Bureau International des Poids et Mesures

Consultative Committee for Ionizing Radiation (CCRI)

17th Meeting (May 2001)

Note on the use of the English text

To make its work more widely accessible the International Committee for Weights and Measures publishes an English version of its reports.

Readers should note that the official record is always that of the French text. This must be used when an authoritative reference is required or when there is doubt about the interpretation of the text.

TABLE OF CONTENTS

MEMBER STATES OF THE METRE CONVENTION AND ASSOCIATES OF THE GENERAL CONFERENCE

as of 29 May 2001

Member States of the Metre Convention

Argentina
Australia
Austria
Belgium
Brazil
Bulgaria
Cameroon
Canada
Chile
China
Czech Republic
Denmark
Dominican Republic
Egypt
Finland
France
Germany
Greece
Hungary
India
Indonesia
Iran (Islamic Rep. of)
Ireland
Israel
Italy
Japan
Korea (Dem. People's Rep. of)
Korea (Rep. of)
Mexico
Netherlands
New Zealand
Norway
Pakistan
Poland
Portugal
Romania
Russian Federation
Singapore
Slovakia
South Africa
Spain
Sweden
Switzerland
Thailand
Turkey
United Kingdom
United States
Uruguay
Venezuela

Associates of the General Conference

Cuba
Ecuador
Hong Kong, China
Latvia
Lithuania
Malta

THE BIPM AND THE METRE CONVENTION

The International Bureau of Weights and Measures (BIPM) was set up by the Metre Convention signed in Paris on 20 May 1875 by seventeen States during the final session of the diplomatic Conference of the Metre. This Convention was amended in 1921.

The BIPM has its headquarters near Paris, in the grounds (43 520 m^2) of the Pavillon de Breteuil (Parc de Saint-Cloud) placed at its disposal by the French Government; its upkeep is financed jointly by the Member States of the Metre Convention.

The task of the BIPM is to ensure worldwide unification of physical measurements; its function is thus to:

- establish fundamental standards and scales for the measurement of the principal physical quantities and maintain the international prototypes;
- carry out comparisons of national and international standards;
- ensure the coordination of corresponding measurement techniques;
- carry out and coordinate measurements of the fundamental physical constants relevant to these activities.

The BIPM operates under the exclusive supervision of the International Committee for Weights and Measures (CIPM) which itself comes under the authority of the General Conference on Weights and Measures (CGPM) and reports to it on the work accomplished by the BIPM.

Delegates from all Member States of the Metre Convention attend the General Conference which, at present, meets every four years. The function of these meetings is to:

- discuss and initiate the arrangements required to ensure the propagation and improvement of the International System of Units (SI), which is the modern form of the metric system;
- confirm the results of new fundamental metrological determinations and various scientific resolutions of international scope;
- take all major decisions concerning the finance, organization and development of the BIPM.

The CIPM has eighteen members each from a different State: at present, it meets every year. The officers of this committee present an annual report on the administrative and financial position of the BIPM to the Governments of

the Member States of the Metre Convention. The principal task of the CIPM is to ensure worldwide uniformity in units of measurement. It does this by direct action or by submitting proposals to the CGPM.

The activities of the BIPM, which in the beginning were limited to measurements of length and mass, and to metrological studies in relation to these quantities, have been extended to standards of measurement of electricity (1927), photometry and radiometry (1937), ionizing radiation (1960), time scales (1988) and to chemistry (2000). To this end the original laboratories, built in 1876-1878, were enlarged in 1929; new buildings were constructed in 1963-1964 for the ionizing radiation laboratories, in 1984 for the laser work, and in 1988 for a library and offices. In 2001 a new building for the workshop, offices and meeting rooms was opened.

Some forty-five physicists and technicians work in the BIPM laboratories. They mainly conduct metrological research, international comparisons of realizations of units and calibrations of standards. An annual report, the *Director's Report on the Activity and Management of the International Bureau of Weights and Measures*, gives details of the work in progress.

