Director’s Report on the Activity and Management of the International Bureau of Weights and Measures
Supplement: Ionizing Radiation Department
(1 January 2016 – 31 December 2016)
BIPM Ionizing Radiation Department
Director: J.M. Los Arcos
(1 January 2016 to 31 December 2016)

1. X- and $\gamma$-rays (D.T. Burns, C. Kessler, S. Picard\textsuperscript{1} and P. Roger)

1.1 Dosimetry standards and equipment

Eight ongoing comparison series, BIPM.RI(I)-K1 to BIPM.RI(I)-K8, are currently supported within the dosimetry programme. The project to develop a new absorbed-dose standard for medium-energy x-rays, which will form the basis for a ninth comparison series, BIPM.RI(I)-K9, was completed, with further measurements of photon attenuation in air and the characterization of three more transfer instruments. Following a pilot comparison with the PTB (Germany) in late 2015, measurements for the first full comparison, also with the PTB, were made during November and December 2016. The new standard will be presented to the CCRI(I) at its 2017 meeting, with the aim of gaining approval to launch the new comparison series and to publish the results of the PTB comparison. Comparison with the PTB will enable the results to be linked to those of a previous EURAMET comparison piloted by the PTB. The new standard will also enable a new calibration series for national standards of absorbed dose to water for x-rays in the 100 kV to 250 kV x-ray range.

For the BIPM.RI(I)-K6 comparison series for absorbed dose to water in high-energy photon beams, new software for data acquisition and analysis was developed and an update was made to the Technical Protocol that now offers two options to determine the dose conversion factor $C_{w,c}$ from graphite to water. One is based on Monte Carlo calculations for a depth of 10 g cm$^{-2}$, which can still be made at the BIPM using the photon spectra supplied by the NMI in question. However, a quadratic fit to twenty complete determinations of $C_{w,c}$ generated between 2009 and 2015 shows deviations consistent with the typical statistical standard uncertainty of 5 parts in $10^{-4}$. For this reason, as an alternative, it is now possible to obtain $C_{w,c}$ by interpolation using the values for TPR$_{20,10}$ measured at the participating NMI.

The tenth comparison in the BIPM.RI(I)-K6 series, was carried out on-site at the NIM (China). The measurements were made in the 6 MV and 10 MV beams of the NIM Elekta accelerator from 15 to 29 November 2016, and the NIM chose to use the new interpolation option for determining the $C_{w,c}$ values. The measurements for higher energies could not be made because of the long delays necessary to fulfill appropriate conditions for radiological protection. This comparison enabled the NIM to verify robustly the present Chinese primary standard to realize absorbed dose to water in accelerator beams and the draft A report is in progress.

The report of the previous comparison with the NMIJ/AIST (Japan) was published. The report of the comparison with the VSL (the Netherlands) which took place at the NPL (UK) accelerator in October 2014, is currently under review by the Key Comparison Working Group KCWG(I) of CCRI(I).

The new laboratory to support measurements for the BIPM.RI(I)-K8 comparison series for high dose rate (HDR) $^{192}$Ir brachytherapy sources was completed. A new system for digital radiography was installed in the laboratory, and the recently installed robotic arm was programmed to operate with both systems. The low-energy x-ray laboratory was refurbished, necessitating the removal of the complete measuring system; after re-installation, the reference plane for each of the standards was re-measured and a series of quality assurance (QA) measurements were performed to assure the stability of the standards.

Primary measurements and reference chamber calibrations have continued in all the reference x- and $\gamma$-ray beams. The programme to update the dosimetry services’ computer hardware and software continued. Minor suggestions from the peer review external audit, which was carried out in December 2015, were implemented and the system was subject to a successful internal audit in December 2016.

\textsuperscript{1}Shared time with the ILC Department as KCDB Coordinator
1.2 Dosimetry comparisons

During 2016, seven dosimetry comparisons were carried out in terms of air kerma or absorbed dose to water using the BIPM x- and gamma-radiation beams, with the IST-LPSR (Portugal), MKEH (Hungary), NIST (USA), PTB, SCK-CEN (Belgium) and two for the VSL. In addition, one high-energy absorbed-dose-to-water comparison BIPM.RI(I)-K6 was carried out with the NIM using their own accelerator facility.

Ten comparison reports were approved and published in *Metrologia Technical Supplement* for the CMI (Czech Republic, two reports), NIM, NMIJ (three reports), NRC (Canada), PTB and the VSL (two reports) (see § 3).

