**Bureau International des Poids et Mesures**

# Consultative Committee for Ionizing Radiation (CCRI)

Report of the 24th meeting
(17 May 2013)
to the International Committee for Weights and Measures


Comité international des poids et mesures

Note:

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 will henceforth be published only on the BIPM website in the form presented here.

Full bilingual printed versions in French and English will no longer appear.

Working documents for the meetings are listed at the end of each Report and those which the Consultative Committee decides are for public use are available also on the website.

M.J.T. Milton,
Director of the BIPM

**LIST OF MEMBERS OF THE**
**CONSULTATIVE COMMITTEE FOR IONIZING RADIATION**
as of 17 May 2013

### President

K. Carneiro, member of the International Committee for Weights and Measures

Executive Secretary

Mr José María Los Arcos, International Bureau of Weights and Measures [BIPM], Sèvres

### Members

The Chairman of Section I

The Chairman of Section II

The Chairman of Section III

The Director of the International Bureau of Weights and Measures [BIPM], Sèvres

### Section I - Chairman

P. Sharpe, National Physical Laboratory, Teddington

### Members

Australian Radiation Protection and Nuclear Safety Agency [ARPANSA], Yallambie

Bundesamt für Eich- und Vermessungswesen [BEV], Vienna

Central Office of Measures/Gtówny Urgad Miar [GUM], Warsaw

Commissariat à l'énergie atomique/Laboratoire National Henri Becquerel [LNE-LNHB], Gif-sur-Yvette cedex

D.I. Mendeleyev Institute for Metrology, Rosstandart [VNIIM], St Petersburg

Ente per le Nuove Tecnologie, l'Energia e l'Ambiente -Istituto Nazionale di Metrologia delle Radiazioni Ionizzanti [ENEA-INMRI], Rome

Federal Institute of Metrology METAS [METAS], Bern-Wabern

Hungarian Trade Licensing Office [MKEH], Budapest

International Atomic Energy Agency [IAEA], Vienna

International Commission on Radiation Units and Measurements [ICRU]

Korea Research Institute of Standards and Science [KRISS], Daejeon

National Institute of Metrology [NIM], Beijing

National Institute of Standards and Technology [NIST], Gaithersburg

National Metrology Institute of Japan, AIST [NMIJ/AIST], Tsukuba

National Physical Laboratory [NPL], Teddington

National Research Council of Canada [NRC], Ottawa, Ontario

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig

VSL [VSL], Delft

### Official observer(s)

Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas [CIEMAT], Madrid

Comision Nacional de Energia Atomica [CNEA], Buenos Aires

Czech Metrology Institute [CMI], Brno

Instituto Superior Tecnico [IST], Sacavém

International Organization for Medical Physics [IOMP]

International Radiation Protection Association [IRPA], Fontenay aux Roses Cedex

National Laboratory for Metrology of Ionising Radiation/Institute of Radiation Protection and Dosimetry CNEN [LNMRI/IRD], Rio de Janeiro

National Metrology Institute of South Africa [NMISA], Pretoria

Norwegian Radiation Protection Authority [NRPA], Østerås

### Section II - Chairman

L. R. Karam, National Institute of Standards and Technology, Gaithersburg

### Members

"Horia Hulubei" National Institute of Research and Development for Physics and Nuclear Engineering [IFIN-HH], Bucarest - Magurele

Australian Nuclear Science &Technology Organisation [ANSTO], Menai

Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas [CIEMAT], Madrid

Commissariat à l'énergie atomique/Laboratoire National Henri Becquerel [LNE-LNHB], Gif-sur-Yvette cedex

Czech Metrology Institute [CMI], Brno

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Ente per le Nuove Tecnologie, l'Energia e l'Ambiente -Istituto Nazionale di Metrologia delle Radiazioni Ionizzanti [ENEA-INMRI], Rome

Hungarian Trade Licensing Office [MKEH], Budapest

Institute for Reference Materials and Measurements [IRMM], Geel

Institute of Radiation Physics [IRA], Lausanne

Korea Research Institute of Standards and Science [KRISS], Daejeon

National Institute of Metrology [NIM], Beijing

National Institute of Standards and Technology [NIST], Gaithersburg

National Laboratory for Metrology of Ionising Radiation/Institute of Radiation Protection and Dosimetry CNEN [LNMRI/IRD], Rio de Janeiro

National Metrology Institute of Japan, AIST [NMIJ/AIST], Tsukuba

National Metrology Institute of South Africa [NMISA], Cape Town

National Physical Laboratory [NPL], Teddington

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig

Radioisotope Centre POLATOM [RC], Swierk

### Personal member

Prof. Dr G. Winkler

### Official observers

Bhabha Atomic Research Centre [BARC], Mumbai

Bundesamt für Eich- und Vermessungswesen [BEV], Vienna

Comision Nacional de Energia Atomica [CNEA], Buenos Aires

International Atomic Energy Agency [IAEA], Vienna

International Commission on Radiation Units and Measurements [ICRU]

International Organization for Medical Physics [IOMP]

International Radiation Protection Association [IRPA], Fontenay aux Roses Cedex

National Research Council of Canada [NRC], Ottawa, Ontario

VSL [VSL], Delft

### Section III - Chairman

D. Thomas, National Physical Laboratory, Teddington

### Members

Commissariat à l'énergie atomique/Laboratoire National Henri Becquerel [LNE-LNHB], Gif-sur-Yvette cedex

Czech Metrology Institute [CMI], Brno

D.I. Mendeleyev Institute for Metrology, Rosstandart [VNIIM], St Petersburg

Institute for Reference Materials and Measurements [IRMM], Geel

Korea Research Institute of Standards and Science [KRISS], Daejeon

National Institute of Metrology [NIM], Beijing

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National Physical Laboratory [NPL], Teddington

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig

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China Institute of Atomic Energy [CIAE], Beijing

Ente per le Nuove Tecnologie, l'Energia e l'Ambiente -Istituto Nazionale di Metrologia delle Radiazioni Ionizzanti [ENEA-INMRI], Rome

International Atomic Energy Agency [IAEA], Vienna

International Commission on Radiation Units and Measurements [ICRU]

## 1.–4. INTRODUCTIONS / RAPPORTEUR / REPORT OF PREVIOUS MEETING

The 24th meeting of the Consultative Committee for Ionizing Radiation (CCRI) was held at the BIPM in Sèvres on 17 May 2013.

The following were present:

K. Carneiro (President), M. Milton (Director of the BIPM), J.M. Los Arcos (Executive Secretary), P. Sharpe (Chairman of CCRI(I)), L. Karam (Chairman of CCRI(II) and representative of SIM), D. Thomas (Chairman of CCRI(III)).

H. Bjerke (EURAMET), S. Korostin (COOMET), F. van Wyngaardt (AFRIMETS), Y. Yuandi (APMP), Z. Jian (APMP).

P. Allisy-Roberts (EFOMP), A. Meghzifene (IAEA), F. Nuesslin (IOMP), A. Wambersie (ICRU).

Invited: A. Aalbers, M. Cox.

BIPM participants: D. Burns (rapporteur), C. Michotte, S. Picard, G. Ratel.

Apologies: O. Kovalenko.

The numbering of the sections follows that of the agenda (except where noted). Detailed presentations are available online and are outlined here along with any relevant discussions.

Dr Milton, Director of the BIPM, welcomed the participants. Dr Carneiro, President of the CCRI, opened the meeting, highlighted the full agenda and encouraged strict timekeeping. He welcomed the presence of representatives from the Regional Metrology Organizations (RMOs) and stakeholders from international organizations. Dr Burns was appointed *rapporteur*. There was no presentation or discussion of the report of the 23rd meeting of the CCRI in 2012.

## 5. REPORT OF THE PRESIDENT

Dr Carneiro presented the structure of the Metre Convention in terms of the CGPM, the CIPM and its consultative committees and working groups, and the BIPM. He stressed the importance of stakeholders in this structure. The vision of the CCRI as the "*undisputed hub for ionizing radiation global metrology*" was outlined. Central to this vision was the Strategic Plan for the CCRI, which had been adopted in 2009 and was now the basis for the annual (and henceforth biennial) reports of the CCRI activities.

He described the lack of confidence in the CIPM that was evident at the 2011 CGPM and the consequent formation of an *ad hoc* Working Group with sub-committees on strategy, finance, conditions of employment, CIPM membership and the BIPM pension scheme. The strategic approach subsequently adopted within all of the consultative committees led to some changes in the CCRI Strategic Plan and consequently a new plan was available for discussion. He also stressed the importance of timing in the strategic work of a consultative committee, namely that the strategic periods (short, medium and long term) be in line with the BIPM budgetary periods, and that a new

Strategic Plan would be developed in time for the CIPM to have its complete strategy ready before the deadline to submit its programme proposal for the coming budgetary period to the signatory Governments in the fall. The General Conference will take place in 2014 and the medium-term period will start in 2016. More immediately, the new CCRI plan will be presented to the CIPM in June 2013.

An evaluation form for the Strategic Plan was given to each participant. This should be completed by the end of the day, if possible, or not later than two weeks following the meeting.

## 6. REVISION OF THE GUM

Prof. Cox, chairman of the BIPM Advisory Group on Uncertainties, presented the work of the Joint Committee for Guides in Metrology (JCGM) on a proposed revision of the Guide to the Expression of Uncertainties in Measurement (GUM). The essential change is an extension of the Bayesian approach, currently adopted only for Type B uncertainties, to Type A uncertainties. This knowledge-based approach replaces the assumption of a Gaussian distribution with a *t*-distribution. In this way, the number of degrees of freedom is automatically taken into account and the 95 % confidence limits are more reliably obtained. The new GUM will include improved guidance on confidence limits for cases when the central limit theorem does not apply.

Structurally, the requirements for scientific rigour and simplicity of presentation will be addressed by hyperlinks; the new GUM will be an online resource with a simplified presentation, but with hyperlinks to more detailed cases and explanations.

Following a question on non-linear treatments, Prof. Cox noted the availability of NPL software to implement the GUM, notably its supplement S1 that deals with Monte Carlo methods of uncertainty analysis.

## 7. REPORT ON THE WORK OF THE CCRI

### 7.1. The CCRI and its working groups

Dr Carneiro enumerated the ten working groups of the CCRI (the RMOWG of the CCRI itself and nine working groups of the three Sections) and re-iterated that working groups should, in general, have fixed-term tasks. Towards the completion of this task, the corresponding working group should be closed and the remaining work transferred to a specific action or to another working group of the CCRI. This will often be one of the three KCWGs or the RMOWG.

### 7.2. CCRI Section I

Dr Sharpe presented the work of the CCRI(I) and its working groups, which had met in March 2013. He highlighted three items; accelerator dosimetry, brachytherapy and physical constants. Following the 101st meeting of the CIPM (2012), a new strategy had been adopted for accelerator dosimetry based on external funding. The ADWG(I) had been reconstituted and focused on preparing a new document (to be discussed later in the meeting), after which the ADWG(I) was to be closed. Regarding the on-site K6 comparisons, a proposal for determining the Key Comparison Reference Value (KCRV) and Degrees of Equivalence (DoEs) had been submitted for approval by the CCRI. In brachytherapy, Dr Kessler had taken over as coordinator and agreement had been reached on the KCRV and on the plan for future comparisons (although a subsequent issue had arisen regarding the University of Wisconsin, which is not a designated institute; measurements will await a new facility at the NIST). Low dose-rate brachytherapy had been postponed until 2015 and was to some extent incorporated into a planned EURAMET comparison. Dr Sharpe outlined the work on physical constants carried out at the BIPM in the context of an ICRU Report on Key Data, noting that the proposed change to air-kerma cavity standards of the order of 0.7 % could not be adopted before the ICRU Report was published.

### 7.3. CCRI Section II

Dr Karam presented the work of CCRI(II) and its working groups, which had met earlier in the week. The evaluation of KCRVs had been simplified by the adoption of the 'power-moderated mean' and a plan was put in place for the publication of the monograph on high-efficiency photon-detection systems. Results were presented for comparisons using the SIR travelling instrument (SIRTI) and the extension of the system to other short-lived radionuclides was discussed. Transport difficulties were noted; the system was currently stuck in Argentina and the planned comparison in Brazil was also experiencing difficulties. As a solution to the inherently fragile nature of the SIR, alternative solutions were discussed including the construction of a backup system at the BIPM. Progress on the becquerel chamber had been presented; the main problems outstanding were the machining of the inner wall and the reproducibility of ampoules. The future of CCRI(II) working groups had been reviewed and both the HEWG(II) and the TIWG(II) would close immediately (with the activities of the TIWG(II) being subsumed into the KCWG(II) and those of the HEWG(II) continuing as a simple action), with the BqWG(II) closing (its activities subsumed into the KCWG(II)) at the end of 2013 and the ESWG(II) in 2014. Two recommendations were made to the CCRI: (i) that Draft B documents be made available in some form to inform the CMC review process and (ii) that the SMU (Slovakia) become an Observer at the CCRI(II). The latter was discussed (and approved) at the end of the meeting.

### 7.4. CCRI Section III

Dr D. Thomas presented the work of CCRI(III) and its sole working group, the KCWG(III), which had met in April (the latter for the first time in many years). Similar to the SIRTI, the K9.Am-Be.1 comparison of neutron source emission rate was experiencing transportation problems with both France and China. The K8 comparison of thermal fluence had produced four results that were not in

good agreement and there was no consensus on how to evaluate the KCRV. The underlying problem was to be investigated by a comparison of gold-foil activity counting. Future comparisons were discussed for fusion energies, for calibrations for operational quantities and for electronic dosimeters. The importance of the National Metrology Institute (NMI) presentations at the CCRI(III) was stressed in view of the lack of other opportunities for the community to meet. The question was asked whether it was feasible for the CCRI(III) to meet in a different location. The reply is given below (see section 12). Dr Allisy-Roberts raised concerns over the transportation problems and in particular why our international agreements were not sufficient for the French Authorities. Dr Milton was unable to shed light on this difficultly.

### 7.5. BIPM Programme of Work 2013–2015

Mr Los Arcos presented a summary of the BIPM work programme in ionizing radiation for the period 2013–2015, based on the BIPM Programme of Work and Budget 2013–2015 and the CCRI Strategic Plan 2013–2023. In dosimetry, maintaining the existing x- and gamma-ray standards for comparisons and calibrations forms a large part of the programme, including the newer facilities for mammography and the travelling calorimeter for accelerator dosimetry (which will travel to the UK and to Switzerland in the coming year). The project to develop an absorbed-dose standard for x-rays continues, as will the comparisons for high-dose rate brachytherapy. In radioactivity, besides maintaining the SIR and organizing and participating in CCRI key comparisons, programmes include testing the extension of the SIR to beta emitters and the extension of the SIRTI to $^{18}$F and other short-lived radionuclides. As well as providing executive secretaries for the CCRI and the CCAUV, and the *rapporteur* and BIPM contact for the JCGM-WG1, the department maintains international coordination through membership of the ICRU, the ICRM and the IAEA Scientific Committee. The department also has responsibility for internal thermometry calibrations for the BIPM.

### 7.6. High-energy photon dosimetry

(This appears as 11.3 in the agenda but for logistical reasons was presented between items 7 and 8)

Dr Sharpe presented the draft document *The provision of international validation and traceability for high-energy photon dosimetry*, which set out four scenarios for accelerator dosimetry and argued the benefits and disadvantages of each: (i) an accelerator at the BIPM, funded separately from the BIPM dotation, for comparisons of national primary standards and calibrations of national secondary standards; (ii) the establishment of a distributed network based on existing national accelerators, each of which would be visited in turn by the BIPM calorimeter and staff for a limited period to make a grouped comparison of NMI standards in the vicinity over that period; (iii) continuation of the K6 comparisons using the BIPM calorimeter at the NMI accelerators; (iv) suspension of the K6 comparisons and a return to accelerator dosimetry based on comparisons in $^{60}$Co. A number of suggestions for improvements and clarifications were made, notably regarding Figure 1 and the argument on uncertainties; the inclusion of a table of uncertainties was suggested. Mr Bjerke expressed deep concern over option (iv) and considered it a threat to health and not a viable alternative. The suggestion was made that this option be moved to the introduction and put in historical context as it was the precursor to the K6 comparisons. Prof. Nuesslin offered to send a ‘patient-driven’ argument on behalf of the IOMP.

Dr Carneiro closed the discussion with a brief description of funding aspects showing a list of five Danish foundations, three of which had been informally approached and gave encouraging replies, requesting a one-page summary. The solution might be a consortium of such foundations in different countries.

## 8. NEW CCRI STRATEGIC PLAN 2013–2023

Dr Carneiro outlined the new CCRI Strategic Plan, which had been modified on the basis of the experience obtained from the first strategic plan and from the wider adoption of strategic planning in all of the consultative committees. The plan contained tables of short-, medium- and long-term strategic actions, and stakeholders were asked to mark (on paper copies of the tables) the boxes relevant to their interests; these were to be completed that day or within one week at most. He highlighted four CCRI initiatives: (i) accelerator dosimetry, as already discussed; (ii) a focus on stakeholders, which included the possibility of organizing a meeting of stakeholders later in 2013; (iii) "from air kerma to absorbed dose", which expressed the increasing need for absorbed-dose standards and was addressed in the current programme for medium-energy x-rays; (iv) the SIR. He also talked of support for two CIPM initiatives: (i) review of the CIPM MRA, particularly in terms of reducing the work load on the NMIs from comparisons and working group obligations - the reduction in the number of CCRI working groups from ten to six was cited; (ii) improving uncertainty calculations - the talk on this subject given by Prof. Cox earlier in the meeting was noted. The deadline for completion of the plan was the end of May, in time for the meeting of the CIPM in June. Dr Allisy-Roberts and Mr Bjerke expressed concern over the closure of working groups that might be working efficiently, to which Dr Carneiro remarked that the challenge was to terminate working groups when appropriate.

## 9. REPORTS FROM INTERNATIONAL STAKEHOLDERS

### 9.1.–9.3 International organizations

Dr Meghzifene (IAEA) outlined the needs for traceability in a number of areas, notably access to absorbed-dose standards for high-energy x-rays and electrons, and to standards for small fields, brachytherapy and diagnostic radiology including mammography. The need for increased auditing was also raised; each beam should be audited once per year but currently this target is less than 50 % complete. An important future need is the provision of high-energy x-ray calibrations to Secondary Standard Dosimetry Laboratories (SSDLs). Other plans include a Code of Practice for small fields (in collaboration with the American Association of Physicists in Medicine). He concluded with concerns over the training of SSDL staff, citing the example of a calibration certificate issued with a stated uncertainty of 0.02 %. Dr Karam expressed gratitude to the IAEA for their support to the SSDLs.