Following the extension of the work entrusted to the BIPM in 1927, the CIPM has set up bodies, known as Consultative Committees, whose function is to provide it with information on matters that it refers to them for study and advice. These Consultative Committees, which may form temporary or permanent working groups to study special topics, are responsible for coordinating the international work carried out in their respective fields and for proposing recommendations to the CIPM concerning units.

The Consultative Committees have common regulations (*BIPM Proc.-Verb. Com. Int. Poids et Mesures*, 1963, **31**, 97). They meet at irregular intervals. The president of each Consultative Committee is designated by the CIPM and is normally a member of the CIPM. The members of the Consultative Committees are metrology laboratories and specialized institutes, agreed by the CIPM, which send delegates of their choice. In addition, there are individual members appointed by the CIPM, and a representative of the BIPM (Criteria for membership of Consultative Committees, *BIPM Proc.-Verb. Com. Int. Poids et Mesures*, 1996, **64**, 124). At present, there are ten such committees:

1 the Consultative Committee for Electricity and Magnetism (CCEM), new name given in 1997 to the Consultative Committee for Electricity (CCE) set up in 1927;

2 the Consultative Committee for Photometry and Radiometry (CCPR), new name given in 1971 to the Consultative Committee for Photometry (CCP) set up in 1933 (between 1930 and 1933 the CCE dealt with matters concerning photometry);

3 the Consultative Committee for Thermometry (CCT), set up in 1937;

4 the Consultative Committee for Length (CCL), new name given in 1997 to the Consultative Committee for the Definition of the Metre (CCDM), set up in 1952;

5 the Consultative Committee for Time and Frequency (CCTF), new name given in 1997 to the Consultative Committee for the Definition of the Second (CCDS) set up in 1956;

6 the Consultative Committee for Ionizing Radiation (CCRI), new name given in 1997 to the Consultative Committee for Standards of Ionizing Radiation (CCEMRI) set up in 1958 (in 1969 this committee established four sections: Section I (X- and γ-rays, electrons), Section II (Measurement of radionuclides), Section III (Neutron measurements), Section IV (α-energy standards); in 1975 this last section was dissolved and Section II was made responsible for its field of activity);

7 the Consultative Committee for Units (CCU), set up in 1964 (this committee replaced the "Commission for the System of Units" set up by the CIPM in 1954);

8 the Consultative Committee for Mass and Related Quantities (CCM), set up in 1980;

9 the Consultative Committee for Amount of Substance (CCQM), set up in 1993;

10 the Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV), set up in 1998.

The proceedings of the General Conference, the CIPM and the Consultative Committees are published by the BIPM in the following series:

- *Report of the meetings of the General Conference on Weights and Measures;*
- *Reports of the meetings of the International Committee for Weights and Measures;*
- *Reports of the meetings of Consultative Committees.*

The BIPM also publishes monographs on special metrological subjects and, under the title *The International System of Units* (*SI*), a brochure, periodically updated, in which are collected all the decisions and recommendations concerning units.

The collection of the *Travaux et Mémoires du Bureau International des Poids et Mesures* (22 volumes published between 1881 and 1966) and the *Recueil de Travaux du Bureau International des Poids et Mesures* (11 volumes published between 1966 and 1988) ceased by a decision of the CIPM.

The scientific work of the BIPM is published in the open scientific literature and an annual list of publications appears in the *Director's Report on the Activity and Management of the International Bureau of Weights and Measures*.

Since 1965 *Metrologia*, an international journal published under the auspices of the CIPM, has printed articles dealing with scientific metrology, improvements in methods of measurement, work on standards and units, as well as reports concerning the activities, decisions and recommendations of the various bodies created under the Metre Convention.

LIST OF MEMBERS OF THE CONSULTATIVE COMMITTEE FOR IONIZING RADIATION

as of 29 May 2001

President

G. Moscati, member of the International Committee for Weights and Measures; Instituto de Fisica, Universidade de São Paulo, São Paulo.

Executive Secretary

P.J. Allisy-Roberts, 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: x- and γ-rays, electrons

Chairman

P. Sharpe, National Physical Laboratory, Teddington.

Members

Australian Radiation Protection and Nuclear Safety Agency [ARPANSA], Victoria.

Bundesamt für Eich- und Vermessungswesen [BEV], Vienna.