1.3 Characterization of national standards for dosimetry

Twenty-eight characterizations of nineteen national secondary dosimetry standards were carried out for the KRISS (Republic of Korea), CIEMAT (Spain), NMISA (South Africa), IAEA, SMU (Slovakia), STUK (Finland), SSM (Sweden), GUM (Poland) and the IST-LPSR.

In addition, the International Atomic Energy Agency (IAEA)/World Health Organization (WHO) dosimetry assurance programme continues to be supported by reference irradiations. This involved two series of irradiations in 2016, for the radiotherapy level in the $^{60}$Co beam and 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 $\gamma$-ray emitting radionuclides

The *Système International de Référence* (SIR) was implemented at the BIPM almost 40 years ago and constitutes a unique tool to provide world-wide equivalence of radionuclide measurements on demand from NMIs/DIs. It is based on the $^{226}$Ra reference sources and includes two ionization chambers to measure gamma emitters and a transfer instrument. The latter is used to carry out measurements on-site at an NMI/DI facility, when the half-life of a radionuclide is too short to allow shipment of ampoules to the BIPM.

This combination supports the ongoing comparisons BIPM.RI(II)-K1 and BIPM.RI(II)-K4. Both activities are subject to the BIPM Quality Management System and the system underwent a successful internal audit in December 2016.

2.1.1 SIR measurements and reports

Within the radionuclide measurements programme, the SIR received four ampoules of three different radionuclides, $^{88}$Y, $^{133}$Ba and $^{134}$Cs from three laboratories (LNE-LNHB (France), NRC and PTB): all of them were sent by the laboratories to generate equivalence values in the ongoing BIPM.RI(II)-K1 comparison.

Measurements of potential impurities in SIR ampoules have been suspended since the failure of the Ge(Li) spectrometer in July 2013. The efficiency curves and uncertainty budget for the replacement high-purity germanium (HPGe) spectrometer are to be finalized.

Updated final reports of three BIPM.RI(II)-K1 comparisons were published in *Metrologia Technical Supplement* for $^{18}$F, $^{113}$Sn and $^{228}$Th. The latter two reports include an evaluation of the first key comparison reference values (KCRVs) for these nuclides. The updated report for $^{60}$Co was also submitted to *Metrologia Technical Supplement*. There are 37 SIR results in the draft B stage awaiting publication in the BIPM key comparison database (KCDB). Reporting forms for five measurements are yet to be received from participating NMIs.

Historic data on the stability of the SIR ionization chambers with measurements of the $^{226}$Ra sources over 15 years were compiled and analysed for a joint research study, with contributions from 14 NMIs. This study is
concerned with analysing the potential solar influence on nuclear decay constants, an effect that is claimed from
time-to-time by some authors. The results obtained are extremely robust: they were supplied by 14 metrology
laboratories that specialize in radioactivity measurements and refute such an influence. The results have been
published in Physics Letters B and constitute a definitive reference article for the future.

2.1.2 Extension of the SIR to short-lived radionuclides

The second series of calibration measurements of the SIR Transfer Instrument (SIRTI) against the SIR were
carried out for $^{64}$Cu ($T_{1/2} = 13$ h) by measuring a solution from the NPL in both systems. The analysis of results
is in progress.

In 2016, the SIRTI comparisons (BIPM.RI(II)-K4) took place on-site at the NIST for $^{18}$F, $^{64}$Cu and at
POLATOM (Poland) for $^{18}$F, $^{64}$Cu and $^{99m}$Tc. These laboratories were the first participants in the
BIPM.RI(II)-K4.Cu-64 comparison. The comparison reports are in the draft A stage.

The BIPM.RI(II)-K4.Tc-99m ($T_{1/2} = 6.0$ h) key comparisons using the SIRTI at VNIIM (Russia) and
ENEA-INMRI (Italy) in 2014 were published in the Metrologia Technical Supplement. The KCRV, which is
defined in the framework of the BIPM.RI(II)-K1.Tc-99m comparison (SIR), was updated to include SIRTI
results for the first time following a decision of the CCRI in 2015.

The first three results in the BIPM.RI(II)-K4.F-18 ($T_{1/2} = 1.8$ h) key comparison (VNIIM, NPL and
ENEA-INMRI in 2014) were presented at the ICRM-2015 conference in Vienna (Austria) on 8-11 June 2015
and have been published in Applied Radiation and Isotopes. The three results linked to the
BIPM.RI(II)-K1.F-18 comparison (SIR) agree with the KCRV within one or two standard uncertainties
showing, for the first time, the usefulness of the SIRTI for comparing $^{18}$F activity measurements world-wide.

The $^{99m}$Tc and $^{18}$F SIRTI comparisons which took place at the NMISA in November 2015 were submitted for
publication in Metrologia Technical Supplement.