Prof. Wambersie (ICRU) listed some recent and upcoming ICRU reports highlighting the importance of radiotherapy, notably reports on proton beams, IMRT, brachytherapy, carbon-ion beams and small field dosimetry. He expressed concern that, while dosimetry was working toward the reduction of uncertainties at the level of a few percent, a lack of uniformity in the reporting of patient doses can lead to errors at the 10 % level; the ICRU was addressing this through its various reports. He described the practice of relating the physical dose given to a patient under 'non-standard' conditions (for example, a proton beam) to the dose that would give the same therapeutic effect under standard conditions (this standard being gamma-radiation, 2 Gy per treatment, 5 treatments per week). This resulted in the iso-effective dose and it was commonplace to refer to this as "gray-equivalent" and to use the symbol GyE. While the ICRU had strongly discouraged this misuse of the SI, it was now very widely used. Although some discussion ensued on personalized medicine and biologically-related quantities (a long-term action in the Strategy Plan), no solution to the quantities and units problem was forthcoming.

Prof. Nuesslin (IOMP) described the structure of the IOMP and its many affiliations and joint activities with other organizations, notably PACT - the Programme of Action for Cancer Therapy operated jointly with the IAEA/WHO. The main activities of the IOMP are in meetings, sponsorship, education, training, web resources and publications.

### 9.4. Regional metrology organizations – technical committee reports

It is noted that because of time constraints the RMO presentations were brief.

Dr Wyngaardt (AFRIMETS) outlined the growing activities in ionizing radiation in Africa, in addition to the long-standing work in dosimetry and radioactivity at the NMISA (South Africa). The NIS (Egypt) holds dosimetry standards and KEBS (Kenya) is active in radiation protection and is developing standards for radiotherapy; AFRIMETS has approved the quality systems for both the NIS and KEBS. (Dr de Felice reported at CCRI(II) that Tunisia has a radioactivity laboratory.) All three (NMISA, NIS and KEBS) have submitted Calibration and Measurement Capabilities (CMCs) to AFRIMETS. Four laboratories named as designated institutes have become associates of AFRIMETS: NIRPS (Nigeria), GRPI (Ghana), TAEC (Tanzania) and INSTN (Madagascar). Dr Wyngaardt acknowledged the help of the IAEA and AFRA, the African Regional Cooperative Agreement, in projects related to SSDLs, particularly training. An AFRIMETS-S1 comparison for air kerma in x- and gamma-ray beams is under way, and there are plans for K1 and K4 dosimetry comparisons. In relation to the 'move' to absorbed-dose standards, Dr Karam noted the importance of air kerma standards in developing countries and Dr Meghzifene stressed the continuing relevance of air-kerma standards for radiation protection.

Prof. Yuandi (APMP) announced the OAP (Thailand) as a new APMP member, bringing the total to fifteen economies. He outlined how the APMP is addressing the strategic actions. They are particularly active in comparisons, having organized seven key and six supplementary comparisons in dosimetry, three in activity and one in neutrons. There are now four institutes (ARPANSA, NMIJ, NIM and KRISS) with clinical accelerators, ARPANSA having taken part in the BIPM-K6 comparison and the three others planning to do so. Three institutes (KRISS, NMIJ, NIM) have received the SIRTI. The NMIJ, having taken part in the BIPM-K7 mammography comparison, are now preparing an APMP-K7 comparison. CMCs for the KRISS, OAP and the NIM are currently under review. The APMP is now focusing on a number of the medium-term strategic actions,

including small-field dosimetry, absorbed-dose standards, the becquerel chamber and neutron metrology.

Dr Korostin (COOMET) summarized the October 2012 TC meeting at which a new president, secretary and vice-presidents were elected. The meeting reviewed the status of quality systems and CMC submissions. Two dosimetry comparisons are in progress, a COOMET-K1 comparison for air kerma and a COOMET-S1 comparison for $^{137}$Cs radioprotection, and there are plans for an x-ray comparison piloted by the PTB and a $^{60}$Co absorbed-dose comparison piloted by the VNIIFTRI. In activity, there have been three COOMET-K2 comparisons ($^{241}$Am, $^{137}$Cs and $^{152}$Eu) and a number of supplementary comparisons are planned to support environmental monitoring.

Mr Bjerke (EURAMET) spoke of the reorganization of the Technical Committee, of EURAMET and EMRP Joint Research Projects (JRPs) in progress, and of CMCs currently under review. He cited four examples of alignment with the CCRI strategy, namely new needs in public security, in health, in industry and small-field dosimetry.

Dr Karam (SIM) noted the success of a SIM Awareness Event that took place in Buenos Aires, Argentina, on 11 November 2011. Linking of the SIM to BIPM comparisons is through the NIST and the NRC, both of whom have participated in almost all of the ongoing BIPM comparisons. The four remaining SIM members (Mexico, Brazil, Uruguay and Argentina) are secondary laboratories and participate in activities and auditing associated with the IAEA/WHO Network of SSDLs (the ININ, Mexico is currently implementing a primary standard for air kerma in $^{60}$Co and has made a comparison at the BIPM). A SIM-K3 comparison for medium-energy x-rays is at the draft A stage. A particular problem was noted for Mexico, where the NMI (CENAM) appeared to be unaware of the ININ as being the designated institute for ionizing radiation. This example of the sometimes poor flow of information between NMIs and designated institutes was particularly worrying in ionizing radiation where the majority of laboratories are designated institutes.

## 10. FUTURE IONIZING RADIATION PROGRAMME OF THE CCRI

Mr Los Arcos presented a draft programme of work in ionizing radiation for the period 2016–2019, consistent with the CCRI Strategy Plan for 2013–2023. To meet the ongoing needs for comparisons and calibrations, the core of the programme will be similar to that of the current programme.

In dosimetry, comparisons and calibrations for x- and gamma-rays will continue, including the facility for absorbed dose in medium-energy x-rays developed during the 2013–2015 programme. The $^{60}$Co source will be changed in 2017 and some of the x-ray equipment will be updated. The comparisons for HDR brachytherapy will continue according to demand, while LDR brachytherapy will depend on the review at the CCRI in 2015. A significant unknown is the accelerator project; if an accelerator is installed at the BIPM, this will entail a significant effort to characterize the reference beams, which in turn will have consequences for the K6 comparisons at the NMIs and for the proposal to develop an electron-beam standard.

In activity, the SIR will continue, including the extension to pure beta emitters developed (in the current programme) and the extension to alpha emitters (postponed from the current programme) will be implemented. Support work for the SIR includes the realization of the becquerel chamber and a

high-stability current source as a backup for the radium sources. The SIRTI will continue according to demand, including the current extension to $^{18}$F, with further extension (for example to $^{11}$C and/or $^{64}$Cu) as decided by the CCRI. Primary measurement methods will be maintained and developed, and proposals for new systems include a 4π-γ NaI well-type counter and a 4π-βγ CsI(Tl) sandwich counter to support low-level, environmental measurements comparisons.

The present activities in international coordination will continue, as will the provision of internal calibrations for thermometry.

## 11. CCRI DECISIONS

(This replaces the original agenda item which was moved earlier in the agenda)

The CCRI(I) proposal on the evaluation of the KCRV for the BIPM-K6 accelerator dosimetry comparisons was agreed.

The CCRI(II) proposal for the SMU (Slovakia) to become an Observer at the meetings of the CCRI(II) was agreed.

There was no discussion of the second CCRI(II) proposal to make Draft B documents available for the CMC review process. However, Dr Carneiro offered to raise the issue in the appropriate forum in the context of the CIPM review of the CIPM MRA.

The CCRI(III) proposal for the ENEA (Italy) and the NRC (Canada) to become Observers at the meetings of CCRI(III) was agreed.

Mr Los Arcos recommended that each of the institutes proposed as Observers should send official letters to the BIPM Director in advance of the meeting of the CIPM in June.

## 12-13. DATES FOR NEXT MEETINGS / CONCLUDING REMARKS

Dr Carneiro proposed re-establishing the two-year cycle, thus abandoning the temporary one-year cycle, while maintaining the arrangement that the CCRI(II) meet in the same week as the CCRI. The week of 18–22 May 2015 was proposed and no objections were raised. Mr Los Arcos agreed to contact the CCRI(I) and the CCRI(III) regarding dates earlier in 2015 for their respective meetings.

In response to a comment made at the CCRI(III), Dr Carneiro remarked that meetings of the three sections could in principle be held elsewhere, in common with meetings of working groups. It was only the meeting of the CCRI that must be at the BIPM. He thanked all present for a profitable meeting, particularly the valuable input from stakeholders, and closed the meeting.

**CONSULTATIVE COMMITTEE**
**FOR IONIZING RADIATION**

Section I: X- and γ-rays, charged particles
Report of the 21st Meeting
(26-28 March 2013)

## 1. OPENING OF THE MEETING

Section I (x- and γ-rays, charged particles) of the Consultative Committee for Ionizing Radiation (CCRI) held its 21st meeting at the Pavillon de Breteuil (the BIPM headquarters), Sèvres, from 26 to 28 March 2013.

The following representatives of member organizations were present:

U. Ankerhold (PTB), D. Butler (ARPANSA), K. Carneiro (President of the CCRI), I. Csete (IAEA), M. D'Arienzo (ENEA-INMRI), F. Delaunay (LNE-LNHB), J. de Pooter (VSL), S. Duane (NPL), I.J. Kim (KRISS), A. Knyziak (GUM), G. Machula (MKEH), M. Mitch (NIST), M. McEwen (NRC-INMS, now NRC-MSS), M. Pinto (ENEA-INMRI), N. Saito (NMIJ/AIST), P. Sharpe (NPL, Chairman of CCRI Section I), A. Steurer (BEV), M.P. Toni (ENEA-INMRI), D. Twerenbold (METAS), A.Y. Villevalde (VNIIM), Z. Yanli (NIM), C.Y. Yi (KRISS).

Observers: H. Bjerke (NRPA, and EURAMET TC-IR Chairman), J. Chavaudra (IOMP), N.A. Cornejo Diaz (CIEMAT), Z. Msimang (NMISA), C. Oliveira (ITN), J.G. Peixoto (LNMRI/IRD), M. Saravi (CNEA), V. Sochor (CMI)

Guests: C.E. Anderson (DTU), C.Omondi (KEBS).

BIPM members also present for all or part of the meeting: J.M. Los Arcos (Executive Secretary of the CCRI), C. Kuanbayev (JCRB Executive Secretary), D.T. Burns, C. Kessler, S. Picard, G. Ratel, P. Roger, C. Thomas (KCDB coordinator).

Apologies were received from: A. Meghzifene (IAEA), A. Berlyand (VNIIFTRI), V. Berlyand (VNIIFTRI) and A. Stefanic (CNEA).

The meeting was called to order at 10 am on 26 March 2013 by the Chairman, Dr Sharpe.

## 2. INTRODUCTIONS

Dr Carneiro (President of the CCRI) welcomed the delegates to the BIPM and to the 21st meeting of the CCRI(I). He excused Dr Milton, Director of the BIPM, from the welcome address.

Dr Sharpe (Chairman of the CCRI(I)), also welcomed the delegates.

The delegates introduced themselves.

## 3. CONFIRMATION OF THE AGENDA AND APPOINTMENT OF A RAPPORTEUR

The agenda has a new structure and follows the formal CCRI(I) strategy structure. The written reports of NMIs will no longer be presented and are for the record. Technical issues from the reports will be represented in the technical section 6.2 of the agenda.

The agenda was approved.

Dr Twerenbold was appointed *Rapporteur* and accepted the challenging task to attain the excellent quality of the reports of the former *Rapporteur,* Dr Ross, who was thanked sincerely for having reported the previous three CCRI(I) meetings.

# 4. PROGRESS REPORTS

## 4.1. CCRI Reports

### 4.1.1. Strategy and actions reports

The CCRI President, Dr Carneiro, reported that all 10 Consultative Committees (CCs) of the CIPM have adopted the strategy approach. He presented an organogram of the BIPM and its supporting structures (CPGM, CIPM, CCs, BIPM staff and NMI directors) and gave an update on developments and changes that have occurred over the last two years. The CGPM decided in 2011 that the BIPM should operate on a minimal budget and that certain structural changes should be implemented.

The role of the CCs was reiterated; they have no executive power within the Metre Convention but a consultative role. They may propose projects and develop a strategy to implement this.

Dr Carneiro emphasized that the CCRI's vision is to be an 'undisputed hub' for global metrology in ionizing radiation.

The CCRI strategic approach was adopted in 2009. It defines a vision over three 4-year intervals and embraces all three sections. It covers 10 working groups, 43 actions and a large number of comparisons. A list of institutional and end-user stakeholders is included.

The CCRI strategy document is 24 pages in length and the current update will be completed by June 2013. It will facilitate the communication of the CCRI President and prepare the CCRI for the future.

The CCRI had increased its number of meetings in recent years but it is the intention to decrease this again.

Future annual reports will focus on implementation of the strategic plan.

### 4.1.2. CCRI RMO WG

The CCRI RMO Working Group is a mandatory working group and its main task is to supervise the Calibration and Measurement Capacities (CMCs) and related comparisons. Dr Carneiro stated that the CCRI has to ask itself whether the appropriate number of comparisons is performed. Some NMI directors have raised criticism against a perceived phenomenon that some comparisons seem to be motivated for scientific pure personal interest coming at CCs. However, with seven comparisons the CCRI is performing well. The CCRI(II) measurement method matrix was mentioned as a good example of how to structure the decision basis for comparisons.

## 4.2. Section I reports

### 4.2.1. Strategy action reports

Previously, the Section I minutes were included directly in the CCRI report. In the future the report will be in form of a report on Section I progress action list. The NMIs will provide annual progress reports to the CCRI(I). These will be summarized in its report to the CCRI. The NMIs are expected to include information about dialogue between the NMIs and the designated institutes (DIs).

Dr Carneiro mentioned the BIPM Forum as a means of information exchange on the strategy report and other issues. It appears that a DI can only enter the BIPM Forum with the permission of its corresponding NMI.

### 4.2.2. Key Comparison Working Group (KCWG(I))

The KCWG did not meet in March 2013. The comparisons are running as planned.

### 4.2.3. Brachytherapy Standards Working Group (BSWG(I))

The Coordinator of the BSWG(I) Dr Allisy-Roberts was not present at the meeting and was represented by Mr Los Arcos. In previous years, the BSWG(I) has reduced its number of members and number of meetings.

The new coordinator of the BSWG(I) will be Dr Kessler and the BSWG(I) will have a new composition: PTB, NPL, NIST, NRC, BEV and ENEA.

The NIST will develop new absorbed dose to water ($D_w$) standards, but will continue to maintain its air kerma standards for the present. NMIs participating in EURAMET will have both $D_w$ and air kerma standards.

Dr Thomas stated that the USA brachytherapy comparison cannot become a KCDB entry because the University of Wisconsin (UoW) is not a DI. The University of Wisconsin can however be declared as a participant. The NIST and UoW will contact their management boards to clarify the status.

Ir-192 HDR comparisons: there is no draft A report yet. In fact, the transfer standard (a cylindrical ionization chamber) cannot yet be considered as a reference standard and a decision has not been made on how to define the key comparison reference value. Brazil, Italy and Japan expressed their wish to participate in future comparisons.

LDR comparisons: if the new BSWG(I) and the CCRI decide to organize a LDR comparison it would be done in 2016. Mr Los Arcos will reconsider this topic at the CCRI(I) meeting in 2015. However, Dr Ankerhold reported that, in the framework of the European iMERA-Plus project JRP6, a brachytherapy comparison was performed with three LDR standards (ENEA, LNE-LNHB, PTB). The situation regarding brachytherapy comparisons was discussed at the EURAMET-TC-IR meeting 2012 in Bucharest and the ENEA (Maria Pia Toni) proposed a new comparison for LDR brachytherapy with I-125 seeds. The ENEA agreed to be the pilot laboratory. The EURAMET LDR comparison could replace the BIPM LDR initiative and the BIPM might instead provide secretarial support and open up the European LDR comparison to other laboratories.

### 4.2.4. Accelerator Dosimetry Working Group (ADWG(I))

The Coordinator of the ADWG(I), Dr Sharpe presented the outcome of the preceding ADWG(I) meeting on 25 March 2013 which took place at the BIPM.

The ADWG(I) reconstituted itself under a new composition consisting of the President of the CCRI, the chairman of the CCRI(I), NMIs with accelerators, NMIs without accelerators, other stakeholders and BIPM experts. The BIPM Director, Dr Milton, also participated in the meeting.

The ADWG(I) meeting on 25 March 2013 discussed ways to define the terms of reference of the working group and to evaluate the document on the BIPM accelerator proposal which is to be sent to the NMI directors. A status report on the BIPM.RI(I)-K6 comparison with the graphite calorimeter was also presented.

The terms of reference as proposed by the ADWG(I) were discussed and modified by the CCRI(I) and then formally approved. Dr Picard noted that the CIPM has to approve the terms of reference and formally constitute the ADWG(I). The modifications were to move the supervision of the BIPM.RI(I)-K6 comparison to the KCWG(I) and to limit the BIPM evaluation to the preparation of the BIPM accelerator document.

Dr Sharpe pointed out that the 2011 proposal to the CGPM for an accelerator at the BIPM was made at an unfortunate time as the CPGM was at that time exposed to the problems of the global economic crisis and the issue of the corporate governance of the Metre Convention and the BIPM. The CGPM (2011) decided that there should not be a budget for a BIPM accelerator in the 2013-2015 period. However, the CGPM agreed that a BIPM accelerator could be pursued for the 2016-2019 period if the funding could come from sources outside the normal dotation.

The document CCRI(I)/13-02 “CCRI Recommendation for a Linear Accelerator at the BIPM” was discussed. The CCRI(I) decided to redraft the document in terms of a strategy for accelerator dosimetry with three scenarios:

a) an accelerator at the BIPM

b) the BIPM travels with a primary standard to a designated facility of each RMO

c) maintain the current arrangement.

In addition, Figure 2 in the document (results of the three K6 comparisons of accelerator dosimetry to date) was adapted to better convey the message to non-therapy dosimetry experts.

## 4.3. Report of the BIPM Programme of Work 2009-2012

Mr Los Arcos presented the BIPM Programme of Work 2009-2012.

The management of the Ionizing Radiation Department changed during this period. The Director of the Department was Dr Allisy-Roberts until her retirement on 31 May 2012. The *ad interim* Director between 1 and 30 June 2012 was Dr Burns and as of 1 July 2012 Mr Los Arcos took over as the new Director of the Ionizing Radiation Department.

During 2009-2012 the BIPM Ionizing Radiation Department comprised a director, eight staff members and one secondee for three months.

The BIPM Dosimetry Group (D. Burns, S. Picard, C. Kessler and P. Roger) cover the following five activities: RI-A1-1 low- and medium energy x-rays (and mammography), RI-A1-2 $^{60}$Co and $^{137}$Cs γ-rays, RI-A1-3 high-energy photon beams, RI-A1-4 brachytherapy and RI-A1-5

medium-energy absorbed dose standard development. The dosimetry team participates in a large number of comparisons and performs a number of certified characterizations of National Standards.