Bureau National de Métrologie, Laboratoire National Henri Becquerel [BNM-LNHB], Gif-sur-Yvette.

Central Office of Measures/Glówny Urzad Miar [GUM], Warsaw.

D.I. Mendeleyev Institute for Metrology, Gosstandart of Russia [VNIIM], St Petersburg.

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

International Commission on Radiation Units and Measurements [ICRU].

National Institute of Metrology [NIM], Beijing.

National Institute of Standards and Technology [NIST], Gaithersburg.

National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology [NMIJ/AIST], Tsukuba.

National Office of Measures/Országos Mérésügyi Hivatal [OMH], Budapest.

National Physical Laboratory [NPL], Teddington.

National Research Council of Canada [NRC], Ottawa.

Nederlands Meetinstituut, Van Swinden Laboratorium [NMi VSL], AR Delft.

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

Swedish Radiation Protection Institute/Statens Stralskyddsinstitut [SRPI], Stockholm.

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

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

Observers

CSIR National Metrology Laboratory [CSIR-NML], Cape Town.

International Atomic Energy Agency [IAEA], Vienna.

International Organization for Medical Physics [IOMP].

International Radioprotection Association [IRPA].

Laboratório Nacional de Metrologia das Radiações Ionizantes, Instituto de Radioproteçao e Dosimetria [LNMRI-IRD], Rio de Janeiro.

Section II: measurement of radionuclides

Chairman

B.R.S. Simpson, CSIR National Metrology Laboratory, Cape Town.

Members

Australian Nuclear Science and Technology Organisation [ANSTO], Menai.

Bureau National de Métrologie, Laboratoire National Henri Becquerel [BNM-LNHB], Gif-sur-Yvette.

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

CSIR National Metrology Laboratory [CSIR-NML], Cape Town.

D.I. Mendeleyev Institute for Metrology, Gosstandart of Russia [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.

National Institute of Standards and Technology [NIST], Gaithersburg.

National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology [NMIJ/AIST], Tsukuba.

National Office of Measures/Országos Mérésügyi Hivatal [OMH], Budapest.

National Physical Laboratory [NPL], Teddington.

National Research Council of Canada [NRC], Ottawa.

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

Radioisotope Centre Polatom [RC], Swierk.

J.-J. Gostely, Institut de Radiophysique Appliquée [IRA-METAS], Lausanne.

G. Winkler, Institut für Isotopenforschung und Kernphysik “Radiuminstitut” [IIK], Vienna.

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

Observers

Czech Metrology Institute/Český Metrologický Institut [CMI], Prague.

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

International Commission on Radiation Units and Measurements [ICRU].

International Organization for Medical Physics [IOMP].

International Radioprotection Association [IRPA].

Laboratório Nacional de Metrologia das Radiações Ionizantes, Instituto de Radioproteçao e Dosimetria [LNMRI-IRD], Rio de Janeiro.

Nederlands Meetinstituut, Van Swinden Laboratorium [NMi VSL], AR Delft.

Section III: neutron measurements

Chairman

H. Klein, Physikalisch-Technische Bundesanstalt, Braunschweig.

Members

Bureau National de Métrologie, Laboratoire National Henri Becquerel [BNM-LNHB], Gif-sur-Yvette.

D.I. Mendeleyev Institute for Metrology, Gosstandart of Russia [VNIIM], St Petersburg.

Institute for Reference Materials and Measurements [IRMM], Geel.

National Institute of Metrology [NIM], Beijing.

National Institute of Standards and Technology [NIST], Gaithersburg.

National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology [NMIJ/AIST], Tsukuba.

National Physical Laboratory [NPL], Teddington.

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

J.J. Broerse [IRI/TNO], Rijswijk.

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

Observers

Chinese Institute of Atomic Energy [CIAE], Beijing.

International Atomic Energy Agency [IAEA].

International Commission on Radiation Units and Measurements [ICRU].

