 % in the determination of absorbed dose is likely to be achieved down to the 100 kV radiation quality.

Work on the development and characterization of cavity ionization chambers continues. Two new graphite-walled cavity standards were built and characterized in the ^{60}Co and ^{137}Cs beams. The standard with graphite walls, which was built in 2013 for use as a transfer standard in the determination of absorbed dose in medium-energy x-rays, was tested and characterized in ^{60}Co radiation.

The Department coordinated the seventh and eighth comparison in the series BIPM.RI(I)-K6 for absorbed dose to water in high-energy photon beams, with the NPL (UK) and the VSL (the Netherlands). The measurements were made in the 6 MV, 10 MV and 25 MV beams of the NPL Elekta accelerator from 23 September to 20 October and the corresponding Monte Carlo calculations (for a depth of 10 g cm^{-2}) were made at the BIPM using photon spectra supplied by the NPL. The BIPM equipment was shipped to the NPL in advance, with the exception of the calorimeter core and ionization chambers which were carried by hand. This comparison enabled the NPL to verify robustly the present UK primary standard to realize absorbed dose to water in accelerator beams. The VSL brought and used its newly-constructed water calorimeter, which is of a unique design, and made a successful determination of absorbed dose to water in the same beams. A problem with one of the BIPM transfer instruments was identified at the beginning of the comparison, but was easily resolved by using a spare chamber. This highlights the value of travelling with a back-up system for key devices, and most key elements now have a spare. This back-up system now includes a second calorimeter core, which is being tested. Substantial modifications to the electronic support have also been made to reduce the number of manual operations it requires.

For these two comparisons which were made in parallel, the BIPM used a remote-controlled motorized monitoring and shutter system for the first time, to reliably track and correct for intrinsic intensity variations in the beams. The new design is compact and showed high reproducibility in the positioning of the shutter. The remotely controlled system avoids staff having to enter the radiation area between irradiations, which improves radiation protection of the operator and saves time. The report of the previous comparison with the ARPANSA, Australia, was published, and a comparison to be carried out with the NMIJ/AIST, Japan, in April 2015 was prepared.

The accumulated data from the BIPM.RI(I)-K6 comparison series and from the work on ionization chamber volume measurements were used for a re-determination of the value for W_{air}, the mean energy required to create an ion pair in air. This important parameter is being reviewed by a report committee of the International Commission on Radiation Units and Measurements (ICRU), which will produce a report on Key Data for

Dosimetry during 2015. The result of the BIPM determination of W_{air} was published in *Physics in Medicine and Biology,* 2014 **59**, 1353-1365.

The comparison series BIPM.RI(I)-K8 for the reference air kerma rate for HDR Ir-192 brachytherapy sources was re-launched. A new protocol was agreed and adopted and the results of previous comparisons were re-analysed following the new protocol. The corresponding comparison reports were produced and published and the KCDB has been updated accordingly. Two new comparisons with the NRC, Canada, and the LNE-LNHB, France, were carried out; the comparison reports are in progress.

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 BIPM Quality System. This system was subject to a successful internal audit in December 2014.

1.2 Dosimetry comparisons

Sixteen comparisons were carried out in the x- and gamma-radiation beams in terms of air kerma with the PTB (4), ENEA (2), BEV (3), NIM (1), NRC (1) and NMIJ (1). Two high-energy absorbed-dose comparisons were carried out in the NPL's accelerator beams with the NPL and the VSL. Two comparisons were carried out in terms of reference air kerma rate for HDR ^{192}Ir brachytherapy sources at the NRC and at the LNE-LNHB.

Fifteen comparison reports were published in the *Metrologia Technical Supplement* for the PTB (5), ENEA (1), BEV (2), VSL (3), NPL (1), ARPANSA (1), NIST (1) and for the METAS (1).

1.3 Characterization of national standards for dosimetry

Fourteen characterizations of national standards were carried out: five for the STUK in low-energy x-rays (1), mammography beams (1) medium-energy x-rays (1) and ^{60}Co (2); eight for the IAEA in the ^{60}Co and ^{137}Cs radiation protection beams and one for the ENEA in the ^{137}Cs radiation protection beam.

The IAEA/WHO dosimetry assurance programme continues to be supported by reference irradiations, which involved only one series of irradiations in 2014 for the radiotherapy level in the ^{60}Co beam.