The pre-1970 $^{60}$Co irradiator was replaced in November 2011 by a new THERATRON-1000 irradiator. The new $^{60}$Co source was installed in October 2012 and the new beam has been characterized satisfactorily over the last few months. The dose rate at the reference position of the new $^{60}$Co source is around 1.1 Gy/min.

Two new primary ionization chambers were constructed for two NMIs and two new chambers were constructed for the new $^{60}$Co source.

High-energy comparisons using the BIPM graphite calorimeter system were performed at NRC, PTB, NIST, LNE-LNHB and ARPANSA and reference measurements were performed in the new BIPM reference $^{60}$Co beam.

As a strategic action, BIPM access to an accelerator was explored following the CGPM decision of October 2011. In the current proposal the budget for an accelerator at the BIPM has been reduced from 3.6 M€ to 1.7 M€ and a source of external funding is to be sought.

HDR Brachytherapy transfer standards are maintained at the BIPM and four comparisons have been undertaken. If LDR comparisons are undertaken, secondments will be needed. The rearrangement of the BSWG(I) is awaited.

The BIPM dosimetry group continued the development of an absorbed-dose standard for medium-energy x-rays including the construction of thin-walled transfer ionization chambers.

The Ionizing Radiation Department organized three CCRI and two CCAUV meetings as well as 29 WG meetings. Three BIPM monographs and three *Metrologia* special issues were published.

The CCRI(I) congratulated Dr Burns on his election as a member of the ICRU in 2012.

The CCRI(I) sincerely thanks the BIPM Dosimetry Team for its outstanding work.

### 4.4. Written reports from the NMIs (for the record)

The written reports from the NMIs have been received from most NMIs and will be kept as an electronic annex on the website.

## 5. CIPM MRA

### 5.1. JCRB report

The JCRB report was presented by the new JCRB secretary, Dr Chingis Kuanbayev, who took office in September 2012.

Dr Kuanbayev presented the most important resolutions of the 28th and the 29th meeting of the JCRB: the QMS of the DIs have to be in place before submitting the CMCs and Resolution 25/1 describes how greyed-out CMCs will be deleted from the KCDB.

The 30th meeting of the JCRB was held on 19 and 20 March 2013. Efforts are being made to speed up the CMC review process (revision of document CIPM MRA-D-04). The JCRB recommends reducing the duplication of RMO comparisons.

Dr Csete noted that certain CMCs submitted in 2001 are delayed as they are waiting for supporting evidence.

Dr Kuanbayev commented that Tunisia and Colombia have recently become Member States of the BIPM and that Botswana, Namibia, Oman and Syria have become Associates of the CGPM. Two States have been excluded from the Metre Convention.

## 5.2. Comparisons

### 5.2.1. BIPM and CCRI(I) key comparisons status

**BIPM.RI(I)-K1, BIPM.RI(I)-K2, BIPM.RI(I)-K3, BIPM.RI(I)-K4,**

**BIPM.RI(I)-K5, BIPM.RI(I)-K6, BIPM.RI(I)-K7, BIPM.RI(I)-K8**

The IR Dosimetry Group presented the status of the key comparisons identified as BIPM.RI(I)-K1 through BIPM.RI(I)-K5 and BIPM.RI(I)-K7. The status of BIPM.RI(I)-K6 was updated by Dr Picard in a separate presentation.

Following the 10 year update plan, the following comparisons have to be performed in 2013:

BIPM.RI(I)-K1: DMDM, NMIJ, NIM and LNE-LNHB

BIPM.RI(I)-K2: PTB and BEV

BIPM.RI(I)-K3: ENEA, NRC, PTB, NIM, BEV and VSL.

BIPM.RI(I)-K4: METAS, MKEH and LNE-LNHB

BIPM.RI(I)-K5: NIST, ENEA, PTB and NMIJ/AIST

BIPM.RI(I)-K7: VNIIM will perform a comparison.

Dr Sharpe stated that looking at the significant demand for medium x-ray comparisons (K3), the BIPM should be more proactive towards the NMIs scheduling the comparisons. At the same time he urged the NMIs to plan the comparisons currently marked “black” sufficiently ahead in order to facilitate the work and planning at the BIPM.

Dr Picard presented a status report on the BIPM.RI(I)-K6 comparison ‘Absorbed-Dose Calorimetry in Accelerator Photon Beams’.

Three reports have been published (comparisons with NRC, PTB and NIST), one draft A report has been completed (LNE-LNHB) and for the ARPANSA comparison the measurements were performed in September/October 2012 and the phase space files made available. The next comparisons are planned as follows: NPL/VSL in September 2013 and METAS in March 2014 and other NMIs will follow (NMIJ, NMI, KRISS and ENEA).

Dr Picard presented a proposal where the results of the BIPM.RI(I)-K6 comparison provide the technical basis for degrees of equivalence in the BIPM key comparison database. The DoE proposal was approved by the CCRI(I) and will be formulated as a recommendation.

Dr Carneiro noted that when entering the KCDB and searching for results of the BIPM.RI(I)-K6 comparison the database displays the message “No results are available from the KCDB for this

comparison". Dr Carneiro considers this unhelpful in the light of the discussions for a BIPM accelerator. Dr Thomas responded that it would be difficult to program an alternative response from the KDCB.

The ADWG(I) stated in its previous meeting that it would be very useful if the results of LNE-LNHB and ARPANSA could be included in the DoE as soon as possible.

#### 5.2.2. Regional key and supplementary comparisons status

**AFRIMETS, APMP, COOMET, EURAMET, SIM**

AFRIMETS: one ongoing air kerma comparison $^{60}$Co, $^{137}$Cs and x-ray radiation protection level including the participation of the PTB and MKEH.

APMP: K1 draft B completed, K2 draft B submitted and K4 published. Various supplementary comparisons planned: radiation protection level and ambient dose equivalent for neutrons.

COOMET: one $^{137}$Cs protection level air kerma comparison with 10 participants and three transfer chambers. Draft A is in progress.

EURAMET: There are two large comparison projects in progress: #1132 (Comparison of the ambient dose equivalent rate for photon radiation) and #1177 (KAP meters in terms of air kerma and kerma area product). Another two bilateral comparisons #1221 (diagnostic x-ray beam qualities) and #1200 (medium energy x-ray radiation) support the IAEA calibration service.

SIM: comparison of medium-energy x-ray standards (SIM.RI(I)-K3) piloted by the NIST, Draft A report is in progress.

#### 5.2.3. Future comparisons

Brachytherapy HDR: circulating well chambers with Ir-192 micro-sensor models. Participating NMIs are ENEA, PTB, NPL, LNE-LNHB and NIST.

High energy electron: circulating alanine and solid water phantom. Participating NMIs are NRC, NPL and METAS. The formal protocol will be registered at the BIPM.

### 5.3. Calibration and measurement capabilities

Four CMCs are in progress. One CMC by NIM was rejected and must be resubmitted.

## 6. STRATEGIC PLANNING 2013-2023

Dr Carneiro described the CIPM initiative following the 24th meeting of the CGPM (2011) which initiated the formation of two *ad hoc* working groups and three sub-committees to deal with the following topics: strategy, financial stability, conditions of BIPM employment, BIPM pension fund and CIPM membership.

Dr Carneiro presented the new strategic plan for the CCRI, which contains the short-, medium- and long-term action plans, to which a new column "BIPM" has been added. There are 10 working groups in the CCRI. The WGs for CCRI(I) are the KCWG(I), BSWG(I) and the ADWG(I). New sections on comparisons and stakeholders have been added to the strategic plan.

Dr Carneiro pointed out that the new strategic plan contains four strategic initiatives: (1) Installation of an accelerator at the BIPM, (2) Focus on stakeholders, (3) From air kerma to absorbed dose to water and (4) The International Reference System (SIR). He commented that the strategic plan will have a four-year cycle and that the CCRI and CCRI(I) meetings will be held every two years, with annual reports. In the reporting of the NMIs, the dialogue between the NMIs and the DIs has to be included.

Dr Carneiro requested that members of the CCRI(I) complete the strategic planning evaluation form. The deadline for the final submission of the CCRI strategic plan to the CIPM is the end of May 2013.

Important objectives for the short-term plan are the completion of the Secondary Standards Dosimetry Laboratories (SSDL) comparisons in the KCDB and the achievement of a BIPM medium energy x-ray standard.

A discussion took place with regard to the strategic initiative (3) "From air kerma to absorbed dose to water". Air kerma is still very much used, especially in radiation protection, and generally in Canada and the USA. Dr Chavaudra pointed out that in medical applications the end quantity is always absorbed dose. Dr Csete presented numbers on the relative use of air kerma and absorbed dose. The CCRI could in future establish a working group to review the air kerma/absorbed dose issue and to evaluate a timetable for such transfers, where appropriate.

Dr Ankerhold wondered why action c "Dosimetry for diagnostic imaging" was included in the short-term list.

### 6.1. Short term (2013-2015), medium term (2016-2019) BIPM Ionizing Radiation programme

Mr Los Arcos noted that the number of staff and the group of activities are planned to remain unchanged. The reference documents for the BIPM Ionizing Radiation Department are the BIPM Work Programme for 2013-2015 and the CCRI strategic plan.

SHORT TERM (2013-2015):

The high-energy plans regarding a BIPM accelerator have been postponed, but the offsite graphite calorimeter activities will continue while external funding for a BIPM accelerator will be sought. The medium x-ray standard will be completed and HDR brachytherapy comparisons will be pursued.

MEDIUM TERM (2016-2019):

If the proposal for a BIPM accelerator is accepted, it will be installed and characterized at the BIPM during this period and an electron dosimetry comparison could be planned. The BIPM will be the pilot laboratory for an LDR comparison if the BSWG(I) decides that this should go ahead in 2016.

A stakeholder meeting will be organized, possibly in autumn 2013/spring 2014 with 20 stakeholders and 30 end-user representatives.

An *ad hoc* working group could investigate new needs with regard to horizontal programmes such as security, health and industry. Issues related to hadron dosimetry will be explored.

The CCRI(I) approved the BIPM work programme.

## 6.2. Status of CCRI Strategic plan

### 6.2.1. Recommended values for physical constants

Dr Burns presented the status on the electron stopping powers and the mean energy $W_a$ required to produce an ion pair in dry air. Using the BIPM graphite calorimeter in conjunction with ionization chambers of known volume, the product $W_a\, s_{c,a}$, where $s_{c,a}$ is the stopping-power ratio graphite to air, could be determined at the BIPM. In a global analysis of the available data, the individual values of $W_a$ and $s_{c,a}$ were obtained using a minimization process. A paper will be published in *Metrologia*.

The results of this analysis are the best estimates $W_a$ = 33.97 eV with standard uncertainty 0.32 %, $I_c$ = 81 eV with standard uncertainty 2 eV, and the product $W_a\, s_{c,a}$ = 33.72 eV with standard uncertainty 0.08 %. Here $s_{c,a}$ is expressed in terms of $I_c$, the mean excitation energy for graphite. Note that this analysis assumes the use of the graphite grain density in the evaluation of $s_{c,a}$ (that is, 2.265 g cm$^{-3}$ rather than the measured bulk density). As a consequence, the resulting stopping power is lower by around 0.7 % for $^{60}$Co gamma radiation, which if adopted would reduce air-kerma determinations using graphite-walled primary standards by this amount.

Dr Sharpe commented that the CCRI(I) is looking forward to the ICRU recommendation for $W_a$ and $s_{c,a}$. According to Dr Burns, the ICRU report should be published in time for the next CCRI(I) meeting where the topic should be reconsidered.

Dr McEwen presented a reanalysis of $W_a$ measurements with the NRC 15 MV – 50 MV research accelerator and a proposal to repeat the experiment. The data should be available in the next few months.

In the discussion that followed, Dr Duane and Dr McEwen discussed the uncertainties.

Dr Ankerhold informed that PTB is planning experiments at the 0.5 MeV – 50 MeV research accelerator to determine graphite stopping power directly by using thin graphite foils.

Dr Duane proposed that the air kerma uncertainties should be increased on a case-by-case basis by NMIs even if the change is not official.

Dr Csete reiterated the need to change to absorbed dose to water.

Dr Sharpe proposed that new data should be sent to the CCRI (confidentially) as soon as possible so that the CCRI is prepared for the next meeting and encourages discussions among the NMIs.

### 6.2.2. Photon dosimetry

#### Air kerma and absorbed dose to water for photon dosimetry

Dr Picard presented the status of technical aspects in the development of the graphite calorimeter. The issue of shutter transit time for $^{60}$Co was discussed.

Dr Burns presented technical aspects of the Monte Carlo calculations for accelerator dosimetry comparisons with the graphite calorimeter. The dose conversion factor $C_{w,c}$, as a function of the calculated $TPR_{20,10}$ has been calculated for four comparisons. The conversion factors for the NRC, PTB and NIST beams follow the same line; however the LNE-LNHB results appear to deviate slightly. The introduction of weighted phase-space files might explain this deviation, the issue is under investigation. The calculations are time consuming and take up to three weeks for each beam quality. Unfortunately, a proposed short cut (calculating collector dose rather than cavity dose) turned out not to be reliable and showed more clearly a different behaviour for the LNE-LNHB phase-space files.

Dr Burns presented a comparison of the BIPM ionometric and calorimetric $D_w$ standards for $^{60}$Co in the light of the new information on the product $W_a\ s_{c,a}$ and the value $I_c$ = 81 eV (with the corresponding graphite grain density). The best estimate for the ionometric standard is 0.15 % lower than the existing standard, while the new calorimetric standard is 0.05 % higher, both estimates being consistent within the (correlated) uncertainties.

The developments at the NMIs were presented according to the seating order of the delegates.

**ARPANSA**: Dr Butler presented the preliminary data of the K6 graphite calorimeter comparison. The phase space files have not yet been sent to the BIPM.

**ENEA-INMRI**: Dr D'Arienzo presented the developments using CVD Shottky-barrier type diamond dosimetry for small field dosimetry. These diamond dosimeters have a volume of less than 0.01 cm$^3$, do not require external basis and show a fast sub-second reaction time. According to Dr Ankerhold these devices are very stable and will be on the market as of June 2013.

Dr Pinto informed about the diaphragm corrections in the free-air chamber standard for medium energy x-rays. In addition, a design for a graphite calorimeter immersed in a water phantom was presented as a standard for medium energy x-rays. The reference depth is 2 cm. Dr Duane noted that the design could also be used for electron dosimetry.

**KRISS**: Dr Yi presented an investigation concerning the uncertainties of air kerma measurements resulting from the inherent isotopic composition of air, the effects being of the order of $10^{-4}$. The temperature response of the chamber was also investigated. Dr Burns addressed the issue of hygroscopic materials. Dr McEwen stated that in this respect graphite is the material of choice because of its low thermal expansion and low hygroscopicity.

**LNE-LNHB**: Dr Delaunay presented the latest developments: determination of the air kerma calibration coefficient for a new contact radiotherapy device "papillon 50", determination of the $k_q$ factor for small fields in the framework of the European JRP7, the $k_q$ dependence on TPR in the context of the K6 comparison and the development of a water calorimeter for medium energy x-rays at 2 cm reference depth. Dr McEwen remarked that the high energy points in the $k_q$ (TPR) data coincide with the Seuntjes(2000) results, is this a coincidence?

**METAS**: Dr Twerenbold presented some results on the effect of build-up caps during the preparation of the K4 comparison. In contrast to POM (Delrin), the PMMA build-up cap shows an increase in the value of the calibration factor when irradiated again after 1 hour. Dr McEwen suggested that POM being radiation-soft is the material of choice because radiation-hard materials accumulate charge.

**NIM**: Prof. Zhang detailed the installations at NIM and reported that NIM will determine the conversion from graphite to water for its graphite calorimeter with the help of a water calorimeter owned by the NRC.

**NIST**: Dr Mitch presented the development of new reference mammography beams with silver, rhodium, molybdenum and aluminium filters at 20 kV to 50 kV using a tungsten anode x-ray unit and the Ritz free-air chamber.

**NMIJ**: Dr Saito reported on a graphite calorimeter where the absorbed dose is compared to the electrical heat input. NMIJ wants to participate in the K6 comparison in 2015. NMIJ developed air-kerma standards for mammography radiation with a Rh/Rh target/filter combination in July 2012 and specially designed glass dosimeters are used for quality control of mammography in many hospitals.

**PTB**: Dr Ankerhold reported that a JRP7 dissemination workshop CAMCT 2011 was held on 29 November to 1 December 2011 at the PTB in Braunschweig and the proceedings were published

in a special issue of *Metrologia* (**49**(5), October 2012). A new European EMRP project "Metrology for radiotherapy using complex radiation fields" has been launched with the participation of 10 European partners. PTB has started a project for modern CT dosimetry using a CT with access to the service control mode. Water calorimetry to determine $k_Q$ has been performed for a number of high-energy beam qualities at both $10 \times 10$ cm$^2$ and $3 \times 3$ cm$^2$ fields. The results indicate that the ratio $k_Q(3 \times 3) / k_Q(10 \times 10)$ for the NE2561 chamber is not constant but increases almost linearly from 1.000 to 1.008 with increasing quality index $TPR_{20,10}$. A new cylindrical water calorimeter has been developed for non-standard irradiations such as IMRT and VMAT. The response of alanine dosimeters was investigated for high-energy photons and also for medium-energy x-rays.

**VNIIM**: Dr Villevalde presented the air-kerma standards of VNIIM and stated that VNIIM had significant involvement in bringing the legal framework up to date in Russia.

**NPL**: Dr Duane reported on the upgrade of the NPL clinical accelerators to Flattening Filter Free (FFF) photon beams. Preliminary results indicate that measurements and modelling of these FFFv beams enables a more direct validation of the Monte Carlo model, and is consistent with the results previously obtained for flattened beams. A new graphite calorimeter that can be used both in isothermal mode and in quasi-adiabatic mode is being commissioned.

**CIEMAT**: Dr Diaz presented the various standards at CIEMAT and noted that it needs to participate in comparisons to support its updated CMCs.

**CMI**: Dr Sochor reported on the development of a free-air chamber for low-energy x-rays which is motivated mainly by the increase of mammography. A non-registered comparison with BEV showed good agreement. The next development will be a free-air chamber for medium energy x-rays. A discussion among the participants ensued on the topic of polished aluminum surfaces versus graphite coatings. Dr Csete commented that the free-air chamber was only stable when including a graphite coating, a view supported by recent experience at the BIPM.

### Brachytherapy

**ENEA-INMRI**: Dr D'Arienzo and Dr Pinto reported on the two new absorbed-dose-to-water standards for LDR and HDR brachytherapy sources which were developed within the framework of the EU joint research project JRP6 "Brachytherapy". The LDR standard consists of a large-angle, variable volume ionization chamber in a full scatter graphite phantom and the HDR standard is a three-body (core, jacket and medium) portable graphite calorimeter for absorbed dose to graphite measurements. The absorbed dose rate to water value obtained from the HDR calorimetric measurements was compared with that obtained from the reference air kerma rate (RAKR) formalism, using the $^{192}$Ir dose rate constant, $\Lambda = 1.108 \times 10^4$. The two $\dot{D}_{w\ 1cm}$ values were in the ratio 1.005, well within the stated uncertainties. From the experimental determination of RAKR for the same source, a value of $1.113 \times 10^4 \pm 1.8$ % was derived for the $^{192}$Ir dose rate constant $\Lambda$.