Consultative Committee for Ionizing Radiation

Report of the 17th meeting

(29 May 2001)

to the International Committee for Weights and Measures

Agenda

1 Opening of the meeting.
2 Report of the sixteenth meeting of the CCRI.
3 Conclusions of the meetings of the three Sections of the CCRI:
  3.1 Section I: x- and γ-rays, electrons;
  3.2 Section II: measurement of radionuclides;
  3.3 Section III: neutron measurements.
4 Discussion of points of common interest:
  4.1 MRA and matters of related interest;
  4.2 Future programme of the BIPM;
  4.3 Report to the CIPM;
  4.4 Membership of Sections;
  4.5 Recommendations to the CGPM (Trends and future needs in ionizing radiation metrology);
  4.6 Future programme of the CCRI.
5 Dates of next meetings.
6 Concluding remarks.

1 OPENING OF THE MEETING

The seventeenth meeting of the Consultative Committee for Ionizing Radiation (CCRI) was held at the Pavillon de Breteuil, in Sèvres, on 29 May 2001.

The following members were present: H. Klein (Chairman of CCRI Section III), G. Moscati (President of the CCRI), T.J. Quinn (Director of the BIPM), P. Sharpe (Chairman of CCRI Section I) and B.R.S. Simpson (Chairman of CCRI Section II).

Also in attendance were: P.J. Allisy-Roberts (Executive Secretary of the CCRI) and C. Thomas (Coordinator of the BIPM key comparison database).

The President complimented the Director on the new Pavillon du Mail saying that it was both a more agreeable and efficient location for Consultative Committee (CC) meetings. He also thanked the Executive Secretary and the Chairmen of the three Sections for the conduct of their meetings. He noted that one effect of the mutual recognition arrangement (MRA) had been to make the Sections more objective in their purpose and better aligned with the work of the BIPM. Each Section had presented good working documents generating interesting discussions. There had been a significant improvement on the resolution of some outstanding problems and some clearer understanding regarding the requirements of the MRA with respect to comparisons, which was beneficial to all concerned.

Professor Moscati thanked Dr Sharpe and Dr Klein as the new Chairmen of Section I and Section III, respectively, for accepting these important roles and he was also grateful to the rapporteurs for agreeing to produce the reports of the meetings in a timely fashion. He expressed his thanks to the outgoing Chairmen, Professor Dr K. Hohlfeld and Dr V. Lewis for their significant contributions to the work of the CCRI and for informing their successors.

Dr Quinn apologized for his absence from the Section meetings owing to prior commitments and was pleased to note the feedback on the new conference room.

2 REPORT OF THE SIXTEENTH MEETING OF THE CCRI

The report of the previous meeting was noted. No specific items were raised.

3 CONCLUSIONS OF THE MEETINGS OF THE THREE SECTIONS OF THE CCRI

The President invited each Section Chairman to present a review of their meeting.

3.1 **Section I: x- and γ-rays, electrons** (Chairman: P. Sharpe)

Dr Sharpe was happy to report that a number of issues that had been unresolved had now reached a satisfactory conclusion. There had been considerable progress on the analysis of the comparisons for absorbed dose to water in ^{60}Co radiation, and for the air kerma comparisons in x-ray beams, destined for Appendix B. The results of these analyses had been agreed in principle. The final reports would be revised in accordance with the wishes of the Section and then recirculated for final agreement including a first set of data entries for Appendix B.

A number of specific issues were raised.

3.1.1 Unresolved deviations in results

Concern had been expressed over the possible misinterpretation of Appendix B data for the support of Appendix C claims by users of the BIPM key comparison database (KCDB). This related to cases in which the difference between the results of two national institutes of metrology (NMIs) is greater than the expanded uncertainty which it was felt could hinder acceptance of calibration certificates. Some wording had been suggested which would explain the equivalence of the data. Dr Quinn responded that any unresolved deviation of results in Appendix B should have a consequence for the corresponding Appendix C entries. This could be either by increasing the uncertainties of the calibrations in Appendix C, or by

removing the relevant calibration capability. In either case the issue should be resolved during the review of calibration and measurement capabilities (CMCs) by the regional metrology organizations (RMOs). He felt it would be inappropriate to produce new statements of "equivalence" which had not been approved within the MRA and unnecessary to repeat statements from the MRA. He stated that the uncertainty quoted in any CMC should be the uncertainty normally available to the client and not necessarily the "best capability".