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

Within the framework of maintenance of the primary activity measurement systems based on the coincidence method, a new digital system for the measurement of dead times by the two-oscillator method has been developed and validated. The system is based on a NI 9402 counter and on a double oscillator that was built at the BIPM and which is compatible with the NI acquisition system. It follows the description and recommendations on the two-oscillator method[3-3]. The frequencies selected are 9729.2 Hz and 6097.5 Hz enabling measurements of dead times up to 51 μs. This new digital system has been validated to better than 1.5 parts in 10^4 for non-extended dead-time values of 5 μs, 10 μs and 50 μs by comparison with the module developed in 1981[4].

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[3] Müller J.W., Une méthode simple pour mesures précises de temps mort, *Rapport BIPM*-1969/03.
[2] Gostely J.-J. and Carval E., NIM, 1978, **150**, 459 – 464.
[3] Gostely J.-J. and Carval E., NIM, 1979, **158**, 537 – 544.
[4] Bréonce P., Description d'un dispositif automatique de mesure précise de temps mort, *Rapport BIPM*-1981/01.

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

2.1.1 SIR submissions in 2014

During 2014, the BIPM received twelve ampoules filled with ten different radionuclides from seven laboratories (i.e. one ampoule each containing ^{22}Na (LNE-LNHB), ^{59}Fe (NMIJ), ^{60}Co (NIM), ^{68}Ge (NMIJ and NIST), ^{89}Sr (PTB), ^{90}Y (PTB),), ^{134}Cs (NRC), ^{137}Cs (NRC), ^{177}Lu (PTB) and ^{223}Ra (NPL and PTB). A further ampoule filled with ^{222}Rn gas with a short half-life ($T_{1/2}$ = 3.8235 d) that was prepared by the LNE-LNHB, was measured first at the BIPM, sent back to the LNE-LNHB and then forwarded to the ENEA. All these submissions had been made to generate equivalence values for the associated ongoing BIPM key comparisons BIPM.RI(II)-K1.

In parallel, measurements of a set of three ampoules of different shapes and sealed at various heights, filled with ^{222}Rn gas and provided by the LNE-LNHB, were carried out to study the influence of the form of the ampoules on the ionization chamber currents. These results were added to a more general study carried out at the LNE-LNHB and presented at a conference in Japan.

2.1.2 SIR reports and quality assurance

Updated reports of four comparisons were published in the *Metrologia Technical Supplement* covering ^{131}I, ^{133}Ba, ^{152}Eu and ^{177}Lu including the linked APMP.RI(II)-K2.I-131, CCRI(II)-K2.Lu-177 and COOMET.RI(II)-K2.Eu-152 comparisons. Two other reports are in circulation. With the exception of four results: reporting forms for ^{51}Cr and ^{125}Sb which are still with the NMIs concerned and ^{111}Ag and ^{222}Rn which are being evaluated by the BIPM, all the Draft A reports have been circulated.

There are 43 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 that have already been removed from the KCDB.

All 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 15 September 2014 by the BIPM Quality, Health and Safety Manager, Mr Maggi (assisted by Mr Fletcher, BIPM).

Following a recommendation made by Prof. Dr Bochud from the IRA-METAS (Switzerland) during a previous external audit, a hand-foot contamination monitor was acquired in 2013 and installed in 2014. To complete the installation and to control the entrance to the hot laboratory, where open radioactive sources are manipulated, a sliding door controlled by the monitor has also been installed.

2.2 Gamma spectrometry

Since the failure of the Ge(Li) spectrometer in July 2013, measurements of potential impurities in SIR ampoules have been suspended. Efficiency measurements of the replacement HPGe spectrometers were carried out several years ago but the data analysis was pending because operation of the SIRTI (see below) was given a higher priority. In 2014, Dr Antohe on secondment from IFIN-HH, Romania, made some additional measurements, analyzed all the measured spectra and evaluated the pile-up corrections. He produced efficiency curves at two distances from the detector, for which only the small true coincident summing correction still needs to be applied. The uncertainty budget needs to be finalized. New procedures will be drafted and the entire process validated before re-offering the gamma-ray spectrometry service to the SIR participants.

2.3 Extension of the SIR to short-lived radionuclides

The BIPM.RI(II)-K4.Tc-99m ($T_{1/2}$ = 6.0 h) key comparison using the SIR Transfer Instrument (SIRTI) continued in 2014 with the VNIIM, Russian Federation, and the ENEA-INMRI, Italy, participating. The NMISA, South Africa, is the next planned participant. The result of the comparison in Romania in 2013 has been published. To date all the degrees of equivalence based on the SIRTI, except the secondary result from Argentina, agree with the KCRV for ^{99m}Tc.