Similarly, the LDR standard allowed an experimental determination of the dimensionless dose rate constant $\Lambda$ from the direct measurement of $\dot{D}_{w\ 1cm}$ and a measurement of the RAKR, this latter traceable to the low-energy air-kerma ENEA-INMRI standard. The result for one type of commercial $^{125}$I seed is $\Lambda_{1cm} = 1.015$ (u = 2.9 %) which is consistent with the corresponding value derived from the international protocols consensus dataset $\Lambda_{1cm} = 1.012$ (u = 4.8 %).

**NIST**: Dr Mitch presented a new calibration facility for the calibration of the Xoft miniature x-ray source, which provides low-energy x-rays (< 50 keV) for electronic brachytherapy applications. The reference air-kerma rate for the sources has been directly realized through use of the Lamperti free-air chamber and a high-purity germanium detector on the opposite side.

**NMIJ**: Dr Saito presented a cylindrical graphite cavity chamber as the HDR brachytherapy standard of NMIJ and the measurement of the photon spectrum for Ir-192 using a Ge detector with a narrow collimator for the evaluation of several correction factors.

**NRC**: Dr McEwen reported that the NRC is developing a HDR brachytherapy standard based on Fricke dosimetry. The advantage over calorimetric techniques being its insensitivity to the self-heating of the source. The Fricke solution is placed in a ring-shaped holder around the $^{192}$Ir source at the reference position of 1 cm. Current research is focused on experimentally determining the G-value of Fricke for $^{192}$Ir energies and using Monte Carlo simulations to correct dose-to-Fricke in an inhomogeneous holder arrangement to dose-to-water in an undisturbed phantom.

**PTB**: Dr Ankerhold reported on two new PTB brachytherapy standards which have been developed in the framework of the iMERA-Plus JRP6: a new extrapolation chamber with water equivalent walls, allowing the determination of the absorbed dose to water at 1 cm depth in a water equivalent material for the realization of a LDR brachytherapy standard, and a primary standard for HDR brachytherapy using a modified water calorimeter with the possibility to position an HDR brachytherapy source close in front of the calorimetric detector. Dr Ankerhold noted that in the new European EMRP project "Metrology for radiotherapy using complex radiation fields" the work package WP4 will determine the basic dosimetry of the two miniature x-ray tubes (MXT) which are commercially available and which are used for electronic brachytherapy in clinical routines.

**NPL**: Dr Duane presented a novel graphite calorimeter for HDR brachytherapy which was developed in the framework of the iMERA-Plus JRP6. It measures the absorbed dose rate to graphite in a ring-shaped core at a distance of 2.5 cm from the source. This quantity is then converted to absorbed dose to water by applying source dependent MC calculated correction factors and a graphite-to-water conversion factor. Two sources were calibrated with the calorimeter and compared with the RAKR as determined with the NPL's HDR air kerma primary standard resulting in an experimentally determined dose rate constant which compared well with published dose rate constants within stated uncertainties.

**NRPA**: Dr Bjerke presented a hospital HDR brachytherapy comparison among five participants which he has found difficult to publish. Scientific journals typically do not publish comparisons because of lack of originality and comparisons among secondary laboratories are not published in *Metrologia*. It was proposed that he should try publishing the comparison in the *Metrologia Technical Supplement*.

### Radiation protection

**NIST**: Dr Mitch presented a new $^{137}$Cs calibration facility delivering dose rates between 45 mGy/h and 1100 mGy/h. It has been designed to produce low background and a high geometrical stability. For the screening of cargo and vehicles using high-energy x-ray beams from accelerators (above 5 MV) a small, brass-walled ionization chamber was designed and built by the NIST to directly realize air kerma in such beams.

**NMIJ**: Dr Saito presented ambient dose measurements from areas affected by the Fukushima accident. Cs-137 and Cs-134 nuclei are now the main sources of gamma rays. The field gamma-rays, however, are not just the mono-energetic lines because they contain photons scattered from the ground, air, etc. The corresponding photon energy spectra have been measured using a CdZnTe detector at several points in Fukushima to evaluate the reference energy spectra after the nuclear accident.

**PTB**: Dr Ankerhold reported that PTB now operates a pulsed x-ray facility which will be used mainly for tests according to ISO/IEC technical specifications and type approvals. A novel pixelated detector (Medipix/Timepix) combined with a novel deconvolution method was used to investigate the spatial- and time-dependent behaviour of the pulsed x-ray fields. Dr Ankerhold gave details of the new PTB underground laboratory for dosimetry (UDO II, 430 m underground) for traceable calibration of detectors at low dose rates. The muon flux inside UDO II is reduced by almost four orders of magnitude and the low specific activity of the surrounding rock salt produces an ambient dose equivalent rate within UDO II of only (1.6 ± 0.2) nSv/h, radon and $^{40}$K being no issue at UDO II. Dr Ankerhold reported on the EURADOS H*(10) area dosimeter comparison which comprised 20 different type dosimeters from 12 participants coming from four countries. According to Dr Csete the H*(10) comparison will be published in 2014.

**CIEMAT**: Dr Diaz presented the CIEMAT facilities for radiation protection calibration in gamma-radiation beams, consisting of a new calibration bench, three $^{137}$Cs sources and one $^{60}$Co source. The calibrations in terms of air kerma are NPL traceable. CIEMAT is developing a free air chamber primary standard for medium x-rays.

**CMI**: Dr Sochor pointed out that CMI will develop a larger version of its low-energy free air chamber in order to have a standard for medium-energy x-rays.

#### Radiation processing

**NPL**: Dr Sharpe mentioned that the 7 MV accelerators with ≥ 100 kW power as used for radiation processing require more precise methods of measurement of the electron energies and a better definition of x-ray beam qualifiers.

### 6.2.3. Charged particle dosimetry

#### Electron/beta dosimetry

**NMIJ**: Dr Saito reported that the NMIJ is going to develop an extrapolation chamber as a standard for Ru-106 beta emitting brachytherapy sources for eye plaque applicators.

**NRC**: Dr McEwen reported on high-precision depth-ionization curves to extract relative perturbation corrections for parallel-plate chambers in electron beams as part of the development of electron primary standards and improvement of dosimetry protocols.

**PTB**: Dr Ankerhold reported that PTB has started the characterization of electron beams for calorimetry. Hp(3) for eye lens dosimetry was implemented in the primary beta dosimetry at PTB and was subsequently implemented in the beta secondary standard (BSS 2). A corresponding software update for the BSS 2 was distributed (free of charge) to the users in December 2012.

#### Protons and other charged particles

**METAS**: Dr Twerenbold reported that the METAS calorimeter for proton dosimetry was shipped to the proton accelerator at KVI in Groningen, the Netherlands, for a collaboration project between METAS, KVI and VSL. The proton dosimetry measurements at the scanned proton facility at PSI will be resumed.

**NIST**: Dr Mitch presented an initiative launched recently by the National Institutes of Health's National Cancer Institute (NCI) and Massachusetts General Hospital to establish NIST traceability efforts in proton therapy. Representatives from NIST and nine clinical proton facilities participated in an intercomparison conducted at the Proton Therapy Center, MD Anderson Cancer Center,

Houston, TX. NIST used thimble and parallel plate ionizing chambers to carry out the measurements. More recently, the NIST brought both chambers and the water calorimeter to one of the proton facilities involved in the intercomparison (Hampton University Proton Therapy Institute, Hampton, VA) and conducted measurements in a similar proton beam.

**PTB**: Dr Ankerhold reported that the EMRP JRP BioQuaRT has been set up in order to develop measurement and simulation techniques for determining the physical properties of ionizing particle track structure on different length scales, and to investigate at the cellular level how these track structure characteristics correlate with radiation. The PTB microbeam that can generate single protons is used for this purpose; α particles or $^{12}C$ ions and have a focal spot of the order of 1 μm on an area of 500 × 500 $\mu m^2$ allowing irradiation of specific areas in a single cell. Dr Ankerhold also reported on measurements of W-values in argon, nitrogen and air for protons and α-particles with energies from 0.7 MeV/u to 3.5 MeV/u at PTB, and for carbon ions between 3.6 MeV/u and 7.0 MeV/u at GSI.

**NPL**: Dr Duane mentioned that a dedicated primary standard graphite calorimeter for dosimetry in therapeutic proton and ion beams has been finalized and was used in the low-energy (60 MeV) clinical proton beam of the Clatterbridge Cancer Centre to confirm measurements performed with an earlier prototype. It was also used in a carbon ion beam at the Southern National Laboratories (LNS) of the Italian National Institute of Nuclear Physics (INFN) in Catania, Sicily.

**IAEA**: Dr Csete mentioned that the high energy part of the TRS 398 protocol might be revised in the coming years including the part on charged particles.

### Other topics

**NPL**: Dr Duane mentioned that the NPL has been involved with the National Rotational Radiotherapy audit (NRRA) which ran a pilot for 10 centres from June to August 2011 and then opened as a national audit to all centres that were using clinical treatment with Volumetric Modulated Arc Therapy (VMAT) or Tomotherapy from January 2012 to March 2013. The results are encouraging and high pass rates have been achieved.

## 6.3. Input from RMOs

**AFRIMETS**: Dr Msimang reported that two new ordinary members have joined: Sierra Leone and Gabon. AFRIMETS has strong ties with the IAEA and PTB and assists many laboratories. There are two training centres in Algeria (French speaking) and South Africa (English speaking). TC-QS has approved the QMS of KEBS (Kenya) and NIS (Egypt) for the CIPM MRA.

**APMP**: Dr Butler reported that the CCRI strategic plan has been discussed in TC-IR and that an accelerator at the BIPM is supported. Questions have arisen about which standards should be implemented and what the criteria for setting priorities should be. APMP faces challenges due to its large geographical area and the many language barriers. APMP is carrying out a K5 therapy level $^{137}Cs$ key comparison with KRISS as the pilot laboratory. Other participants were invited to join.

**COOMET**: A seminar on air-kerma protection level dosimetry was organized together with the PTB. A new comparison for medium x-ray energies is planned; however the problem is to choose the beam qualities as the CCRI qualities are not generally available.

**EURAMET**: Dr Bjerke informed that as of May 2013 Lena Johansson, NPL, will take over the EURAMET TC-IR chair. There are three working groups in TC-IR: CMCs, healthcare and

radionuclides. A total of 1941 CMCs have been published and under review. In the EMRP programme, the TC-IR is participating in eight JRPs. Three roadmaps of the TC-IR are currently under revision.

**SIM**: Paraguay is new member.

### 6.4. Input from institutional stakeholders

**AAPM**: Dr Malcolm McEwen was also representing AAPM (as well as NRC-MSS).

**SIM**: Uruguay is a new member.

**IAEA**: Dr Csete noted that the IAEA has published a new Technical Series report TRS 457 on the Implementation of the International Code of Practice on Dosimetry in Diagnostic Radiology. Diagnostics calibrations are increasing at the SSDLs. During 2011-2012, 22 SSDLs participated in the therapy level comparison programme for ionization chamber calibration coefficients in a $^{60}$Co gamma ray beam. Calibrations both in terms of air kerma and absorbed dose to water were included. The uncertainty budgets are not yet complete and the report has not yet been published. There is an increasing demand for radiotherapy TLD audits. In such audits 5 % do not improve after follow up. In the radioprotection TLD audits the acceptance limit is 7 % which is achieved by 96 % of the participants. The IAEA will contribute to the short- and medium-term actions of the CCRI strategic plan in the following fields: small field dosimetry together with AAPM, a new diagnostic comparison and the inclusion of SSDL comparisons in the KCDB. A new IAEA-BIPM Memorandum of Understanding has been signed.

**ICRU**: Dr Burns stated that an ICRU report on key data is under way and should be published in 2014. The target at the ICRU is to publish two reports per year. ICRU is open for suggestions for new reports or revisions of existing reports and Dr Burns proposed that such suggestions be sent to him so he can present them at the annual meeting.

**IOMP**: Dr Chavaudra mentioned that the IOMP wishes to receive the CCRI strategic plan.

**IRPA**: no representative was present.

## 7. PUBLICATIONS

### 7.1. NMIs bibliographies

The NMIs were asked to extract their list of publications from their annual reports and to send them to Mr Los Arcos.

### 7.2. Other publications

None

## 8. CCRI(I) MEMBERSHIP CHANGES

None

## 9. DATE OF NEXT MEETING

Mr Los Arcos proposed that the meetings should be held end of March / beginning of April 2015. The schedule for 2015 will be proposed at a later date.

## 10. ANY OTHER BUSINESS

Mr Los Arcos asked that the evaluation form be sent to him.

## CONCLUDING REMARKS

Dr Sharpe concluded that it had been a very successful meeting and he thanked everyone for their participation. He noted especially the efforts of the BIPM staff and of Mr Los Arcos in hosting the meeting.

Damian Twerenbold, rapporteur
May 2013

## APPENDIX R(I) 1
## Working documents submitted to the CCRI(I) for its 21st meeting

Documents restricted to Committee members can be accessed on the restricted website.

| Document CCRI(I)/ | |
|---|---|
| 13-00 | Draft Agenda-revised 20130301, P. Sharpe, 2pp |
| 13-01 | CCRI strategic plan for the period 2013-2023, K. Carneiro, P. Sharpe, L. Karam, D. Thomas and J.M. Los Arcos, 23pp |
| 13-02 | CCRI Recommendation for a Linear Accelerator at the BIPM, P. Sharpe, K. Carneiro and J.M. Los Arcos, 17pp |
| 13-03 | Proposal for the KCRV and DoE of national primary standards for absorbed dose to water in accelerator photon beams, S. Picard, D. Burns and J.M. Los Arcos, 6pp |
| 13-04 | NRC Activities and Publications 2011-2013, Malcolm McEwen, 17pp |
| 13-05 | Status report on Monte Carlo calculations for accelerator dosimetry comparisons, D.T. Burns, 2pp |
| 13-06 | Report of the NIST Dosimetry Group to CCRI Section I, Michael G. Mitch, 7pp |
| 13-07 | BIPM comparisons and calibrations in dosimetry 2011 to 2013, C. Kessler, D.T. Burns, S. Picard and P. Roger, 7pp |
| 13-08 | LNE-LNHB Highlights 2011-2012, Frank Delaunay, 19pp |
| 13-09 | Progress Report on Radiation Dosimetry at the VNIIM, A.V. Oborin, S.A. Fedina, I.I. Tsvetkov, A.Y. Villevalde, 5pp |
| 13-10 | PTB Progress Report, U. Ankerhold et al., P. Ambrosi et al., U. Giesen, A. Arndt et al., 41pp |
| 13-11 | Report to the CCRI section I on the activity carried out at ENEA-INMRI on photon and charged-particles dosimetry in the period 2011-2013, M.P. Toni, M. Pinto, M D´Arienzo, A.S. Guerra, M. Pimpinella, M. Bovi, 21pp |
| 13-12 | Progress report on the photon dosimetry at CMI, Vladimír Sochor, 5pp |
| 13-13 | Progress Report on Radiation Dosimetry Standards at NMIJ/AIST and Photon Energy Spectra Measured in Fukushima, Norio Saito, Tadahiro Kurosawa, Masahiro Kato, Yuichiro Morishita, Takahiro Tanaka, and Morihito Shimizu, 17pp |
| 13-14 | Report of SIM Labs to CCRI 2013, L. Karam, 9pp |
| 13-15 | Progress Report (2013) on Radiation Dosimetry at NPL, P. Sharpe and S. Duane, 10pp |
| 13-16 | Report on ICRU activities, D.T. Burns, 1p |

13-17 Recent Activities in Measurement Standards and Dosimetry at ARPANSA, 2011-2013, Nkem Anele, Duncan Butler, Andrew Cole, Ramanathan Ganesan, Peter Harty, Chris Oliver, David Webb and Tracy Wright, 8pp

13-18 Status Report on key data for dosimetry, D.T. Burns, 2pp

13-19 EURAMET-TC-IR Annual Report 2012/2013, H. Bjerke, 4pp

13-20 Comparison of the BIPM ionometric and calorimetric Dw standards for 60Co, D.T. Burns, S. Picard, C. Kessler and P. Roger, 3pp

13-21 Progress report from the SSDL of the NRPA, H. Bjerke, 3pp

13-22 IAEA_CCRI_(I)_report_2012-2013, IAEA, 35pp

13-23 Progress Report (2013) on the Radiation Dosimetry at MKEH, G. Machula, 2pp

13-24 ITN/IST Publications list as at March 2013, C. Oliveira, 7pp

13-25 KRISS Progress Report to the 21st Meeting of the CCRI(I), Chul-Young Yi, Suck-Ho Hah, Kook Jin Chun, In Jung Kim, Byoung Chul Kim, Hyun-Moon Kim and Young Min Seong, 6pp

13-26 Temperature dependence of cavity ionization chamber response, Chul-Young Yi and Hyun-Moon Kim, 6pp

13-27 Inherent uncertainty of air kerma, Chul-Young Yi, 6pp

13-28 Progress report on radiation dosimetry at NIM , Zhang Yanli, Wu Jingjie, Wang Peiwei, Li Dehong and Wang Kun , 11pp

13-29 Report of activity of the COOMET Technical Committee 1.9, S. Korostin, 3pp

13-30 METAS CCRI(I) Report 2011-2013, B. Boillat, C. Meyer, A. Steiner, A. Tschudin, D. Twerenbold, S. Vörös, 14pp

13-31 Recent Activities in Measurement Standard and Dosimetry at the GUM, 2011-2013, Adrian Bozydar Knyziak, 5pp

13-32 LMRI (IST-ITN) Activity Report (2011-2012), C. Oliveira, 2pp

13-33 Evaluation form for CCRI Strategic Plan for the period 2013-2023, K. Carneiro, 1p

13-34 DoE for BIPM.RI(I)-K6 as recommended by the CCRI(I) (20130327), CCRI(I), 4pp

13-35 Minutes 21st Meeting of CCRI(I), D. Twerenbold, 16pp

**CONSULTATIVE COMMITTEE**
**FOR IONIZING RADIATION**

Section II: MEASUREMENTS OF RADIONUCLIDES
Report of the 22nd meeting
(14-16 May 2013)

## 1.-3. OPENING OF THE MEETING:

WELCOME / INTRODUCTION BY THE CHAIRMA/APPROVAL OF THE AGENDA / APPOINTMENT OF RAPPORTEUR

Section II (Measurement of radionuclides) of the Consultative Committee for Ionizing Radiation held its twenty second meeting at the Pavillon de Breteuil (the BIPM headquarters), Sèvres, from 14 to 16 May 2013.