3.1.2 Bilateral comparisons

It had been agreed that results from bilateral comparisons between NMIs that have already been compared at the BIPM could be included as footnotes to the relevant Appendix B table. The footnote would include the reference to the report and the result. It was noted that this process did not refer to a bilateral comparison enabling a third-party NMI to participate which would be treated as a normal extension to the equivalence tables. Dr Quinn stated that the CCRI needed to be informed in advance of bilateral comparisons, that the protocol should be compatible with that for the corresponding key comparison and that the results of a third-party NMI would be related to the tables through the linking NMI. A footnote expressing the concept "approved for provisional equivalence" was deemed to be acceptable for such results until the third-party NMI is able to undertake a BIPM comparison.

3.1.3 New comparisons

Some new comparisons had been identified as necessary to demonstrate the degrees of equivalence between NMIs:

- calibration capabilities for low- and medium-energy x-rays;
- electron beam absorbed dose, where there is not yet any coverage;
- mammographic qualities, where the dose-rate and the qualities are different from point one above.

3.1.4 Future work of the BIPM Ionizing Radiation Section

The discussion of future work for the Ionizing Radiation Section led to the discussion of staff resources and a note that these were insufficient to allow the increasing number of comparisons to be undertaken with a timely completion of comparison reports. A spontaneous resolution to resource another member of staff for the section had been supported unanimously.

The response from the Director was that this was much appreciated, that it was recognized as needed but may not be realizable. The President responded that the NMI representatives on CCRI(I) are requesting this increase in resource at the same time as asking for more work and projects to be undertaken. Dr Klein also supported the recommendation noting that he recalled a promise that the positions becoming free with the closure of the neutron section would be moved to the dosimetry section.

3.1.5 Correction factors for cavity standards

There had been significant discussion on correction factors for cavity standards with increasing evidence now in favour of calculated factors. Dr Aalbers is coordinator of a working group charged with resolving these issues and with Dr Allisy-Roberts would make recommendations to enable the comparison results to be entered into Appendix B of the MRA.

3.1.6 CMC submissions

A submission of CMCs from the IAEA had been made to the CCRI in place of an inter-regional review and some *ad hoc* rules had been proposed that three primary NMIs (the BIPM, the NIST and the PTB) would act as the reviewers. Dr Quinn expressed his satisfaction with this proposal.

3.2 Section II: measurement of radionuclides

(Chairman: B.R.S. Simpson)

The Chairman of Section II, Dr Simpson made some general comments about the running of the Section meeting. He reported that the new deadline for the submission of working documents by one month before the meeting had been followed and that this had helped members prepare for the discussions. By eliminating the need for each NMI to make a formal report on their activities during the meeting, extra time had been allowed for the scientific discussions. Dr Cassette, an invited speaker from the BNM-LNHB, had given a talk that was relevant to the extension of the International Reference System (SIR) to pure beta emitters.

3.2.1 Working groups

The Working Group on Standards Equivalence and the Working Group on the Systematic Analysis of the SIR had both been closed formally and their work combined into one Working Group on Key Comparisons. Dr Woods

had been designated as coordinator of this group. The ^{204}Tl Working Group had also been closed as the consensus was that the problems concerning the earlier comparison had been resolved. The ^{192}Ir Working Group had been enlarged to include discussion of the electron capture branch of the decay scheme that had posed difficulties in the comparison. Detection efficiency equations would be needed and the comparison would be repeated in due course. A Working Group on Uncertainties had been created to help resolve the questions on uncertainties raised during the key comparisons. An analysis of the SIR data to identify the key comparison reference values that had taken place at a Working Group meeting in February 2001 at the BIPM had raised a list of issues and all these had been resolved except that regarding potential outliers.