The link SIRTI-SIR for ^{99m}Tc was re-measured after six years of use giving a slightly lower result (12 132(26)). Consequently, the weighted mean linking factor changed from 12 173(20) to 12 165(23), and the latter value will be used for all BIPM.RI(II)-K4.Tc-99m comparisons to be published in future, starting with the VNIIM.

The original SIRTI equipment which had been in Argentina since a comparison in November 2012 was returned to the BIPM in spring 2014. The stability of the SIRTI using the niobium reference source No. 1 was re-measured and no significant change was observed. It is remarkable that, in spite of being transported around the world, the SIRTI has shown a very high reproducibility since 2007, with a relative standard deviation of 2×10^{-4} for the count rate of the ^{94}Nb reference source measured world-wide.

Significant efforts were made to extend the SIRTI to ^{18}F ($T_{1/2}$ = 1.8 h), which is one of the most frequently used radionuclides in positron emission tomography (PET), e.g. to study of the influence of the pulse shape, reproducibility of measurements, production of a copy of the PVC liner and tests of a new centrifuge for the SIR ampoules. A new specific protocol was established and the link SIRTI-SIR was measured for ^{18}F using both a commercial solution and a solution from the LNE-LNHB. The validation was made at the NPL by comparing the SIRTI result with the NPL's SIR result from 2003. Monte Carlo simulations of the SIRTI response as a function of the ampoule shape and filling height need to be finalized for the evaluation of the corresponding uncertainty components of the SIRTI measurements.

A significant milestone in 2014 was the effective use of the SIRTI for ^{18}F through a new BIPM.RI(II)-K4.F-18 ongoing comparison, on-site at each participating NMI's premises, starting with comparisons at the VNIIM, the NPL and the ENEA-INMRI. Other NMIs that have expressed an interest in the ^{18}F comparison are the ANSTO (Australia), BARC (India), BEV (Austria), CNEA (Argentina), IFIN-HH (Romania), KRISS (Republic of Korea), LNMRI/IRD (Brazil), NIM (China), NIST (USA), NMIJ (Japan), NMISA (South Africa), NRC (Canada) and SMU (Slovakia).

Finally, trial measurements of ^{11}C, a PET radionuclide with a 20 min half-life, have been carried out at the NPL with encouraging results.

2.4 Extension of the SIR to pure beta emitters

A significant step towards the extension of the SIR to β-emitters was made in November 2014. A trial exercise was launched to measure samples of ^{3}H, ^{14}C, ^{55}Fe and ^{63}Ni using three commercial liquid-scintillation spectrometers (Beckman TS 6000 TA, Perkin Elmer Tri-Carb 2910 TR and Perkin-Elmer Quantulus 1220) and a TDCR counter that was fabricated at the BIPM. The samples were sent by 14 NMI/DIs (ANSTO, CIEMAT, ENEA, IFIN-HH, IRMM, LNE-LNHB, MKEH, NIM, NIST, NMIJ, NPL, NRC, PTB, POLATOM-RC). These samples were prepared using four different commercial scintillators (Ultima Gold, HiSafe III, Hionic Fluor and Bio Fluor +) in two different scintillator volumes, 10 mL and 15 mL. These measurements will extend over five to seven months and will serve to demonstrate the appropriateness of using the universal efficiency curves (UEC), based on the commercial spectrometers or the apparent efficiencies relying on TDCR measurements, to extend the SIR to β-emitters.

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

The Ionizing Radiation Department provides internal calibration services for thermometry at the BIPM under the terms of the BIPM Quality Management System. A problem occurred with the BIPM high-precision resistance bridge during 2014 that prevented calibration certificates from being issued for SPRTs. Work has been carried out during the second half of the year to resolve the problem. Six calibration certificates for commercial laboratory thermometers belonging to the Chemistry and Mass Departments were issued.

4. Publications

1. Alvarez J.T., de Pooter J.A., Andersen C., Aalbers A.H.L., Allisy-Roberts P.J. Kessler C., Comparison BIPM.RI(I)-K8 of high dose-rate Ir-192 brachytherapy standards for reference air kerma rate of the VSL and the BIPM, *Metrologia*, 2014, **51,** *Tech. Suppl.*, 06022.