The following representatives of member organizations were present:

I. Alexeev (VNIIM), D. Arnold (PTB), C. Bobin (LNE-LNHB), F. Bochud (IRA), R. Broda (RC), M. Capogni (ENEA-INMRI), M. Cox (NPL), C.J. da Silva (LNMRI/IRD), P de Felice (ENEA-INMRI), C. Fréchou (LNE-LNHB), E. García-Toraño (CIEMAT), L. Johansson (NPL), L. Karam (Chairman of Section II CCRI, NIST), J. Keightley (NPL), J.M Lee (KRISS), K.B Lee (KRISS), S. Pommé (IRMM), M. Reinhard (ANSTO), M. Sahagia (IFIN-HH), J. Sochorová (CMI), L. Szücs (MKEH), U. Wätjen (IRMM), F. van Wyngaardt (NMISA), Yang Yuandi (NIM), A. Yunoki (NMIJ/AIST), J. Zhang (NIM).

**Observers:** R. Galea (NRC-INMS), A. Harms (IAEA), F.J. Maringer (BEV).

Also attending the meeting for all or part of the time: D.T. Burns (BIPM), K. Carneiro (CIPM), S. Courte (BIPM), C. Kuanbayev (BIPM, JCRB coordinator), J.M Los Arcos (Executive Secretary of the CCRI), C. Michotte (BIPM), M. Milton (Director BIPM), M. Nonis (BIPM), G. Ratel (BIPM), C. Thomas (BIPM, KCDB coordinator).

Apologies for absence were received from: C. Borras (IOMP) (Departemento de Energia Nuclear (Recife)),

The Chairman, L.R. Karam, welcomed the delegates, in particular those new to the CCRI, and asked those present to introduce themselves.

Dr Carneiro, President of the CCRI, also welcomed the delegates and expressed his thanks to those present and to previous contributors.

Dr Martin Milton (Director of BIPM) welcomed the participants, stating that he was new in this post, having started on 1 January 2013. He stressed the importance of these meetings to not only the BIPM, but to the CCRI and ultimately the NMIs themselves. Dr Milton said that he could not stay for the entire meeting as he had an appointment with the Columbian Ambassador.

The meeting confirmed the appointment of John Keightley (NPL) as *rapporteur*[1].

[1] The initial draft prepared by the *Rapporteur* was eventually completed with contributions from the Section Chair, Lisa Karam (NIST), and from the Executive Secretary, José M. Los Arcos (BIPM).

# 4. Progress reports

## 4.1. CCRI Reports

The Agenda Item 4.1 relating to strategy and action reports of the CCRI and the CCRI RMO WG was shifted to the morning of Wednesday 15 May 2013, following a reshuffle of some agenda items. To correctly follow the flow of discussions within this meeting, these Agenda Items will be reported just prior to Agenda Item 6.

## 4.2. Section II Reports

A series of reports on status of the various CCRI(II) Working Groups were presented, following a 'Strategy Actions Report' by the CCRI(II) Chair.

### 4.2.1. Strategy Actions Report (L. KARAM, NIST)

Lisa Karam, the CCRI(II) chair, gave a presentation on the current CCRI(II) strategy, reminding participants of the need for continuing active collaborations, and ongoing work towards updating the Measurement Methods Matrix (MMM) which is fundamental for NMIs to support their CMCs and also enables each NMI/DI to determine which comparisons are most in line with national strategies and goals. She stressed that such collaborations play a key role in increasing efficiency in reaching identified goals. She stressed the role of Quality Systems, particularly for the "emerging laboratories".

Lisa Karam then discussed how we assess the impact of this work, and mentioned the roles of the CCRI(II) Working Groups, and publications stemming from their activities.

### 4.2.2. Key Comparisons WG : KCWG(II) (Coordinator: John Keightley, NPL)

John Keightley (NPL) gave a report on recent actions of the CCRI(II) KCWG. He mentioned that in line with the CCRI(II) strategy and in order to facilitate transparency and foster collaborations, all RMO TC chairs are to be invited to attend KCWG(II) meetings. He summarized the status of all ongoing Key and Supplementary Comparisons:

Key Comparisons

| | |
|---|---|
| CCRI(II)-K2.Tc-99 | Results all now received. Draft A in progress |
| CCRI(II)-K2.Pu-241 | Published *Metrologia* Technical Supplement |
| CCRI(II)-K2.Lu-177 | Published. Link of NPL result to SIR ongoing |
| CCRI(II)-K2.H-3 | Draft B: ongoing |
| CCRI(II)-K2.Kr-85 | Draft A: ongoing |

Supplementary Comparisons

| | | |
|---|---|---|
| CCRI(II)-S3: | Shellfish | (Published) |
| CCRI(II)-S6.I-131/S6.Co-57 | IAEA | (Draft B) |
| CCRI(II)-S7: | Uncerts in 4πβ-γ C/C | (Draft B, *Metrologia*) |
| CCRI(II)-S8: | Bilberry | (Draft B, ICRM 2013) |
| CCRI(II)-S9: | Cs-137/K-40 in rice | (Draft A) |
| CCRI(II)-S10: | Wide area sources | (results received) |

The KCWG(II) had held four meetings since the last CCRI(II) meeting, summarized briefly below:

November 2011:

A dedicated "roundtable" discussion on the results of recent comparisons was held, focusing mainly on CCRI(II)-K2.Pu-241, CCRI(II)-K2.Lu-177, CCRI(II)-K2.Kr-85 and CCRI(II)-S7.

A review of the International Conference for Radionuclide Metrology and its Applications (ICRM 2011) was made, focusing on actions arising for the KCWG(II) and possible collaborations between ICRM and KCWG(II).

The possible use of the Power Moderated Mean (PMM) for calculations related to Key Comparison Reference Values (KCRVs), for the CCRI(II) was discussed in depth.

The KCWG(II) Ten-Year Plan was reviewed and the BIPM reported on all updates of KCRVs.

The logistics of the KCWG(II) publication of the *Metrologia* Special issue on Uncertainties in Radionuclide Metrology was reviewed.

May 2012:

Current status and review of Summaries for the various *Metrologia* Special Issue chapters.

The KCWG(II) Ten-Year Plan was reviewed, with particular emphasis on the upcoming Ge-68/Ga-68 and Rn-222 exercises.

November 2012:

The meeting primarily focused on the Uncertainties Special Issue of *Metrologia*, with review of chapter submissions, deadlines, authorship and possible reviewers.

May 2013:

A short meeting was held on 13 May, primarily focusing on the Uncertainties Special Issue of *Metrologia*, with review of chapter submissions, deadlines, authorship and possible reviewers.

Work has begun on 17 chapters of the *Metrologia* Special issue on Uncertainties in Radionuclide Metrology, with the following deadlines: Spring 2014: authors to meet at the KCWG(II) meeting, to present drafts, September 2014: revised manuscripts in final form to be submitted to *Metrologia*, early 2015: publication in *Metrologia*.

The KCWG(II) has received new proposals/suggestions for $^{166m}$Ho, $^{129}$I, "Wheat Powder" and $^{223}$Ra.

The electronic voting option to reach consensus for subjects presented at CCRI(II) was approved.

Stefaan Pommé (IRMM) made a presentation to the CCRI(II) on the PMM or "Power Moderated Mean" for use in determination of KCRVs within CCRI(II), which keeps a fine balance between efficiency and robustness whilst providing reliable uncertainties, and allows simple calculation of the degrees of equivalence. At the same time, it provides useful guidance on the identification of outliers. He stressed that in the use of such a scheme, the CCRI(II) is the final arbiter regarding the correction or exclusion of data from the calculation of the KCRV.

A discussion ensued on the merits of the scheme, with the KCWG(II) making the proposal that the scheme should be used within CCRI(II) activities.

Pierino De Felice asked if Supplementary Comparison exercises and RMO Comparisons should use the PMM. The consensus was that it should be used in all exercises. Pierino De Felice said he will use this in the analysis of CCRI(II)-S7.

Franz-Josef Maringer asked if we would re-visit "old" data, and the consensus was that it should not be done.

Finally, a vote was taken by CCRI(II) members, who accepted the use of PMM within the CCRI(II).

### 4.2.3. High-Efficiency systems WG

José María Los-Arcos presented the activities of the HEWG(II), on behalf of Prof. Winkler who could not attend the CCRI(II) meeting, and would not be doing so in the future. Prof. Winkler had produced a 25-page report. Franz-Josef Maringer and Pierino de Felice had worked with Prof. Winkler, and reported that some Monte Carlo simulations are required to complete the report. The ENEA offered to perform these simulations.

A new team comprising Pierino De Felice, Franz-Josef Maringer, Christophe Bobin and Stefaan Pommé was set up, led by Stefaan Pommé, who would report to Lisa Karam with a plan by the next KCWG(II) meeting in October 2013.

### 4.2.4. Realization of the becquerel WG

Uwe Wätjen presented the report of the BqWG, which has the remit to design and build an ionization chamber based on definitions traceable to SI units, defining mechanical drawings, material compositions and operating specifications. This system would act as a backup for the SIR, and facilitate the scenario where NMIs can build an identical system to enable the maintenance of the Becquerel at NMIs and facilitate bilateral comparisons. The fundamental requirements of the system are for an inter-chamber variation of between 0.1 % and 0.2 % for photon energies greater than 40 keV. Uwe Wätjen stated that the original RWD (Reher, Woods, Denecke) design had been rejected by CCRI(II) due to the complexity of the source holder, the lack of a clear definition on the measurement volume and the fact that the HV was applied to the inner and outer walls, with the collecting electrode held at ground. This had been replaced by the "IC2010" conceptual design which circumvents these issues, exhibiting a separation of the active volume from the structural components (where the structural components for gas containment are not used to maintain the electric field), an improved guard-ring design, inner and outer walls at ground potential and will be easier to construct.

Issues still remain regarding the composition of the inner tube material to be utilized, and the choice of Al, Mg AZM alloy and BeS200F alloys are being investigated, along with possibilities for the use

of additive machining techniques (3D printing). Although the use of Be tubes provides the possibility to detect photons of lower energies, there are issues with the end user licensing (as Be is a "dual use" material) and its excessive cost. Studies had been undertaken on the tolerances required on the wall thicknesses for the inner and outer electrodes, the effect of chamber and holder eccentricity and asymmetry, electric field distribution, non-destructive ampoule selection techniques (particularly important for low energy photon emitters) and ampoule holder machining reproducibility. Indeed, holders manufactured at IRMM and the BIPM had produced differences in thicknesses measured with a newly purchased thickness gauge device. A new low-current source has been built by the VSL and purchased by the IRMM to test electrometer systems.

Future work/goals and questions requiring answers include:

Studies to minimize the achievable tolerances in the machining of critical components for the IC2010 chamber design.

The feasible selection of a more uniform subset of BIPM ampoules.

Investigation of reproducibility of new source holder.

Sensitivity of IC to radial and axial source displacement

Investigation of pathways to achieve required or best tolerance of the well tube

The tackling of remaining open issue (until autumn 2013): which way to go for well tube construction?

### 4.2.5. Transfer instrument WG

Carine Michotte reported on the progress of the TIWG(II), which has the objective to support the BIPM in development of the SIRTI, providing guidance about the experimental setup, methods of data analysis and advice in defining comparison protocols.

The TIWG(II) met in May 2012 to discuss the present status and updates of the SIRTI equipment, the outcomes of the first three $^{99m}$Tc comparisons (NIST, KRISS and NMIJ) as well as the extension to the short-lived positron emitting radionuclides $^{18}$F and $^{11}$C. The stability of the SIRTI has been monitored since 2006 via repeated measurements of a $^{94}$Nb check source, and no significant trend has been observed. However, some fluctuations are apparent in the readings with a reduced chi-squared statistic $\chi_v^2 = 2.7$. A series of experiments were undertaken to study the $^{94}$Nb corrected count rate as a function of temperature, with no observable correlations identified. An additional component in the SIRTI uncertainty budget has been introduced to account for these fluctuations.

Additional experiments were undertaken to study the SIRTI results as a function of count rate. Above count rates of 50 000 $s^{-1}$ an underestimation of the equivalent activity of 0.2 % becomes apparent (possibly related to pile-up of x-rays below the threshold, baseline restoration ("afterglow") and/or PMT gain shift. The order of magnitude is not at present fully understood, so the SIRTI results are limited to count rates below 20 000 $s^{-1}$.

As for the extension of the SIRTI to $^{18}$F and $^{11}$C, a plastic liner has been machined at the BIPM to replace the brass liner used for $^{99m}$Tc, thus maintaining control of the position of the positron annihilation, as well as minimizing effects of bremsstrahlung.

From Monte Carlo simulations, it has been noted that the detection of 511 keV annihilation photons is more sensitive to threshold position than for the 140 keV γ-rays of $^{99m}$Tc, and threshold resetting introduced a relative bias of 0.09 % in early trial measurements of $^{18}$F. This may be understood by

comparing the relative amounts of Compton and photoelectric interactions within the detector at low photon energies. However, the bias observed could not be reproduced systematically.

Carine Michotte reported that the SIRTI is part of the BIPM QMS and passed an external audit in September 2012. New National Instrument counting scales (USB-6341) were implemented and tested using a 1 MHz frequency from the BIPM Time Department. Also, issues related to driver compatibility for Windows 7 have been resolved for the MCA from Amptek.

Future studies include studying the behaviour of the SIRTI at high count rates when utilizing bipolar signals.

Monte Carlo simulations (Penelope 2008) are in progress to evaluate the uncertainty contributions related to the ampoule glass thickness and solution filling height. LNE-LNHB and NPL volunteered to send $^{18}$F ampoules to the BIPM for the calibration of the SIRTI against the SIR. Once the SIRTI is validated for $^{18}$F, no additional developments are necessary for the extension to $^{11}$C, and other positron emitters such as $^{64}$Cu.

A grouped SIRTI comparison of $^{11}$C at a production centre in Spain was suggested by the CIEMAT.

Carine Michotte also reported on a recent change to the "BIPM measurement and consultancy services policy", where participants to the SIRTI will be requested to pay the local accommodation of the BIPM staff (applicable for laboratories registered on the list of participants after June 2012).

#### 4.2.6. Extension of the SIR WG (ESWG)

J.M. Los Arcos reported on the work developed in the ESWG. Two methods have been proposed to be tested for implementing the extension to pure beta emitters, namely the Apparent Activity and the Cross-efficiency Curves Method. This has led to three main actions:

- The BIPM will organize a trial exercise with NMI submissions of $^{3}$H, $^{14}$C, $^{55}$Fe and $^{63}$Ni, to be measured with the Beckman, Quantulus and TDCR counters over a period of 6 months, to start by the end of the year.

- LNHB and PTB will send some sources to the BIPM to re-evaluate both methods.

- LNHB and ENEA to construct a compact TDCR with a precise (and repeatable) design that could be used for the extension of the SIR.

### 4.3. Report of the BIPM programME of work 2009-2012

#### 4.3.1. BIPM Programme of Work 2009-2012

J.M. Los Arcos reported on the work developed at the BIPM during the Programme of Work 2009-2012.

During this period the IR directorate changed: until 31 May 2012 the IR department was directed by Dr Allisy-Roberts, between 1 and 30 June 2012 *ad interim* by Dr Burns and as of 1 July 2012 by the new IR Department Director Mr J.M. Los Arcos. The IR department comprised one director and eight staff members during the period and one secondee for 3 months. The work covered dosimetry and radionuclide activity comparisons and internal thermometry calibrations. The Department provides international coordination of CCRI, CCAUV and CCT, as well as the JCGM-WG1 (GUM).

The Department is still seeking a secondment for recalibration of the HPGe detector for the gamma-spectrometry measurements in the frame of the SIR.

### 4.3.2. Recent Comparisons in the SIRTI

Carine Michotte reported in more detail on the recent SIRTI comparison exercises, including NIST (2009), KRISS (2010), NMIJ (2011), NIM (2012) and CNEA (2012).

It has been noted that in some instances, there have been issues of drops forming on the ampoule walls, which effectively alters the counting geometry for the SIRTI, and the magnitude of the effects have been confirmed via a series of Monte Carlo simulations. These can be overcome via centrifugation of the samples. In the KRISS (2010) exercise the background count rate was twice that seen at the BIPM, but the KRISS were unique in that no drops of solution formed on the ampoule walls. The NMIJ (2011) exercise was faced with a deceasing background over the measurement regime due to the presence of a high activity $^{99}$Mo source in the next room, some contact/cabling issues related to the MTR2 dead-time module and an earthquake (magnitude 5.3) occurring during the measurement regime. The NIM (2012) exercise initially revealed a large bias from expected results, but a typographical error in the evaluation of the preliminary result was identified, and the results are satisfactory. In the CNEA (2012) exercise, an electronics failure in the CNEA coincidence counting system was identified, and a HPGe gamma-ray spectrometry measurement result was reported for the comparison. Timing issues were faced where connection to the NTP time server was not possible, so absolute time was determined via a "talking-clock" service.

The SIRTI is presently in Argentina awaiting the resolution of customs issues. The next comparison is planned for June 2013 at LNMRI, Brazil, and a copy of the SIRTI equipment (including the new NI USB scalers) has been assembled and tested before export to Brazil.

Further K4 comparisons for $^{99m}$Tc are planned for IFIN-HH (2013), VNIIM (2014) and NMISA (2015), with BARC, ANSTO and NRC expressing an interest in future participation.

### 4.3.3. Status of the SIR (2011-2012)

Guy Ratel reported that from the period 2005-2009, measurements have been made using both the old and new electrometer systems, and since 2009 using the new system alone.

In 2011, eight ampoules were received for eight radionuclides from six participants. A new entry from NPL for $^{111}$Ag was received.

In 2012, nine ampoules were received for six radionuclides from six participants. Guy Ratel welcomed the first submission from the NRC for $^{60}$Co.

This year, the 41st SIR circular was sent to the usual participants, and two new Institutes were contacted: Nacional de Investigaciones Nucleares (ININ): Mexico and Turkish Atomic Energy Agency (TAEK): Turkey.

Carine Michotte then presented the link to the SIR of the CCRI(II)-K2.Lu-177 exercise, with NPL and IRMM acting as the linking laboratories. This exercise effectively replaced the values from both PTB and NIST. The CCRI(II)-K2.Lu-177 was published at the ICRM conference, and as a *Metrologia* Technical Supplement. The Draft B report for the BIPM.RI(II)-K1.Lu-177 exercise is currently in progress.

Carole Fréchou (LNE-LNHB) raised some issues regarding the delay in reports being produced following SIR submissions, as these create difficulties for both NMIs and CMS reviewers, as "official proof" is required to justify CMC claims in a timely manner.

Lisa Karam made the point that CCRI(II) had recently agreed to altering the reporting rules, to simplify the report production process. She also stated that Draft B reports may be used to support CMCs.

A lively discussion on delays included an example from Eduardo Garcia-Toraño (CIEMAT) stating that the $^{238}$Pu exercise is over 12 years old with still no report.

The BIPM was actioned to compile a list of the status of all Draft A and Draft B reports, and send to the CCRI(II) chair and the KCWG(II) chair.