The Working Group on the Realization of the Becquerel had produced a design for the prototype and a table of tolerances necessary for its construction on the basis of a 0.1 % change in efficiency as a tolerance limit. The next step would be to build two prototypes. Professor Winkler, coordinator of the High Efficiency Detection System Working Group was producing a monograph on the subject which it was hoped would be published as a BIPM Monograph. The Working Group on the Extension of the SIR, to include pure beta emitters, would produce a new monograph on liquid scintillation counting. Dr Los Arcos, the coordinator, had planned two working group meetings in the next two years. The SIR monograph would appear on the BIPM website once published as this was the basis for all Appendix B results and the relevant key comparison reference values in particular.

3.2.2 Extension to the SIR

Two proposals for an extension to the SIR had been put forward. The first was to adapt the CIEMAT-NIST method and the other was to have a triple-to-double coincidence ratio (TDCR) system at the BIPM. The results of their respective measurements of activity would be compared at the BIPM in parallel to test the robustness of future comparisons of beta emitters.

The extension to the SIR of short-lived radionuclides was in progress with a comparison of ^{18}F. This was being organized by the EUROMET and although not yet complete, the results so far looked promising. It was hoped to establish a link to the SIR through the provision of an ampoule of ^{18}F by the BNM-LNHB to the BIPM.

3.2.3 Key comparisons

The ^{152}Eu comparison had produced a larger spread in the results than anticipated and further attention was needed. A first draft of the report was available. In the ^{89}Sr comparison, nineteen out of twenty-three NMIs had now submitted their results; these were generally in agreement and would provide a useful link into the extended SIR. The ^{238}Pu comparison was still in progress and an extension of three months for the submission of results had been agreed in view of the transport difficulties and consequent delays in delivery of the samples. Six future key comparisons had been approved and these would be held over the following two years. Activity comparisons of short-lived radionuclides would be interspersed with those of longer-lived radionuclides to give more flexibility on making the measurements at the NMIs. The schedule is given in the report of Section II.

The NMIs had agreed to continue to submit ampoules of diverse radionuclides to the SIR to ensure that the key comparison reference values are robust. The ^{75}Se comparison had been published in *Nuclear Instruments and Methods* and the ^{90}Sr comparison report was in progress.

3.2.4 CMC submissions

The progress of CMC submissions in activity measurements was noted. Most of the RMOs were likely to be ready to submit by the end of 2001.

During the discussion on the report of Section II, Dr Thomas mentioned that a new database was being constructed specifically for ionizing radiation CMCs. This would allow the source of traceability to be identified and enable searches to be made using the radionuclide as the key. Strong support was given to the proposal to keep the SIR Appendix B information up to date. Some discussion ensued on the SIR monograph and database entries in general.

3.3 **Section III: neutron measurements** (Chairman: H. Klein)

Dr Klein presented his report of Section III under three major headings.

3.3.1 Resources and tools of the NMIs

He discussed first the availability of neutron sources, fission sources, radionuclide sources and accelerators. Then he mentioned the organizational changes occurring in many laboratories. At the NIST, resources had been closed and direction changed; at the PTB 50 % of their customers now came

from the United States. More laboratories were not just measuring fluence but also making spectroscopic measurements. The time-of-flight method used not to be a common procedure but is the favoured method to characterize fields properly. Although there are many applications of characterized fields, they are mostly needed for radiation protection instruments. Various national regulations require radiation protection calibrations to be made in well-specified fields. The development of close collaboration with research laboratories for neutron detection and spectrometry was mentioned and it was noted that Japan has particularly close collaboration with research laboratories and their universities. Most of the national laboratories in the field have manganese baths and other tools to determine the emission rate of neutron sources.

The specification of detector systems needs experience with Monte Carlo codes: how to apply the codes and to adjust them to the particular problem as they are not immediately applicable in the field of neutron detection. For example, the PTB has been undertaking such work for the last twenty years and now they are modifying the multi-purpose codes at the request of and with the great interest of their customers.

3.3.2 CMC submissions

The services described above form the basis of submissions to Appendix C, the CMCs. EUROMET is close to finalizing its CMCs and will be submitting them to the rapporteurs and then to the Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB). It was noted that the breadth of the CMCs is based on the resources of the NMIs.