2. Alvarez J.T., Sander T., de Pooter J.A., Allisy-Roberts P.J., Kessler C., Comparison BIPM.RI(I)-K8 of high dose rate ^{192}Ir brachytherapy standards for reference air kerma rate of the NPL and the BIPM, *Metrologia*, 2014, **51,** *Tech. Suppl.*, 06024.

3. Anton M., Allisy-Roberts P.-J., Kessler C., Burns D.T., A blind test of the alanine dosimetry secondary standard of the PTB conducted by the BIPM, *Metrologia*, 2014, **51**, *Tech. Suppl*., 06001

4. Arias F., Los Arcos J M., Stock M., Wielgosz R., Milton M., News from the BIPM laboratories-2013, *Metrologia*, 2014, **51**, (2014) 121-125.

5. Bailat C.J., Keightley J., Nedjadi Y., Mo L., Ratel G., Michotte C., *et al*., International comparison CCRI(II)-S7 on the analysis of uncertainty budgets for 4πβγ coincidence counting, *Metrologia*, 2014, **51**, *Tech. Suppl.*, 06018.

6. Burns D.T., Picard S., Kessler C., Roger P., Use of the BIPM calorimetric and ionometric standards in megavoltage photon beams to determine W_{air} and I_c, *Phys. Med. Biol*., 2014, **59,** 1353−1365.

7. Burns D.T., Kessler C., de Prez L., Joulaeizadeh L., Key comparison BIPM.RI(I)-K2 of the air-kerma standards of the VSL, Netherlands and the BIPM in low-energy x-rays, *Metrologia*, 2014, **51,** *Tech. Suppl*., 06010.

8. Burns D.T., Kessler C., Büermann L., Key comparison BIPM.RI(I)-K2 of the air-kerma standards of the PTB, Germany and the BIPM in low-energy x-rays *Metrologia*, 2014, **51,** *Tech. Suppl*., 06011.

9. Burns D.T., Kessler C., Pinto M., Cappadozzi G., Silvestri C., Toni M.P., Key comparison BIPM.RI(I)-K3 of the air-kerma standards of the ENEA, Italy and the BIPM in medium-energy x-rays, *Metrologia*, 2014, **51,** *Tech. Suppl*., 06020.

10. Burns D.T., Kessler C., Büermann L., Key comparison BIPM.RI(I)-K3 of the air-kerma standards of the PTB, Germany and the BIPM in medium-energy x-rays, *Metrologia*, 2014, **51,** *Tech. Suppl.*, 06016.

11. Kessler C., Burns D.T., Büermann L., Key comparison BIPM.RI(I)-K1 of the air-kerma standards of the PTB, Germany and the BIPM in ^{60}Co gamma radiation, *Metrologia*, 2014, **51,** *Tech. Suppl*., 06012.

12. Kessler C., Allisy-Roberts P.J., Miniti R., Comparisons of the radiation protection standards for air kerma of the NIST and the BIPM for ^{60}Co and ^{137}Cs gamma radiation, *Metrologia*, 2014, **51,** *Tech. Suppl.*, 06013.

13. Kessler C., Burns D.T., Büermann L., Key comparison BIPM.RI(I)-K5 of the air-kerma standards of the PTB, Germany and the BIPM in ^{137}Cs gamma radiation, *Metrologia*, 2014, **51,** *Tech. Suppl.*, 06015.

14. Kessler C., Burns D.T., de Prez L., Joulaeizadeh L., Key comparison BIPM.RI(I)-K7 of the air-kerma standards of the VSL, Netherlands and the BIPM in mammography x-rays, *Metrologia*, 2014, **51,** *Tech. Suppl.*, 06025.

15. Michotte C., Ratel G., Courte S., Caffari Y., Fréchou C., Thiam C., Brettner-Messler R., Maringer F.J., Update of the BIPM comparison BIPM.RI(II)-K1.Ba-133 of activity measurements of the radionuclide ^{133}Ba to include the 2009 result of the IRA (Switzerland) and the 2012 results of the LNE-LNHB (France) and BEV (Austria), *Metrologia*, 2014, **51**, *Tech. Suppl.*, 06017.