Chingis Kuanbayev stated that Draft B reports cannot be published in the KCDB. Carole Fréchou asked if Draft A reports can be made available on the KCDB. Chingis Kuanbayev replied that CMC reviewers want to see "finalized" Draft B reports.

Uwe Wätjen suggested that since the Draft A report could in theory consist of only a table, and these tables are effectively "final", that they should be made available on the BIPM website.

Lisa Karam was actioned to make a recommendation to the CCRI that Draft B reports are made available in the KCDB at the earliest opportunity, and to seek permission for Draft A reports to be made available "somewhere" on the BIPM website.

### 4.4. Written reports from NMIs

They were received for the record. Specific topics were discussed in Section 6.2.

## 5. CIPM MRA

### 5.1. JCRB Report

Chingis Kuanbayev presented the JCRB Report to CCRI(II). He summarized the procedures and guidelines published on the BIPM website. i.e: participation in comparisons is the cornerstone underpinning CMC claims, and these CMCs are subject to peer review of both CMC declarations and Quality Systems by the technical committee of the appropriate RMO and reviewed inter-regionally. Following successful review, CMCs are published in the KCDB.

Mr Kuanbayev also reviewed some highlights of the 30th meeting of the JCRB, focusing on:

Recommendation 1/30: The JCRB strongly encourages the CCs and the RMOs to use the BIPM Web Forum as a tool for effective information exchange and consider increased use of the "fast track" to promote more rapid processing of CMCs.

Recommendation 2/30: The JCRB recognizes the maturity and effectiveness of the CMC review process and the degree of trust established between the RMOs. Consequently, the JCRB strongly

recommends that duplication, resulting from an RMO reviewing the same CMCs during interregional review, be reduced wherever possible.

Recommendation 3/30: The JCRB recommends that RMOs pay greater attention to the appropriate guidelines during intra RMO review in order to improve the efficiency of the inter RMO review of CMCs.

Recommendation 4/30: The JCRB recommends that the CIPM regularly monitors the status of Key Comparison reports in order to minimize the number of reports experiencing significant delays.

Action 1/30: The JCRB Executive Secretary will develop text on "greying-out CMCs" and reinstating "greyed-out CMCs" for CIPM MRA-D-04 for approval at the next meeting of the JCRB.

Action 29/3: The JCRB executive secretary will change the procedure for monitoring the impact of comparisons detailed in document on CIPM MRA-D-05 to include a provision for addressing communications related to inconsistencies between comparison results and published CMCs to the Quality TC/WG of the RMO to which the NMI in question belongs. The JCRB chairman will present the changes to the CIPM for approval.

Mr Kuanbayev also mentioned some changes to the document CIPM MRA-D-05 which consist of a change in the text in Section 7.2 concerning the approval procedure for RMO supplementary comparisons that bring it in accordance with CIPM MRA requirements for CC approval while avoiding, as far as possible, an unnecessary additional burden on CC working groups.

Mr Kuanbayev mentioned that Namibia, the Syrian Arab Republic and Botswana and the European Space Agency have all signed the CIPM MRA since January 2012.

## 5.2. Comparisons

### 5.2.1. BIPM and CCRI(II) Key Comparisons Status

This was dealt with in Section 4.2.2.

### 5.2.2. Regional Key and Supplementary Comparisons Status

These were dealt with in Section 4.2.2. However, some presentations and further discussions were made on current status as detailed below:

CCRI(II)-S10 : Pierino De Felice.

Calibration of surface contamination monitors is made using standard large area sources of different nuclides. The technical requirements for these sources are reported in ISO standards 8769 and the measurement of surface emission rate is detailed in ISO 7503 and IEC 325.

A proposal for an international comparison exercise was initiated as an action item arising from an ICRM RMT Working Group meeting in 2007. The comparison was endorsed by the CCRI(II) at its meeting in June 2009. The exercise is for National Metrology Institutes and other interested laboratories actively involved in the calibration of large area reference sources. To be included in the KCDB the participants must be National Metrology Institutes or CIPM MRA Designated Institutes for activity measurements. In other cases, their country or state, normally through the signatory of the CIPM MRA, should give its consent for the participation.

The sources circulated were typically 100 mm x 100 mm anodised Al sources of approximately 1-3 kBq/source. These included a low energy beta emitter ($^{14}$C), two higher energy beta emitters ($^{147}$Pm and $^{90}$Sr/$^{90}$Y) and an alpha emitter ($^{241}$Am). An additional source ($^{90}$Sr/$^{90}$Y) was supplied for source uniformity checking. All sources were kindly supplied by Eckert & Ziegler Nuclitec.

Detailed instructions were provided by the pilot laboratory for the safe and correct manipulation of the sources. It was the responsibility of each participant to follow these indications strictly.

The data was sent to the BIPM as the ENEA (as pilot) was taking part in the exercise. Once the ENEA had submitted its results, the BIPM made the data available for analysis. The analysis is presently ongoing, but Pierino De Felice showed some preliminary results.

CCRI(II)-S8: Uwe Wätjen.

The IRMM has been developing a reference material for the activity concentration of three radionuclides in bilberry samples. Uwe Wätjen reported that the results (including CRVs) for two photon emitting radionuclides $^{137}$Cs and $^{40}$K have been presented at the ICRM 2011 conference, and published in *Applied Radiation and Isotopes* (*Appl. Rad. Isot*. 70 (2012) pp 1843-1849). The CRVs will be used as certified values for the IRMM certified reference material. A variety of independent methods were used to establish a link of the gamma-ray spectrometer efficiencies (as secondary measurement standards) for the test samples to primary-standardized radionuclide solutions and standard point sources. Nine percent and 17 % of the results for $^{137}$Cs and $^{40}$K, respectively, deviated by more than 20 % from the reference values. This part of the exercise presented several difficulties dealing with the matrix material, encompassing the (remaining) water content of the samples, the reproducible preparation and mechanical characterization of volume sources for gamma-ray spectrometry, and the efficiency calibration for such volume sources together with the corresponding correction and efficiency transfer methods from SI-traceable standard sources to the geometry and density of the bilberry powder samples.

The part of the exercise focusing on $^{90}$Sr activity concentration, is being presented at the ICRM 2013 conference, and will be published in *Applied Radiation and Isotopes*. Five results from IRMM, CENTIS-DMR, IAEA, NIST and TAEK were used in formulation of the CRV of (153 ± 8) Bq.kg$^{-1}$ (dry mass). The CRV results Uwe Wätjen presented were based on an arithmetic mean, and he said he would revise these values (if necessary) after using the Power Moderated mean described in Section 4.2.2 for use in the Supplementary Comparison Report.

Among the wider exercise incorporating not only results from NMIs and DIs, a large number of different analysis procedures were used, including gas-flow proportional counting, liquid scintillation counting, Čerenkov counting, plastic scintillation counting and Geiger-Müller counting. The performance in the determination of $^{90}$Sr, given the complexity of radiochemical procedures, is remarkable with only 12 % of results lying outside ± 30 % from the reference value, and significantly better than that observed in previous exercises.

CCRI(II)-S9:

K.B. Lee confirmed that the Draft A report for the CCRI(II)-S9 comparison exercise on $^{137}$Cs and $^{40}$K in rice is complete, and he estimates that the Draft B report will be available by the end of 2013.

SIM

Lisa Karam stated that SIM is relatively small region compared to EURAMET, with the SIM Signatory laboratories in Ionising Radiation comprising: CNEA (Argentina), LNMRI/IRD (Brazil), NRC-INMS (Canada), ININ (Mexico), MIEM (Uruguay) and NIST (USA). Not all of these

laboratories have radioactivity measurement facilities, with MIEM contributing in the Dosimetry field only. The ININ are participating only sporadically in comparisons at present, whilst NRC-INMS is currently "ramping-up" its activities. Consequently, SIM relies on a heavy use of the Measurement Methods Matrix to support CMC claims, and utilizes other comparisons, not just CCRI(II) and BIPM exercises but also those organized by the IAEA and other RMOs where possible.

With regards to upcoming comparison exercises with SIM participation, NIST will be piloting the upcoming CCRI(II) key comparison on $^{68}$Ge/$^{68}$Ga and is also organizing a $^{18}$F comparison exercise among hospital clinics, and whilst this will not be a registered supplementary comparison, it will be published and peer reviewed, and thus can be used for CMC validation for the NIST, and this is a key aspect for their Nuclear Medicine programme.

EURAMET:

Lena Johansson (NPL) had been taken ill and had left the meeting by this point. She was scheduled to present the EURAMET activities in her role as incoming EURAMET TC Chair, so this item was deferred until the next day.

COOMET:

No report was presented

AFRIMETS:

The report focused on the participation in CCRI and BIPM comparisons.

APMP:

A key comparison of $^{131}$I is in draft B status and the protocol for a comparison on $^{59}$Fe is under development.

### 5.2.3 Future Comparisons (10-year plan)

Several possible comparisons (to be discussed within the KCWG(II)) were mentioned:

Proposal from APMP for wheat flour post-Fukushima: it would be a CCRI(II) supplementary comparison with 15 participants interested.

Other proposed comparisons included $^{124}$I (MKEH), $^{223}$Ra (NPL) and a comparison on uncertainties with TDCR $^{3}$H data measurements.

A large scale trial exercise was accepted for the ESWG: 19 NMIs declared their interest to participate and send $^{3}$H, 14C, $^{55}$Fe and $^{63}$Ni to the BIPM for testing the Apparent Activity and the Cross-efficiency curves methods.

## 4.1. (rescheduled from section 4)

Kim Carneiro presented the CCRI strategy and action report, the CCRI President having the role of coordinator among three sections and representing the CCRI to the CIPM.

The final 2013 revision of the strategic plan is expected at the end of May. An overview of what happened at the last CGPM and the CIPM's response by creating several subcommittees was also presented. Regarding the new strategy plan, four strategic initiatives have been identified:

- Accelerator dosimetry

- Focus on stakeholders

- Switch from air-kerma to absorbed-dose-to-water

- Update, protect and maintain the SIR

A proposal to merge the KCWG of the three sections was discussed but no significant advantage was found.

For other working groups:

- BqWG(II): will close and produce a report.

- HEWG(II): will close and produce a report.

- TIWG(II): should be incorporated back into the KCWG(II).

- ESWG(II): would be maintained until the extension of SIR is operative and then incorporated back into the KCWG(II).

## 6. Strategic Planning (2013 – 2015)

### 6.1. Short term (2013 – 2015) and Long Term (2016 – 2019) BIPM Ionizing radiation Programme.

J.M. Los Arcos made a presentation on the involvement of the BIPM in the current strategy actions.

### 6.2. Status of CCRI strategic plan

#### 6.2.1. CCRI strategic actions and working groups 2013–2023 strategic trends

##### *6.2.1.1. Establishing a rigorous infrastructure*

The backup to the SIR (U. Wätjen) has remaining issues such as which way to go for the well-tube construction, with potential manufacturers at NRC Canada and at kdcc@mek.dtu.dk.

TIWG (C. Michotte) is expected to reintegrate into KCWG(II) in 2014: status for $^{99m}$Tc; schedule for $^{18}$F (NIST in 2015); an extension to $^{11}$C is considered. Within the ESWG(II), the possibility of using a detector established by the ENEA for the MetroMRT project is suggested and the call to laboratories to submit $^{14}$C, $^{55}$Fe, Ni-63, $^{3}$H, for the trial exercise of the extension of the SIR was announced.

##### *6.2.1.2. Quantitative medical imaging*

Quantifiable radioactivity in diagnostic imaging (PET, SPECT) (Lisa Karam)

Molecular radio therapy (John Keightley)

Evaluation of product from alternative method of isotope production (R. Galea) Alternative radionuclide production; NRC services for hospitals; starting in 2016, expecting sources from other than reactors such as cyclotron production of $^{99m}$Tc; there is a need for other results from alternative production such as for impurities; will need measurements and radionuclide calibrator factors evaluated; medical isotope production published by R. Gales, *et al*., *Phys Med Biol* 58 2737 (2013).

#### *6.2.1.3. Newly emerging radionuclides*

Decay schemes (LNHB): $^{64}$Cu project presented at ICRM 2011 on the decay scheme; plans for $^{211}$At and $^{67}$Cu; $^{82}$Sr/$^{82}$Rb coming up; difficulties with extremely short half-life

Standardization methods for new radionuclides (Lisa Karam); Propose $^{223}$Ra comparison

Molecular imaging agents (Lisa Karam)

Input from RMOs, some stakeholders, some NMIs: Brief updates

AFRIMETS to report in 2 years

EURAMET given by F.J. Maringer (have established a strategy in ionizing radiation)

ENEA by M. Capogni

LNHB by C. Bobin on advances in beta measurement,

CIEMAT by E. García-Toraño on involvement and updates on EMRP

NIM with an overview, participation in comparisons, TDCR, Digital Coincidence Counting and $^{222}$Rn measurements

IFIN-HH (M. Sahagia) about accreditation, primary and secondary standards, and services

LNMRI (C. da Silva) major efforts, Brazilian hospitals, plans for future work in Brazilian network of laboratories, and more new radionuclides (interest in $^{106}$Ru)

Request to the CIPM: Accept SMU as observer to Section II (have hosted 2009 ICRM meeting, has 32 CMC's since 2008, anticipate request for membership in 2015)

ICRM update: P. De Felice gave an overview of the ICRM, and U. Wätjen gave an update of the upcoming ICRM meeting.

KCRVs: "Recommendation to the CCRI to remove the NIST $^{177}$Lu SIR result dating from 2000 from the KCRV due to technical issues ($^{177m}$Lu impurity)"; CIEMAT, KRISS, ENEA and BIPM to investigate the status of their result in the CCRI(II)-K2.Eu-152 comparison and linked to the SIR.

All the KCRV updates based on PMM agreed:

$^{85}$Sr: 29 975(46) kBq to include Polatom

$^{133}$Ba: 43 906(55) kBq to include LNHB update

$^{152}$Eu: 14 919(35) kBq to include CNEA and update of LNHB and VNIIM

$^{65}$Zn: 29 694(44) kBq to include BARC

$^{177}$Lu: 560.1(1.8) MBq to include NPL and IRMM and exclude NIST

## 6.5. Revision of the GUM: ImPAct oN NMIs and Industry (M. Cox, NPL)

Dr M. Cox gave a presentation of the revision of the GUM. The GUM has been virtually unchanged for 20 years; it is limited by a lack of generality for coverage intervals and has little guidance for more than one measurand (although this is addressed by some specific guidance documents). The need for revision: influence of a Bayesian world leads to estimates of variances and degrees of freedom (probabilistic approach). Going from rectangular distribution to Gaussian, in many circumstances, assumptions are justified but not all. The new revision is *evolutionary* not *revolutionary* and Maurice Cox noted its readability. It will be available electronically (so there will be hyperlinks) and will leave out much of the history in the body of the main text (but this will be downloadable).

Main differences

Improved guidance of standard uncertainties. Including type A (standard deviations), knowledge-based type B, and controlling coverage intervals.

Bayesian approach extended to type A

Improved guidance on coverage intervals

Effective degrees of freedom and Welch-Sutterthwaite formulae no longer needed

More examples are given

A draft is expected for review by the end of 2014. A *Metrologia* publication (Bich *et al*.) summarizes the new GUM.

## 6.6. Summary of actions

$^{152}$Eu KCRV: CIEMAT agrees to drop their result; BIPM, ENEA and KRISS to decide to drop or not

Consensus electronically determined

Updated KCRV values

Remove NIST result from $^{177}$Lu KCRV

Use of the PMM method

Make a recommendation to the CCRI that Draft B reports are made available in the KCDB at the earliest opportunity, and to seek permission for Draft A reports to be made available “somewhere” on the BIPM website

## 7. Publications (for the record)

Participants were asked to submit their updated list of publications to the BIPM.

## 8. CCRI(II) Membership changes

SMU to be proposed as Observer to Section II

## 9. Date of next meeting

Next meeting is expected in spring 2015.

## 10. Any other Business

None.

**CONSULTATIVE COMMITTEE**
**FOR IONIZING RADIATION**

Section III: NEUTRON MEASUREMENTS
Report of the 20th meeting
(24-26 April 2013)

## 1. OPENING OF THE MEETING

Section III (Neutron Measurements) of the Consultative Committee for Ionizing Radiation (CCRI) held its 20th meeting at the Pavillon du Mail, Sèvres, from 24 to 26 April 2013.

The following representatives of member organizations were present:

M.S. Dewey (NIST), V. Gressier (LNE-IRSN), H. Harano, (NMIJ), J. Kim (KRISS), M. Kralik (CMI), T. Matsumoto (NMIJ), N.N. Moiseev (VNIIM), R. Nolte (PTB), N. Roberts (NPL), C. Thiam (LNE-LNHB), D.J. Thomas (Chairman, NPL), H. Zhang (NIM).

Observers: R Mendez (CIEMAT).

Guests: J.-P. Archambault (NRC-INMS), P. De Felice, L. Quintieri, and S. Loreti, (ENEA).

BIPM members also present for all or part of the meeting: J.M. Los Arcos (Executive Secretary of the CCRI), C. Kuanbayev (JCRB Executive Secretary), S. Picard, C. Thomas (KCDB coordinator).

Apologies were received from: S. Oberstedt (IRMM).

## 2. WELCOME

The BIPM Director, Dr Milton, and the CCRI President, Dr Carneiro, were absent. The Chairman, Dr D.J. Thomas, welcomed the delegates. Everyone introduced themselves. Spain was present as an observer. Italy was present as a guest for the first time and Canada was also present as a guest.

## 3. APPOINTMENT OF THE RAPPORTEUR

Dr Dewey (NIST) was appointed as the Rapporteur.

## 4. CHANGES OR ADDITIONS TO THE AGENDA

There were a couple of minor changes to the agenda. **Actions are indicated in bold italic fonts.**

# 5. PROGRESS REPORTS

## 5.1. CCRI reports (President Kim Carneiro, CIPM)

These reports were presented by Mr Los Arcos.

### 5.1.1. Strategy and actions reports

This report was prepared by Dr Carneiro, president of the CCRI. It detailed who and what we are and described the line organization. The Consultative Committees are "side" organizations. The vision of the CCRI is to become the undisputed hub for ionizing radiation global metrology. A strategic approach was adopted in 2009. It covers the periods 2009-2012, 2013-2016, 2017-2020; includes the three sections of the CCRI; and contains 11 working groups, 43 actions, and comparisons. The plan has been the basis for annual reports in 2011 and 2012 (in progress). The strategic framework has provided an improved overview, better efficiency and planning; unified the sections; improved transparency and stakeholder relations; prepared the CCRI for the future; increased the meeting frequency; and imposed a significant workload. In 2011, the CGPM questioned several aspects of CIPM governance and the CIPM subsequently undertook several initiatives in 2012.