3.3.3 Key comparisons

Due to the time needed to make measurements with the circulation of neutron detectors, only one set of comparison results has been produced (CCRI(III)-K1) during the last ten years in Section III. However, the final results of this comparison are not yet agreed and the final report is subject to revision by CCRI(III). The main reason is that although this 24.5 keV comparison was finished in 1996 and a report prepared for *Metrologia*, a number of serious comments have been made about the draft. The comparison was designed before the requirements of the MRA were known and so the report is not really complete nor the data adequately analysed. Some NMIs have more than one entry and full uncertainty budgets are missing. Consequently, it is not really appropriate for the production of a key

comparison reference value. Dr Klein will contact Dr Lewis and the participants in order to complete the data and to revise the report for publication.

For the future, there are three new comparisons for Section III. One is proposed for the determination of fluence for thermal neutrons and two comparisons are in progress, one for monoenergetic neutron fluence and the other for neutron emission rate.

For thermal neutrons (CCRI(III)-K8.B-10), not many NMIs have appropriate fields available; reactors have been shut down and reproducible conditions are difficult to achieve. There are four or five NMIs that are able and willing to participate and it will take one and a half years to carry out this comparison.

It will be two and a half years before the emission rate comparison (CCRI(III)-K9.AmBe) can be finished, so the results can be expected in three years' time.

The most recent comparison (CCRI(III)-K10) was started one year ago and the measurements were made at the PTB in March 2001 at four different energies. All the raw data should be available in June and the laboratory reports are expected in October 2001. It is planned to finish this comparison by March 2002 and have the final report for discussion at the next CCRI meeting in 2003.

When these four comparisons are finished, most of the need for comparisons to support the Appendix C CMC entries will be fulfilled. This should support the CMC entries, except for the services that are really only available from a single NMI for which no external comparison is possible.

In conclusion Dr Klein commented that neutron metrology continues with not too many changes. He expressed his personal regret that Dr Lewis was to retire early from the NPL and, in view of recent organizational changes at the NIST, that strong support should be given to maintain the neutron capability at the NIST.

4 DISCUSSION OF POINTS OF COMMON INTEREST

4.1 MRA and matters of related interest

It was noted that the RMOs needed to be encouraged to submit their comparisons as key or supplementary comparisons to the CCRI so that they could be approved and entered into the KCDB. It was also noted that the EUROMET guidance for key comparisons does not mention the necessary communication with the relevant CC. A request was made for a formal mechanism to be put in place for the automatic communication of JCRB matters to RMO technical chairmen.

4.2 Future programme of the BIPM

The heavy BIPM investment in equipment was noted and deemed to be a welcome improvement to update the facilities. Dr Sharpe raised again the possibility of electron beam absorbed dose measurements at the BIPM. The situation regarding mammography was also discussed and the possibility of having a Research Fellow to study this was supported. Professor Moscati raised the question of the future of nuclear energy and the need for environmental activity measurements. The brachytherapy standards being disseminated by the NIST, PTB and the NPL were also mentioned as subjects for key comparisons. It was decided that this was not yet appropriate.

The arguments for supporting the research programme at the BIPM included the cost-effectiveness and efficiency of having such a central facility. Dr Sharpe commented that it was generally more efficient for such work to be done at the BIPM. It was noted that the MRA has considerably increased the workload in terms of the comparisons and the related reports.

Regarding comparisons, it was noted that there is no statistical argument to reject outliers and they should be dealt with as part of the population, using medians if necessary. There was a long discussion on uncertainties and it was agreed that each result needed to be judged on its merits. Generally, if a result was more than three standard uncertainties from the others, the laboratory should be contacted to ensure that no error had been made in the measurement. Once confirmed, a result should always be included in the comparison report unless all the NMIs agree to exclude it.

4.3 Report to the CIPM

Professor Moscati would be making a report to the CIPM and requested that the draft minutes from each Section be available as quickly as possible and preferably within two weeks' time. Dr Allisy-Roberts agreed to contact the rapporteurs to advise them of this request.

4.4 Membership of Sections

It was noted that applications for membership and changes to membership category need to be submitted to the Director of the BIPM prior to September each year for consideration at the CIPM held in October.