16. Michotte C., et al., BIPM comparison BIPM.RI(II)-K1.Lu-177 of activity measurements of the radionuclide ^{177}Lu for the NPL (UK) and the IRMM (EU), with linked results for the comparison CCRI(II)-K2.Lu-177, *Metrologia*, 2014, **51**, *Tech. Suppl.*, 06002.

17. Michotte C., et al., BIPM comparison BIPM.RI(II)-K1.Eu-152 of activity measurements of the radionuclide ^{152}Eu for the VNIIM (Russia), the LNE–LNHB (France) and the CNEA (Argentina), with linked results for the COOMET.RI(II)-K2.Eu-152 comparison, *Metrologia*, 2014, **51**, *Tech. Suppl.*, 06004.

18. Michotte C., *et al*., BIPM comparison BIPM.RI(II)-K1.I-131 of activity measurements of the radionuclide ^{131}I for the NMIJ (Japan), the NIST (USA) and the LNE-LNHB (France), with linked results for the APMP.RI(II)-K2.I-131 comparison, *Metrologia*, 2014, **51**, *Tech. Suppl.*, 06003.

19. Michotte C., Sahagia M., Ioan M.R., Antohe A., Luca A., Activity measurements of the radionuclide ^{99m}Tc for the IFIN-HH, Romania in the ongoing comparison BIPM.RI(II)-K4.Tc-99m, *Metrologia*, 2014, **51**, *Tech. Suppl.*, 06014.

20. Picard S., *et al*., Key comparison BIPM.RI(I)-K6 of the standards for absorbed dose to water of the ARPANSA, Australia, and the BIPM in accelerator photon beams, *Metrologia*, 2014, **51**, *Tech. Suppl.*, 06006.

5. Activities related to the work of Consultative Committees

J.M. Los Arcos is the Executive Secretary of the CCRI, an *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 2014 the Key Comparisons Working Group (KCWG(II)) met in April and September.

D.T. Burns is a member of the CCRI(I) Key Comparisons Working Group (KCWG(I)) and the 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 a member of the Key Comparisons Working Group (KCWG(II)) which met in April and September 2014.

S. Picard is Executive Secretary of the Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV). She is the Interim Acting Executive Secretary of the Consultative Committee for Thermometry (CCT) which held its 27th meeting on 21-23 May 2014.

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)) and of the KCWG(II), which met in April and September 2014.

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. In 2014 he was appointed Chairman of the ICRU Committee on Fundamental Quantities and Units. He is a member of the ICRU Report Committee on Key Data for Dosimetry and is Commission Sponsor for three ICRU reports (Key Data for Dosimetry, Operational Quantities for Radiation Protection, and Small and Non-Standard Fields). He is a member of the Scientific Committee of the IAEA/WHO Network of Secondary Standards Dosimetry Laboratories.

C. Michotte is the Scientific Secretary and *rapporteur* for the JCGM-WG1 meetings, which were held in June and October 2014.

G. Ratel is the BIPM representative on the International Committee for Radionuclide Metrology (ICRM) and is the President of the ICRM Nominating Committee. He is a member of the Scientific Committee for the 20th International Conference on Radionuclide Metrology and its Applications (ICRM 2015), which will be held in Vienna (Austria) on 8-11 June 2015.

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

D.T. Burns to:

- Vienna (Austria), 10-14 March 2014, to participate in a meeting of the Scientific Committee of the IAEA/WHO Networks of SSDLs.
- Bethesda (Maryland, USA), 10-16 May 2014, to attend the annual meeting of the ICRU.
- Teddington (UK), 26-29 September 2014, to participate in the BIPM.RI(I)-K6 comparison of absorbed dose to water in accelerator beams with the NPL.
- Brussels (Belgium), 29-30 September 2014, to participate in a meeting of the Commission Sponsors for the ICRU Report on Small-field Dosimetry.
- Teddington (UK), 12-24 October 2014, to participate in the BIPM.RI(I)-K6 comparison of absorbed dose to water with the VSL in the accelerator beams of the NPL.
- Paris (France), 3 November 2014, to participate in a meeting of the ICRU Report Committee on Operational Quantities for Radiation Protection, held at the LNE.

C. Kessler to:

- Ottawa (Canada), 21-29 August 2014, to carry out the BIPM.RI(I)-K8 comparison for reference air kerma rate for HDR Ir-192 brachytherapy sources with the NRC.
- Saclay (France), 16-19 September 2014, to carry out the BIPM.RI(I)-K8 comparison for reference air kerma rate for HDR Ir-192 brachytherapy sources with the LNE-LNHB.
- Oslo (Norway), 29-31 October 2014, to participate in the EURAMET Technical Committee for Ionising Radiation.