### 5.1.2. CCRI RMO WG

A report from the CCRI RMO WG (Interregional CMC review working group) was presented. It was noted that the WG helps the CCRI with CIPM MRA CMCs. Some NMI directors expressed an interest in becoming more involved. There was no criticism of the scientific work of the BIPM. The connection between delegate and NMI is not always good. Dr Thomas asked how this might affect Section III. Mr Los Arcos did not anticipate any changes. In general, comparisons must be as efficient and useful as possible.

## 5.2. Section III reports

### 5.2.1. Key Comparisons Working Group (KCWG(III))

This KCWG(III) met for the first time on 23 April 2013. There was a detailed discussion of comparison K-11. Six of the nine participants were present. It had been hoped to have all the results before this meeting, but this was not possible. Therefore, a new deadline of 30 September 2013 was set. Agreement is still required from those participants who were not present at this meeting.

**5.3.** Mr Los Arcos mentioned the requirement to produce two-year reports of activities for each NMI. These are required and will be archived. To facilitate this everyone was reminded about the Section III restricted area password. A password for the working group KCWG(III) will be emailed to the delegates.

# 6. CIPM MRA PART 1:

## 6.1. Present comparisons

### 6.1.1. CCRI(III)-K11 neutron fluence – progress report Vincent Gressier

Previous series of measurements included K1 (24.5 keV) and K10 (144 keV, 1.2 keV, 5.0 keV, 14.8 keV). The latest, K11 features 27.4 keV (produced with $^{45}$Sc(p,n) at 0 deg), 565 keV, 2.5 MeV, and 17 MeV and is similar to K10. Measurements were carried out at the AMANDE facility operated by the LNE-IRSN. Participants were charged with measuring the fluence of unscattered neutrons at 1 metre and 0 degrees in vacuum per M1 monitor count. The AMANDE facility was described. Measurements were carried out during 2011-2012. The order of participants was: IRSN, NPL, VNIIM (detector MAR-150 measured the three lowest energies), CIAE, IRSN, IRMM (two energies), PTB, NIST, IRSN, AIST, PTB 2, IRSN, and LNMRI. The groups had more than one year to carry out their measurements. Comparisons of relative fluence per monitor with the IRSN PLC indicate that for 27.4 keV, 565 keV, 2500 keV, and 17 000 keV there were similar conditions for all participants. There were some setbacks such as tritium target problems at 17 MeV: D in Au, D in Ti, T in Au/Ti. In March 2012, a target was "ruined" because of D implantation in a calibration measurement. It was queried whether it would be better to use a silver backing rather than a gold backing. The PTB uses silver. The key dates are: 1 March 2013, energy distributions and parameters required for the analysis were produced; 23 April 2013, KCWG meeting dedicated to CCRI-K11 comparison; 30 September 2013, final reports of the participants, approved by their institutions, at the disposal of the evaluator; 31 December 2013, compilation of the results submitted by the participants and the evaluated key comparison reference values to be circulated to the participants for comments and approval; April 2014, final report of the evaluator sent to all members of CCRI(III) for discussion and approval; summer 2014, a summary report will be prepared for publication in *Metrologia* (autumn 2014) providing the members of CCRI section III approve the evaluated results. The three missing groups will be informed about the deadline. Final results should be sent to Mr Los Arcos at the BIPM.

### 6.1.2. CCRI(III)-K8 thermal neutron fluence – progress report Ralf Nolte

This measurement of the fluence of thermal neutrons included four detectors with different responses and has been running for five years. The NPL, NMIJ, PTB, and CIAE participated. Results have been disclosed to the participants and a draft A report has been prepared and circulated. An attempt to check normalization failed and the discrepancies will stand. The PTB and NMIJ are in good agreement. The NPL is consistently lower by -6 % to -9 % for all conditions. The CIAE results are discrepant and it is thought that either the temperature is wrong or there is an undetected epithermal component in their beam. Only the NPL and NMIJ are still operating. It was thought that it is time to convert to draft B despite the large discrepancies. NIST does not have a thermal neutron beam. NMIJ is satisfied with its very small uncertainties. There was considerable discussion on how to proceed, including how to deal with very discrepant results, whether standard techniques should be used and if there is a normalization problem (Au foils). Pursuant to this there was a suggestion for a set of Au foil measurements. Italy is interested in doing this. NIST *have done it in the past, and it could be done again, but it would be a development project*. 4πβ-γ capability for use with foils is no longer very widespread. This comparison measurement was sensitive to temperature, which Au counting is not. A former Au comparison, reported by Axton in *Metrologia*, **6,** (1970), 25-32, was successful.

One possibility is to proceed to draft B and then carry out an Au foil comparison. The Au measurements would be supplementary. All participants have a copy of the potential draft B. A search was made to find someone to organize the Au-counting exercise. The use of foils makes counting gold difficult. A debate on how to treat the results started and continued the following day. The decision was to produce a draft B report based on the draft A report, which is already available. The statistical analyses will be based on an unweighted mean, as it was thought that the very small errors by the NMIJ were probably carrying too much weight.

### 6.1.3. CCRI(III)-K9.AmBe.1 emission rate – progress report Neil Roberts

K9.AmBe.1 is a subsequent key comparison with CIAE, NIM, LNHB, and NPL as a link to the original K9. NIM provided the Am-Be source which has three times higher activity than the previous source. The present situation is: NIM sent a report to NPL, NPL measurements are complete, LNHB measurements are due in May 2013, CIAE measurements are due in July 2013, and ***ENEA (Italy) needs to confirm its interest***. There is a problem getting it into and out of France, so it has not yet been sent to France. It is currently delayed because the French authorities require more documentation than other countries; the LNHB is discussing the situation with the authorities. The source was sent to to NPL as a temporary import; it must be returned in 12 months (July 2013). It will be difficult to fit LNHB into the schedule, although it may be possible to extend the deadline to 24 months (July 2014). Several questions were discussed including whether the protocol should be written by the NPL; to whom the results should be sent; and whether there should be optional anisotropy measurements. It was noted that the BIPM should receive the results and ***the protocol should be written as soon as possible. A copy of the protocol should be sent to the CCRI Secretary, Mr Los Arcos***. All participants must agree to the protocol. ENEA would like to see the source but not before September 2013 and they would require 1-2 months to do it. The scheduling for the ENEA is complicated but it can measure the anisotropy.

## 6.2. Future needs for CCRI(III) comparisons

Dr Thomas commented that for future key comparison ideas, the strategy document can be used as a guide. Long- and medium-term requirements may not yet be ready for a comparison. Short-term requirements included: comparisons of $H_p(10)$, standards for fusion, high energy standards; spectrometry was mentioned at the last meeting. It was queried whether or not spectrometry is a CCRI-type of activity and what about 14 MeV (d-t), 2.5 MeV (d-d) neutrons? Fusion requires very intense fields and probably pulsed fields. At present metrology labs cannot provide such fields. It was queried if there is a way to proceed.

The possibility of carrying out calibrations of operational quantities was queried. Techniques for calibrating survey instruments are well covered in ISO standards (8529 parts 1 - 3) and at least one regional comparison is under way for this type of device – see 6.3.1. Calibrations of personal dosimeters are not as well advanced because not much has been done to underpin the quality of their calibrations. Very little guidance is found in the ISO standards.

The issues with calibrations to personal dose equivalent were queried. Key comparisons demonstrate that it is possible to produce standardized fields, but is it possible to perform $H_p(10)$ calibrations and all get the same result? One problem is that personal dosimeters are insensitive. The way forward is probably to use an active personal dosimeter. These are now available, e.g. Thermo Fisher Scientific EPD-N2, Mirion DMC 2000 GN, Fuji Electric NRF31. Reasons for not holding a comparison were

discussed, including whether there is enough interest and the fact that it is not directly a comparison of a primary quantity but of calibration techniques, although it would show up errors in the primary quantity. Reasons for holding a comparison: if undertaken using neutron sources, many more labs than usual could participate; electronic personal dosimeters are small and can be sent easily to other countries; readout is easy, particularly for the EPD-N2. There are international standards for personal dosimeter performance. In many countries there are national requirements for regular personal dosimeter testing with consequences for dosimetry services if they fail.

There was not much interest in running a comparison, even though it is "relatively" simple, however, see also section 15.

## 6.3. RMO neutron comparisons:

### 6.3.1 Present comparisons

Neil Roberts discussed the EURAMET #936 Long Counter Comparison: Measurements were made at the NPL in 2008. Radionuclide sources and monoenergetic neutrons were measured. A paper was presented at NEUDOS11 (2009). The PTB De Pangher was 1.6 % higher than the NPL De Pangher but both had the same response function shape (difference was due to $BF_3$ gas pressure). There was good agreement between the NPL and the IRSN. The IRSN has subsequently amended its response calculations. Since then some source emission rates have been revised. Am-Li increased by 1.08 % due to an error in the Mn bath correction factors. Am-F increased by 1.19 % because the previous value did not include new Mn bath correction factors. New values will be fed into a new normalization factor for the NPL long counter response functions. New spectra are available for Am-Li, Am-F, and Am-B. The final NPL long counter response functions are required for writing up the comparison. It was queried whether there had been any progress on response function measurements/calculations for the PTB De Pangher. It was noted that the Long counter is not a primary instrument but it is an efficient instrument.

EURAMET #1104: this concerned Bonner sphere measurements of Am-Be sources. The goal was to obtain improved Am-Be spectra for different sized sources, particularly at low energies where high-resolution spectrometers do not work. Internal scattering leads to a size dependence of the spectra. Analysis is ongoing. There is an ISO8529 recommended spectrum for Am-Be sources, but it is not adequate (evidence shows this), especially at low energies.

APMP.RI(III)-S1: Neutron survey instrument calibration. All measurements have been completed. Transfer instruments were monitored between measurements made by the KRISS and were stable within uncertainties. Final reports were submitted except for one participant that will submit the report by 24 April 2013. The results look encouraging. Only the shadow cone method was used for calibration, except at KRISS and NIM. KRISS, NIM, BARC, ARPANSA, VNIIM, INER, and NMIJ were participants. The source was $^{252}Cf$ in most cases.

## 7. EXCHANGE OF INFORMATION ON NEUTRON METROLOGY IN PROGRESS, NMIs Part 1:

**7.1.** **CMI (Czech Republic)**: Recent activities at the CMI were described. Revitalization of the 14 MeV neutron generator has been completed. Associated particle monitoring is not finished. Bonner sphere measurements of spectra around pulsed sources with passive detectors of thermal neutrons have been carried out and will be presented at NEUDOS12, to be held in Aix-en-provence, France, in June 2013. The CMI can no longer participate in the organization of a key comparison devoted to the calibration of personal dosimeters. It measured several sources in its Mn bath. These will be fluence standards: $^{252}$Cf, Am-Be. It is interested in calibrations and tests of neutron area and personal dosimeters in ISO 8529-1 neutron fields. It was noted that the source should be 75 cm from the face of ISO water phantom. The CMI has carried out low resolution neutron spectrometry with its Microtron. Mn tablets are used as activation detectors. Results were published in *Rev. Sci. Instrum*. **83**, 083502 (2012): Microtron MT25 as a source of neutrons. It has measured neutron spectra at the interim storage for spent nuclear fuel around casks, including new CASTOR-V19 casks. MCNP and MCNPX are routinely in use and are part of its programme of numerical dosimetry. The CMI did not participate in any comparisons during the last period.

**7.2.** **ENEA (Italy)**: 2008-2012 activity. Neutron work in the lab was stopped for many years, but it has been restarted. Its responsibilities include neutron standards. A new building which houses a low scatter room has been built. It has a modernized Mn bath that incorporates a Marinelli beaker and a NaI(Tl) detector. The ENEA is presently carrying out Mn bath testing. The detector was calibrated using a known quantity of $MnSO_4$. It is characterizing neutron leakage and neutron capture on Mn, O, and S as a function of Mn concentration. It also operates a long counter which is used to partially validate the Mn bath results. The ENEA is re-establishing a thermal neutron flux density standard consisting of six Am-Be sources located on a horizontal plane moderated by graphite and polyethylene, with a small cavity in the centre. Neutron monitors are calibrated with an Am-Be source. The ISO 8529-2 procedure is followed. A closed circuit TV with special software is used to read the instruments. Instrument readings as a function of distance are used to extract the desired result. The ENEA would like to join the CCRI(III) and will write a letter to that effect.

**7.3.** **KRISS (Republic of Korea)**: The KRISS operates a 1.25 m diameter Mn bath. Several of its measurements of $^{252}$Cf and Am-Be sources were described. It has constructed a thermal neutron field starting with an Am-Be source. It uses graphite for moderation: $1.4 \times 1.2 \times 1.2$ m$^3$. The source is not in the centre of a graphite pile. The density of the graphite is 1.786 g/cm$^3$ and the only impurity is boron (GDMS method). The boron component is ~0.12 micrograms/gram. The facility has been simulated using MCNPX: Au foils were placed in plugs and measurements compared with MCNPX calculations. This required the creation of an NaI(Tl) system for Au foil measurements. Gamma-ray efficiency calculations were done using PENELOPE, GEANT4 and these were compared with gamma CRMs. There is a new $^{252}$Cf source in the neutron irradiation room. Neutron spectroscopy is carried out with a Bonner Sphere Spectrometer (BSS). This has been used to measure the spectral fluence of cosmic neutrons. Results from two different sites (Bohyunsan Optical Astronomy Observatory, BOAO, and KRISS) have been compared. The very humid conditions at BOAO may help to explain the observed differences. There is now a system for activation foil-based BSS. Future plans by the KRISS include Bonner Sphere Spectrometry of accelerator-produced neutrons, neutron

spectrometry with liquid scintillation counters for high resolution spectroscopy, characterization of their thermal neutron field, and producing a draft for APMP.RI(III)-S1.

**7.4.** **LNE (France)**: Cheick Thiam: The addition of Cerenkov-Gamma coincidence counting into its Mn bath was the subject of the PhD thesis of Florestan Ogheard. Modelling was carried out using MCNPX, FLUKA, and GEANT4. The facility allows for anisotropy measurements. A 2 % discrepancy was found between MCNPX-FLUKA and ~5 % MCNPX-GEANT4. Low rates were obtained in the gamma and beta channels. Both channels need to be improved: the beta channel uses coincidence between two PMTs; gammas are detected using a NaI(Tl) detector. Another approach is to use the triple to double coincidences ratio in the beta channel. Future work includes experimental validation of the MC calculation of the bath efficiency (two approaches). It is also involved in a bilateral comparison of $^{252}$Cf with the NPL.

**7.5.** **LNE/IRSN (France)**: The neutron irradiator facility has been updated with a new detector transportation system. It is expected that the old Am-Be neutron source will be replaced in 2014. LNE/IRSN was the host laboratory for the comparison K-11 at the AMANDE facility. At AMANDE there were updates to the IRSN long counter characterization including a revision of the dead time and a new determination of the effective centre. It is developing a CMOS recoil proton telescope to work in the range 5 MeV - 20 MeV and a gaseous μ-time projection chamber in the range 8 keV to 1 MeV. It studied low-energy monoenergetic neutron fields below 100 keV. LNE/IRSN will inaugurate a new facility dedicated to cell irradiation with a micro-beam for radiobiology research studies at the AMANDE facility in 2015. Investigations for the development of high-energy quasi-monoenergetic neutron fields in Nice, France, have concluded and a collaboration project with ITER for a new facility is now uncertain.

**7.6.** **NIM (China)**: Its work from 2010 to the present and its future plans were discussed. NIM's main work is routine calibration. Its Am-Be derived reference neutron radiation field will be modelled. A Mn bath facility was put into operation in 2009 and it is participating in the supplementary comparison CCRI(III)-K9.Am-Be.1. Future plans include the improvement of its neutron reference radiation field, development of a method to calibrate neutron personnel dosimeters, and cooperation with other groups. The laboratory consists of only one person. The NIM has a $^{137}$Cs irradiator in its neutron laboratories for routine testing of photo sensitivity of neutron detectors.

**7.7.** **LMRI-CIEMAT (Spain)**: After eight years, the new Neutron Standards Laboratory is complete. Work commenced in 2005 and there were many problems along the way. Construction work finished about six months ago. The laboratory is now awaiting a license. It includes an irradiation room with shielding that is suitable for 1 mg $^{252}$Cf as a maximum. The sources are stored under water. The LMRI-CIEMAT has $^{252}$Cf ($4.3 \times 10^8$) and Am-Be ($1.1 \times 10^7$) sources. The system for remote manipulation of sources uses a sophisticated computer program. It has neutron monitors, personal dosimeters, and a Bonner sphere system that uses Au foils. The LMRI-CIEMAT has measured a neutron spectrum around a cyclotron to optimize shielding. It is developing a new spectrometer based on recoil protons detectors. In the future it will design and construct shadow cones, characterize its irradiation room, develop calibration procedures, complete a bilateral comparison with the CMI, design and develop a heavy water sphere for Cf, design a thermal neutron facility using the storage pool, and build a Mn bath.

## 8. STRATEGIC PLANNING 2013-2023:

A document was prepared by Dr Carneiro and presented by Mr Los Arcos. The new CCRI strategic plan for the period 2013-2013 discusses, among other things, action plans, CCRI working groups, BIPM work load in comparisons and calibrations, and stakeholders. Of further interest to the CCRI(III) are the NMI work load in comparisons, the existence of one working group, several actions, and stakeholders' participation. The strategic initiatives discussed include: installation of a LINAC at the BIPM; a focus on stakeholders; moving from air kerma to absorbed dose to water; and the International Reference System (SIR) which might reduce comparison work for the other two groups. The delegates were asked to comment on document CCRI(III)/13-01 (restricted access documents).

### 8.1. Short term (2013-2015), medium term (2013-2019), long term (2013-2023)

A table was presented for 2013-2015 and activities for sections I, II, III, and the BIPM were noted.

### 8.2. Status of the CCRI strategic plan

There is an evaluation form for the CCRI Strategic Plan for the period 2013-2023 in restricted access documents (CCRI(III)/13-15). The Strategic Plan will be presented to the board of directors in October 2013. The deadline for final submission of a new strategy plan is the end of May 2013. The delegates were asked to complete the evaluation form CCRI(III)/13-15.

### 8.3. CCRI(III) strategic actions and working groups 2013-2023

During this session several things were discussed including delegate's wish lists, comparisons, news from other NMIs, the current state of affairs, CMCs and the CIPM MRA. Throughout the discussion there was an effort to identify new trends.

#### 8.3.1. Short term:

- Comparison of personal dose equivalent: There is perhaps enough interest here, but a pilot is needed.
- Increase meaningful dialogue between NMIs and DIs (designated institutes): Perhaps an NMI person could come to these meetings with a delegate. The situation in China is confusing.
- New neutron cross-section data – identify needs and potential funding.
- Standards for fusion – identify needs and possible actions: obtain talks on trends.
- Evaluation and improvements of the CIPM MRA.
- Stakeholder workshop (both institutional and end-user): should section 3 be separated or not.
- New needs in public security, health, and industry.
- Radiobiological data for neutrons: no ideas at present.

The delegates were reminded to send any ideas to Mr Los Arcos at the BIPM and to Dr Thomas within approximately one week.