2.1.3 Extension of the SIR to pure beta emitters

An extension of the SIR to beta emitters using liquid scintillation counting (LSC) techniques is being studied by
the CCRI(II) working group ESWG(II). A pilot study is in progress to test the two LSC methods proposed: the
Universal Cross-Efficiency method and the Apparent Activity method.

The pilot study for the extension of the SIR to beta emitters by liquid scintillation counting resumed with the
collaboration of Dr Laureano-Perez, a secondee from the NIST. A newly purchased balance has been used to
prepare 10-ml sources of $^3$H with three scintillators from the six ampoules previously received from the IFIN
(Romania), IRMM, NIM, NMIJ, POLATOM and PTB. Measurements have been completed in the Beckman
LSC TA 1000 counter and are in progress in the Quantulus 1220. Measurements with the Perkin Elmer TriCarb
2910 TR and with the BIPM-designed Triple-to-Double Coincidence Ratio (TDCR) counters are under way.

2.2 Primary measurement facilities

The coincidence systems using atmospheric and pressurized proportional counters were re-set up following
reorganization of the laboratories in the Marie-Curie building. The atmospheric system has restarted and the
pressurized system’s electronics awaits checking. A monitoring system and alarm for CH$_4$ levels in the room has
been installed.
2.3 Radioprotection and regulatory activities

In parallel to the programme of measurements, the French Autorité de Sécurité Nucléaire (ASN) was provided with the necessary documents to renew the authorization for working with and the import and export of radioactive substances for a new five-year term. Additional documents to obtain these authorizations were requested by the ASN and are in the process of being completed.

3. Publications


18. Michotte C., Ratel G., Courte S., *et al.*, Update of the BIPM comparison BIPM.RI(II)-K1.Sn-113 of activity measurements of the radionuclide $^{113}$Sn to include the 2010 results of the PTB (Germany) and the LNE-LNHB (France), and the 2011 result of the CIEMAT (Spain), *Metrologia*, 2016, 53, Tech. Suppl., 06010.


### 4. Activities related to the work of Consultative Committees and RMOs

J.M. Los Arcos is the Executive Secretary of the CCRI, an *ex-officio* member of all CCRI working groups, Coordinator of the CCRI(II) Working Group on the Extension of the SIR to beta-emitters using liquid scintillation (ESWG(II)) and Rapporteur of the CCRI RMO Working Group (RMOWG). During 2016, meetings of the CCRI(II) Key Comparisons Working Group (KCWG(II)) were held in March and November.

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 two *ad hoc* groups within the CCRI(I), one evaluating the effect of excess charge on the value for W$_{air}$ (work that was incorporated into the International Commission on Radiation Units and Measurements (ICRU) report 90 on key data [publications, reference 1]) and the second to report on the implementation of the ICRU Key Data recommendations.

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

C. Michotte is a member of the CCRI(II) Key Comparisons Working Group (KCWG(II)), which met in March and November 2016.

S. Picard is the Executive Secretary of the Consultative Committee for Thermometry (CCT). She was invited to participate in the EURAMET-TC-T meeting in February.

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 the KCWG(II). The latter met in March and November 2016.

The department’s cooperation work with the RMOs included two comparison reports for ionizing radiation (APMP.RI(I) and EURAMET.RI(I)), and six comparison reports for thermometry (CCT, the APMP.T (4) and the SIM.T) being reviewed prior to circulation to the CCRI or CCT for approval. The reports are published in *Metrologia Technical Supplement.*
5. Activities related to external organizations

J.M. Los Arcos is an Associate Member of the International Committee for Radionuclide Metrology (ICRM). He also evaluates scientific projects for the Spanish National Evaluation and Foresight Agency (ANEP) and is a technical auditor for the Spanish accreditation body. In 2016 he was appointed as a member of the Comité Scientifique Rayonnements Ionisants du Laboratoire national d’essais (France), which met in June and November to evaluate the progress and the proposals for new research projects.

D.T. Burns is a Fellow of the Institute of Physics (FInstP) in the UK, an elected Commissioner of the ICRU and Chairman of the ICRU Committee on Fundamental Quantities and Units. He attended the annual ICRU Commission meeting in Rome in April 2016. He is a member of the ICRU Report Committee on Key Data for Dosimetry, which published its ICRU Report 90 in 2016 [Publications, reference 1] 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, which met in Vienna in March 2016 and reported to the IAEA its recommendations for the future work programme. He is also a consultant to the IAEA on the revision of the international code of practice on Absorbed Dose Determination in External Beam Radiotherapy (IAEA-TRS-398) and attended a consultants meeting in Vienna in August 2016.