J. M. Los Arcos to:

- Madrid (Spain), 12-14 February 2014, to give two lectures at the Master in Metrology-Ionizing Radiation, organized by the Universidad Complutense de Madrid and the Centro Español de Metrología.

S. Picard to:

- Cavtat (Croatia), 2 April 2014, to attend the EURAMET TC-T workshop on "Comparisons: Regional, Key, Linkage and Associated CMC Review".
- Cavtat (Croatia), 3-4 April 2014, to participate at the EURAMET TC-T meeting and to present recent

news from the BIPM and the CCT.

- Brdo (Slovenia), 15-16 September 2014, to participate at the Workshop Metrology for Meteorology and Climate, where she gave the talk "BIPM: Climate and Environment". She also gave a talk on behalf of Dr R.I. Wielgosz (Chemistry Department, BIPM) entitled "Linking Essential Climate Variables to SI Traceable Measurements: BIPM Gas Standard Comparison Activities".
- Teddington (UK), 23 September to 9 October 2014, to carry out two parallel BIPM.RI(I)-K6 comparisons of absorbed dose to water in accelerator beams with the NPL and the VSL at the medical accelerator facility of the NPL.
- Teddington (UK), 1 October 2014, to visit the thermometry laboratories at the NPL.

C. Michotte to:

- NPL, Teddington (UK), 22-26 September 2014, to validate the SIRTI-SIR link for ^{18}F, to carry out an activity comparison of ^{18}F (BIPM.RI(II)-K4.F-18) and to make trial measurements of ^{11}C using the SIR Transfer Instrument.
- Casaccia (Italy), 23 October to 1 November 2014 to carry out activity comparisons of ^{99m}Tc (BIPM.RI(II)-K4.Tc-99m) and ^{18}F (BIPM.RI(II)-K4.F-18) at the VNIIM using the SIR Transfer Instrument.

C. Michotte and M. Nonis to:

- St Petersburg (Russia), 19-28 June 2014 to carry out activity comparisons of ^{99m}Tc (BIPM.RI(II)-K4.Tc-99m) and ^{18}F (BIPM.RI(II)-K4.F-18) at the VNIIM using the SIR Transfer Instrument.

G. Ratel to:

- Vienna, (Austria) 23-24 April 2014, to attend the International Conference on Radionuclide Metrology and its Applications (ICRM) Executive Board.
- Vienna, (Austria) 25-26 November 2014, to attend the ICRM Scientific Committee of the 20th ICRM Conference.
- Vienna, (Austria) 27 November 2014, to attend the ICRM Executive Board.

G. Ratel and C. Michotte to:

- Issy-les-Moulineaux (France), 13-14 November 2014, to attend the "Neuvième rencontre des personnes compétentes en radioprotection".

P. Roger to:

- Teddington (UK), 23 September to 9 October and 20-21 October 2014, to carry out two parallel BIPM.RI(I)-K6 comparisons of absorbed dose to water in accelerator beams with the NPL and the VSL at the medical accelerator facility of the NPL.

8. Visitors

A number of delegations from different countries or organizations visited the Ionizing Radiation Department in 2014:

- M. Hirayama, President of the Institute Council of the Federal Institute of Metrology (METAS) and C. Bock, Director of METAS, 15 May 2014
- E. Cabrera Herebia - General Director of the National Metrology Institute of Paraguay, 25 July 2014
- J.-M. Reiff, Director of the Bureau luxembourgeois de métrologie (ILNAS), Director of ILNAS and P.

Kadok (ILNAS), 1 October 2014

- Delegates attending the 25th CGPM, 17 November 2014

9. Guest workers

- L. Büermann (PTB, Germany), 24 March to 4 April 2014
- M. Pinto (ENEA, Italy), 7-18 April 2014
- A. Antohe (IFIN-HH, Romania), 5 May to 31 July 2014
- L. Czap (IAEA), 23-27 June 2014
- P. Wang and D. Li (NIM, China), 1-5 September 2014
- L. Rodríguez (ex-CIEMAT, Spain), 8 September to 31 December 2014
- E. Mainegra-Hing (NRC, Canada), 15-19 September 2014
- M. Shimizu and T. Tanaka (NMIJ, Japan), 27-31 October 2014