8.3.2. Medium term:

- Operational quantities for radiation protection (nano-dosimetry) - needs in the neutron area.
- Radiobiological data for neutrons – is this a Section (III) activity.
- High-energy (>20 MeV) neutron standards – is there a way forward.
- New needs in public security, health and industry – what are the needs.
- New therapy modalities (hadron, BNCT) – neutron metrology needs.

Some of these are related to high-energy standards.

8.3.3. Long term:

- Any long-term needs identified since the last edition of the strategic plan.

Dr Gressier gave a presentation on the characterization of a Bonner sphere system which illustrated the need for high-energy references to solve the discrepancies between different models used in simulation codes for neutron reactions above several tens of MeV.

Dr Harano raised the problem of characterizing BNCT fields which are now increasingly being produced using accelerators rather than reactors.

Dr Kralik noted the requirement to perform neutron field measurements around proton therapy facilities.

### 8.4. Input from RMOs: AFRIMETS, APMP, COOMET, EURAMET, SIM.

### 8.5. Input from institutional stakeholders.

There is a need to better define the stakeholders in CCRI(III). Each NMI could provide feedback about this for the short term, medium term, and long term.

## 9. CIPM MRA Part 2:

### 9.1. RMO activities: AFRIMETS; APMP; COOMET; EURAMET; SIM.

Dr Dewey touched on highlights from the SIM document (CCRI(III)/13-02). The NMIJ delegate discussed some measurements. There was a brief discussion concerning New Zealand and Australia.

### 9.2. BIPM-KCDB: Appendix C submissions for discussion and approval

There were no CMCs to discuss and approve. The meeting was reminded that it had been agreed that the review of CMCs could occur in the Section III meeting. This was because neutron representation in many RMOs is very sparse. **This is something that needs to be on the next agenda**. It would take a few hours to do the reviews. The CCRI(III) was reminded that we are the experts. IRSN intends to present some new CMCs at the next meeting and Brazil and Italy have something in the works, but

they appear to have followed, at least initially, the usual RMO route. The CMC approval process was described. The chair of the technical committee in the RMO evaluates candidate CMCs. Finally, they are presented to this committee for approval. CMCs do need supporting data. For more details, please see document CIPM MRA-D-04.

### 9.3. JCRB Report

Highlights of the 28th, 29th, and 30th meetings of the JCRB were mentioned. A major topic during these meetings was the way CMCs are treated. There is an ongoing call for better organization of CMCs. Greyed-out CMCs and the way capabilities are added and removed are other important topics.

## 10. EXCHANGE OF INFORMATION ON NEUTRON METROLOGY IN PROGRESS, NMIs Part 2:

**10.1. NMIJ/AIST:** Recent activities in neutron standardization at NMIJ/AIST were presented. Their work includes measuring fast neutron fluence; the production of accelerator-based monoenergetic spectra; measuring thermal neutron fluence rates; a graphite pile produced thermal neutron field; and measuring neutron emission rates. They had to rebuild the graphite pile following the earthquake in 2011; it is now more 'earthquake-proof'. The accelerator was also damaged by the earthquake but it is now working again. It is developing a $D_2O$ Moderated $^{252}Cf$ neutron field and the service will start in 2014. They are also developing a high-E neutron field (20 MeV to 100 MeV). They have extended the lower limit on their TOF measurements. They participated in comparisons K11 and APMP.RI(III)-S1 (calibration of neutron survey meters). They have developed a compact flat-response neutron detector to use as a transfer instrument in Japan. It has a good flat response from 10 eV to 20 MeV. It consists of two $^{3}He$ counters in a polyethylene moderator. The positions and $^{3}He$ pressures of the two counters have been optimized to achieve a flat response. They installed a pulsing system on their 4 MV Pelletron in order to apply the time of flight technique. They plan to incorporate thermal neutron fluence rate and neutron emission rate measurements into the JCSS (Japanese radiation system) in 2013.

**10.2. NIST:** Highlights at NIST included the construction of a new cold neutron beam in the new guide hall to be put into use in mid-2014 (it will be used for fundamental physics with cold neutron experiments); the large Mn bath was renovated; a thin foil neutron monitor was successfully calibrated to 0.06 % absolute accuracy; a second small Mn bath was put into routine service; and a segmented liquid scintillator-based fast neutron counter (FaNS) was built. The FaNS is currently being tested.

**10.3. NPL:** With regard to the NPL's Mn bath, an observed decrease in Ra-Be source strength is partly due to unscrewing of the outer Be shell. Retightening the source increased its output by 0.5 %. However, it is still 0.5 % below its historic mean. There may be other factors involved. The NPL has measured the spectra of Am-F and Am-B sources using Bonner sphere measurements. These were compared with spectra calculated using SOURCES-4C and MCNP. Am-B agrees with Zimbal and Marsh, but

not with ISO. SOURCES-4C has proved very useful, especially at low energies. They have a theoretical design for a facility producing a 1/E spectrum. They are part of a Transpolar Cosmic Ray Dosimetry Collaboration which measures dose over the poles using TEPC measurements. There is good agreement with codes. They are studying photon doses and spectra from neutron fields (Van de Graaff, VdG, targets and neutron sources) because these are becoming increasingly important for neutron detecting instruments with incomplete gamma rejection. These can be modelled with MCNP and GEANT (via SWORD). An HPGe detector is on loan from the Radioactivity Group at the NPL. A digital acquisition system has been implemented, but it is not ready for prime time yet. They are exploring plastic scintillators with pulse shape discrimination. They have had some success with gamma/neutron discrimination. The use of organic diodes as neutron sensors has not yet been successful. There are problems with large and fluctuating noise signals and no neutron signals have been observed. New projects include: a self-calibrating absolute Mn bath (similar to the LNHB); work with organics, plastics, and graphene; and a directional dose meter (Graham Taylor).

**10.4.** **NRC Canada:** NRC Canada is in the process of re-commissioning its neutron programme. They have a large irradiation lab (16m × 16m × 10m), an Am-Be source (1.6e6 n/s) and a neutron generator. They have carried out radiation shielding calculations for the neutron generator using MCNP5 to calculate the neutron dose at various locations. They have started renovating their Mn bath which is now 75 % full with $MnSO_4$. They have been able to count neutron-induced counts and to observe the gamma spectrum.

**10.5.** **PTB: 2011-2013.** The topics included were: VdG, recoil proton telescope RPT1, time correlated associated particle standard (TCAP), new thermal field at PTB, high energy neutrons and nuclear data activities, and future perspectives. There were belt problems with the VdG. CIGO belts run reasonably well on the VdG; maximum voltage was limited to 3.3 MV; energy resolution 0.8 -> 1.2 keV at $^{13}C(p,\gamma)$ resonances; pulsing running at 2 ns FWHM for 3.3 MeV protons. It is becoming increasingly difficult to get spare parts. The availability of spare parts is becoming critical for the CV28 cyclotron as well. The power triodes were discontinued and there are less off-the-shelf solutions possible. They abandoned plans to upgrade to a Tandetron Facility. Instead they are looking at a replacement of the VdG; possibly with an NEC 2 MV Pelletron at a cost of 1.2 million euros. There is cooperation with IRMM sample production unit to obtain new tristearin or polyethylene radiators for the PTB proton recoil telescopes. Status of the $T(d,n)^4He$ TCAP Standard at PTB: there is a dedicated MC simulation; design by the PTB workshop is complete; and construction is to be finished before June 2013. They use MCNPX Patch MCUNED (P. Sauvan, UNED Madrid); MCNPX with low energy ions works better with neutron production. This is used for simulation of the TCAP setup. In fact this is a replacement for their TARGET code. There is a new thermal standard consisting of Am-Be sources plus a graphite block. Its dimensions are 1.5 m × 1.5 m × 1.8 m. It has been modelled using MCNP and PHITS calculations. Fluence measurements have been made with $^{197}Au(n,\gamma)$ and CCRI(III)-K8 SP9 counters. The low fluence rates result in low activities. There is a new $^{252}Cf$ source at the PTB: 6e8 n/s. Their nuclear data activity with ERINDA will finish in October 2013. They are studying cross sections for background studies such as $^{nat}Ge(n,x)^{68}Ge$ with regard to MetroFission (NDA). In the area of high energy neutrons they are working with RPTs for 35 MeV-200 MeV at iThemba LABS. In summary: the VdG accelerator is partially recovered; their problems with RPT1 are partially solved; the TCAP standard is taking shape; the new thermal field at PTB is operational; they still carry out work with high energy neutrons and nuclear data; and their future perspectives contain some unknowns. **Further discussion is needed on how to proceed with the K8 comparison**.

**10.6.** **VNIIM:** Their work includes scientific research, key comparisons, certification of secondary standards, testing and certification of new types of measuring systems. They have a set of radionuclide sources, a TD/DD neutron generator, and 3 methods of measurements of radionuclide sources emission rates. During the past two years a lot of repairs were carried out. They participated in K11 using the home-made MAR-150 device to measure the three lowest energies. They participated in APMP.RI(III)-S1. They operate a heavy water moderated Cf source. As part of their routine work, a secondary standard for the Russian defence ministry was re-established; emission rate measurements were carried out; and an irradiation facility for the calibration of neutron sensitive devices was operated. There is a new device for gold foils induced activity measurement using beta-gamma-coincidence technique in geometry close to $4\pi$ for both types of radiation. A secondary standard for thermal neutron fields, being used for the quality control of nuclear power station safety systems at the Kurchatov Institute, was certified.

## 11. EXCHANGE OF INFORMATION ON NEUTRON METROLOGY IN PROGRESS, INSTITUTIONAL STAKEHOLDERS:

**11.1.** **ICRP:** Nothing to report.

**11.2.** **ICRU:** A document, prepared by Dr Burns, BIPM and ICRU, was presented by Mr Los Arcos. It is available on the CCRI(III) website. It lists various reports that are either available or under preparation. Most are concerned with traditional dosimetry. There is some joint ICRU/ICRP work. There are practical radiological protection recommendations on mitigating secondary cancer risks in modern radiation oncology. Finally, RC 20 is of some interest to us. Report 85a was supposed to correct some errors in 85. It failed to correct them all, and in fact it added some new errors.

## 12. PRESENT AND FUTURE MEMBERSHIP OF THE CCRI(III)

ENEA would like to become an official observer. A letter must be sent by the laboratory to the Director of the BIPM. These letters are forwarded from the Director to the CC, which meets next on 17 May 2013. “Observer” requirements are not clearly defined. The NRC should also become an observer (they are a guest at present). Interest in attending CCRI(III) has been shown by India. A representative failed to attend this year due to funding problems.

## 13. WORK PROGRAMME OF THE BIPM IONIZING RADIATION SECTION (FOR INFORMATION)

The Ionizing Radiation staff consists of nine persons. Their work includes dosimetry, radionuclide metrology, thermometry, and international coordination. First, activities in dosimetry were described: RI-A1-1 to RI-A1-5; low- and medium-energy x-rays; mammography qualities with x-rays; $^{60}$Co and $^{137}$Cs (gamma-rays); replacement of a $^{60}$Co unit; construction of primary ionization chambers; high energy comparisons using the BIPM calorimeter standard at NMI accelerators; strategic plan for high-energy photon comparisons; a budget reduction at the BIPM; the Accelerator Dosimetry Working Group (ADWG) is issuing a new strategy; they are still trying to obtain an accelerator; brachytherapy $^{192}$Ir HDR comparisons; and develop absorbed-dose standard for medium-energy x-rays. Radionuclide activities included: SIR (equivalence of $\gamma$ emitters); impurity measurements using gamma spectrometry; liquid scintillation counters; triple-to-double-coincidence-ratio system (TDCR); $4\pi$-$\beta$(PC/PPC)-$\gamma$(NaI) (anti) coincidence counting system; SIR extension to pure beta emitters (ESIR); SIR transfer instrument (SIRTI) for short-lived radionuclides; develop SIRTI for other radionuclides; organize/participate in the CCRI key comparisons (5); and maintain BIPM primary methods for SIR and CCRI comparisons. BIPM internal thermometry calibrations were also described. Finally, international coordination activities were described: in support of CIPM committees there are CCRI meetings, BIPM monographs, and *Metrologia* special issues; CCAUV meetings; JCGM. The international organizations that the CCRI works with include: ICRU, ICRM, and the IAEA Scientific Committee of SSDL (secondary standards dosimetry laboratories) network. Expect IAEA-BIPM contacts for future cooperation on radionuclide reference materials.

Ionizing Radiation Programme 2013-2015 Strategic Actions. Reference documents for this discussion were: BIPM programme of work and budget for 2013-2015 and the CCRI strategic plan for the period 2013-2023. Dosimetry deliverables 2013-2015 and activities were described. Radionuclide deliverables 2013-2015 and activities were described. Coordination activities were described. Four strategic initiatives were discussed: installation of a LINAC at the BIPM; focus on stakeholders; from air kerma to absorbed dose in water; and the SIR (extensions to alpha and beta emitters: comparisons optimization; SIRTI transfer instrument). Actions: short term (2013-2015) 16 actions; medium term (2016-2019) nine actions; long term (2020-2023) six actions. Tables were then presented.

***Everyone was reminded to fill in evaluation forms as soon as possible (one week; BIPM deadline end of May 2013; Dr Thomas deadline (section III): end of next week)***. A PDF version has been uploaded to the working documents. Particular consideration should be given to our stakeholders.

## 14. CCRI(III) WORKING DOCUMENT STATUS

### 14.1. Bibliography

***A separate list of publications from each member*** (even if it is already in the report) should be sent to Mr Los Arcos.

### 14.2. Other publications

The question was raised as to whether there is anything available on uncertainties or analysis relevant to neutrons. There appears to be nothing specific but the recent *Metrologia* special issue does cover uncertainties. It was recalled that draft B reports of comparisons should be sent to the BIPM (Mr Los Arcos). They are published in the *Metrologia Technical Supplement*.

## 15. OTHER BUSINESS

a) Personal dose meters. A comparison of dose delivered to the dose meters, using possibly Fuji NRF31 and EPD N2 instruments, was discussed. **A pilot laboratory is needed**; the PTB is a possibility. The dosimeters would need to be transported around the world. An evaluator is also needed. The quantity to be measured would be total personal dose equivalent $H_p(10)$. In view of the low sensitivity of these devices the feasibility should first be tested at one or two laboratories (e.g. NPL, PTB). Devices to measure $H_p(10)$ are traditionally calibrated at a distance of 75 cm from the source in very large room where room return is small. Hopefully, the scattered neutrons are not very important in this case. For more information consult CIPM MRA document: CIPM MRA-D-05. This can be registered without a protocol, but the protocol should come quickly.

Another pilot study was also proposed.

b) Au foil activity measurements (really a radioactivity measurement). This can be a first step towards solving the K8 problems. **NPL will make proposals**.

## 16. DATE OF THE NEXT MEETING

This will be decided during the CCRI meeting. It will be held during 2015.

| LIST OF ACTIONS | | | |
|---|---|---|---|
| **Action** | **Description** | **On** | **Deadline** |
| A13-01 | ENEA (Italy) need to confirm interest on CCRI(III)-K9.AmBe.1 emission rate comparison to pilot laboratory (section 6.1.3). | ENEA | Jan 2014? |
| A13-02 | CCRI(III)-K9.AmBe.1 protocol should be written and sent as soon as possible to the Executive Secretary José María Los Arcos (section 6.1.3). | Pilot Laboratory | Feb 2014 |
| A13-03 | CMCs review during CCRI(III) to be included in next meeting Agenda (section 9.2). | D.J. Thomas | Apr 2015 |
| A13-04 | Further discussion is needed on how to proceed with the K8 comparison (section 10.5). | All participants | Dec 2013? |
| A13-05 | The delegates are asked to fill out this evaluation form CCRI(III)/13-15 (section 13). | All | 30 Apr 2013 |
| A13-06 | A separate list of publications from each member to be sent to J.M. Los Arcos (section 14.1) | All | May 2013 |
| A13-07 | A pilot laboratory is needed for the personal dose meters comparison (section 15). | PTB/all | 2015 |
| A13-08 | NPL to make proposals on Au foil activity measurements (section 15). | NPL | 2013? |

## APPENDIX R(III) 1
## Working documents submitted to the CCRI(III) for its 19th meeting

Documents restricted to Committee members can be accessed on the restricted website.

| Document CCRI(III)/ | |
|---|---|
| 13-00 | Draft Agenda-revised 20130424, D. Thomas and J.M. Los Arcos, 2pp |
| 13-01 | CCRI strategic plan for the period 2013- 2023, K. Carneiro, P. Sharpe, L. Karam, D. Thomas and J.M. Los Arcos, 23pp |
| 13-02 | Report of SIM Laboratories to the CCRI 2013, L. Karam, 9pp |
| 13-03 | Report on ICRU activities, D.T. Burns, 1p |
| 13-04 | Report of the NIST Neutron Physics Group to CCRI Section III, M.S. Dewey, 9pp |
| 13-05 | NIM Report to the 20th meeting of CCRI(III), Z. Hui and Z. Jian, 3pp |
| 13-06 | Report to the CCRI Section III on the activity carried out at the ENEA-INMRI on neutron measurements in 2008-2012, S. Loreti, L. Quintieri and P. De Felice, 7pp |
| 13-07 | NPL Neutron Metrology Group, Publications 2004-2013, D. Thomas, 4pp |
| 13-08 | Recent activities in neutron standardization at NMIJ/AIST, H. Harano, T. Matsumoto, A. Masuda, A. Uritani, K. Kudo, 7pp |
| 13-09 | Recent publications from the neutron group of NMIJ/AIST from 2011 to 2013, H. Harano, 2pp |
| 13-10 | Recent activities in neutron standardization at KRISS, H. Park, J. Kim, and K-O. Choi, 8pp |
| 13-11 | Recent Developments in Neutron Metrology at the NPL, A. Bennett, S. Cheema, N. Hawkes, N. Horwood, P. Kolkowski, C. Matei, N. Roberts, G. Taylor, and D. Thomas, 7pp |
| 13-12 | VNIIM activity in neutron metrology during the 2011 -2013, N.N. Moiseev, 1p |
| 13-13 | Report of activity of the COOMET Technical Committee 1.9 “IONIZING RADIATION AND RADIOACTIVITY”, V. Krutikov, 4pp |
| 13-14 | Developments in neutron metrology at the LNE-IRSN in 2011 and 2012, V. Gressier, 7pp |
| 13-15 | Evaluation Form for the CCRI Strategic Plan 2013-2023, K. Carneiro, 1p |
| 13-16 | CIEMAT-LMRI Report to the 20th Meeting of CCRI (III), R. Méndez, 3pp |
| 13-17 | 2013 Report on Neutron Metrology at the National Research Council Canada, J.P. Archambault, P.R.B. Saull, 6pp |
| 13-18 | KRISS Recent Publications, J. Kim, 1p |

13-19 PTB-Publications 2011-2013, R. Nolte, 8pp

13-20 CCRI(III)-2013 Minutes, Scott Dewey, 11pp