C. Michotte is the Scientific Secretary and rapporteur for the JCGM-WG1 meetings, which were held in May and November 2016.

G. Ratel is the BIPM representative at 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 21st International Conference on Radionuclide Metrology and its Applications (ICRM 2017), which will be held in Buenos Aires (Argentina) on 15-19 May 2017. He also acted as a member of the Scientific Committee for the Low-Level Radioactivity Measurement Techniques (LLRMT) Conference to organize the submitted abstracts and to review four papers presented at the conference before publication in Applied Radiation and Isotopes.

6. Travel in 2016 (conferences, lectures and presentations, visits)

D.T. Burns to:

- Vienna (Austria), 14 to 18 March, to participate in the biennial meeting of the Scientific Committee of the IAEA/WHO Network of Secondary Standards Dosimetry Laboratories.
- Rome (Italy), 15 to 19 April, to participate in the annual meeting of the ICRU Commission.
- Vienna (Austria), 8 to 12 August, to participate in a consultants meeting on the revision of the international Code of Practice TRS-398 for external-beam radiotherapy.

C. Kessler to:

- Buenos Aires (Argentina), 19 to 21 October, to perform a technical audit of the Secondary Standard Dosimetry Laboratory of Argentina (CRRD)
- Beijing (China), 14 to 30 November, to participate in the BIPM.RI(I)-K6 comparison of absorbed dose to water with the NIM in the reference photons beams of its accelerator facility.

P. Roger to:

- Beijing (China), 14 to 30 November, to participate in the BIPM.RI(I)-K6 comparison of absorbed dose to water with the NIM in the reference photons beams of its accelerator facility.
S. Picard to:
- Berlin (Germany), 26 to 27 January, to participate at the EURAMET TC-IR meeting and to present recent news from the BIPM and the CCRI.
- Valetta (Malta), 25 to 26 February, to participate at the EURAMET TC-T meeting and to present recent news from the BIPM and the CCT.
- Zakopane (Poland), 29 June to 1 July, to attend at the TEMPMEKO conference and participate in a number of working and task group meetings linked to the CCT.
- Beijing (China), 16 to 22 November, to carry out the BIPM.RI(I)-K6 comparison of absorbed dose to water in accelerator beams with the NIM at its medical accelerator facility.

C. Michotte to:
- Otwock (Poland), 17-28 October, to carry out activity comparisons of $^{99m}$Tc (BIPM.RI(II)-K4.Tc-99m), $^{18}$F (BIPM.RI(II)-K4.F-18) and $^{64}$Cu (BIPM.RI(II)-K4.Cu-64) at the POLATOM using the SIR Transfer Instrument.

C. Michotte and M. Nonis to:
- Gaithersburg (USA), 18-28 May, to carry out activity comparisons of $^{64}$Cu (BIPM.RI(II)-K4.Cu-64) and $^{18}$F (BIPM.RI(II)-K4.F-18) at the NIST using the SIR Transfer Instrument.

G. Ratel to:
- Rome (Italy), 2-4 November, to attend the Scientific Committee of the 21th ICRM conference to be held in Buenos Aires (Argentina) in 2017 and the Executive Board Meeting of the ICRM.

7. Visitors in 2016
- Dr Zhang, ISO President; Mr McKinley, ISO Secretary-General ad interim; Mr Peyrat, ISO Vice-President and Director General of AFNOR; Mr Poupet, Head of the International Affairs Department, AFNOR; Mr Zhu, Director of the International Standards Section, ANSTEEL Group; Mr Ma, Secretary to Dr Zhang. 26 February.
- Visit by Mr A.A. Haj (ESMA) and Mr M. Al Mulla (EMI) Abu Dhabi, Dr M. Alharthi (SASO) and Mr O. Kanakrieh (GSO) Riyadh, and Mr S. Al-Remaihi (QS) Doha: 17 March.
- Dr Sylvie Pierre (LNE-LNHB, France) with Alfredo Lopez Ferreira (IRD, Brazil) and Liu Haoran (NIM, China), 15 December.

- Dr V. Sochor, CMI (Czech Republic), 29 February.
- Dr N. Durny, Slovak Institute of Metrology SMU (Slovakia), 22-24 August.
- Dr R. Nylund and Dr J. Huikari, Radiation and Nuclear Safety Authority STUK (Finland), 12-15 September.
- Dr L. Laureano-Perez, National Institute of Standards and Technology NIST (USA), 13 September 2016 – 5 March 2017.
- Dr C. Mihailescu, Belgian Nuclear Research Centre, Studiecentrum voor Kernenergie - Centre d’Etude de l’Energie Nucleaire (Belgium), 26-30 September.