4.5 Recommendations to the CGPM (Trends and future needs in ionizing radiation metrology)

The President requested that each NMI consider the need for recommendations to be made to the next CGPM scheduled for 2003. Specific items that had arisen at this meeting were the movement of radioactive materials and customs requirements (the Executive Secretary was to contact the IAEA concerning the international transport arrangements). Any other recommendations would have to be presented to the CIPM not later than October 2002.

4.6 Future programme of the CCRI

It was agreed that the CCRI should continue to have a half-day meeting following the three Section meetings. The Chairmen of the Sections should continue to be invited to attend each other's Section meeting but there would be no compulsion to attend.

5 DATES OF NEXT MEETINGS

The dates of the next meetings were agreed as:

CCRI(I): 21 to 23 May 2003

CCRI(II): 28 to 30 May 2003

CCRI(III): 26 to 27 May 2003

CCRI: 30 May 2003

subject to approval by the CIPM in October 2001.

[Note: these dates were approved by the CIPM.]

6 CONCLUDING REMARKS

The President concluded the meeting by thanking the members of the CCRI for their work in the CCRI Sections and the BIPM for its warm welcome and hospitality.

March 2002

Consultative Committee for Ionizing Radiation

Section I: x- and γ-rays, electrons

Report of the 15th meeting

(23-25 May 2001)

Agenda

1 Opening of the meeting; approval of the agenda; appointment of a rapporteur.

2 Report of the sixteenth meeting of the CCRI.

3 Comparisons of measurement standards (x- and γ-rays):

- 3.1 BIPM and CCRI comparisons;
- 3.2 MRA Appendix B key comparison reports;
- 3.3 Air kerma (^{60}Co) key comparison;
- 3.4 Current and future regional comparisons.

4 Programme at the BIPM:

- 4.1 Air kerma beams;
- 4.2 New cobalt source installation;
- 4.3 Development of a graphite calorimeter.

5 Development of national standards for photon dosimetry:

- 5.1 Diagnostic radiology;
- 5.2 Mammography;
- 5.3 Brachytherapy;
- 5.4 Radiation protection;
- 5.5 Radiation processing.

6 Development of national standards for charged-particle dosimetry:

- 6.1 Electron beams;
- 6.2 Beta-ray fields;
- 6.3 Proton beams;
- 6.4 Other radiations.

7 Calibration and measurement capabilities:

- 7.1 Dissemination of $N_{D,\mathrm{w}}$ and N_K calibration factors;
- 7.2 Submissions to MRA Appendix C;
- 7.3 Supporting supplementary comparisons.

8 Reports from member laboratories.

9 Reports from international members and observers:

9.1 ICRU;

9.2 IAEA;

9.3 IOMP and IRPA.

10 Publications:

10.1 Bibliographies from NMIs;

10.2 CCRI(I) web pages.

11 Future membership.

12 Trends and future needs in ionizing radiation metrology: recommendations to the CCRI, CIPM and the CGPM.

13 Date of next meeting.

Abstract

Section I (x- and γ-rays, electrons) of the Consultative Committee for Ionizing Radiation (CCRI) held its fifteenth meeting at the Pavillon de Breteuil, Sèvres, in May 2001. The meeting took place in the newly constructed Pavillon du Mail where the facilities were much appreciated. The discussions focused on analysis of the results of the various key comparisons to be included in the BIPM key comparison database (KCDB). Correction factors relating to free-air standards and cavity ionization chambers used in key comparisons were debated and a Key Comparison Working Group was tasked to resolve some of the outstanding issues. Decisions were reached on those procedures to follow that will ensure as many results as possible are included in the KCDB by the end of the year 2001. The recent work and upgrading of the laboratory facilities of the BIPM were reviewed. The future needs of radiation metrology were discussed and members presented their current research programmes in radiation dosimetry. In view of the requirements imposed by the mutual recognition arangement (MRA) and key comparisons, it was acknowledged that a heavy programme of work lies ahead for the national metrology institutes and the BIPM. Reports from the international observers were noted.

1 OPENING OF THE MEETING; APPROVAL OF THE AGENDA; APPOINTMENT OF A RAPPORTEUR

Section I (x- and γ-rays, electrons) of the Consultative Committee for Ionizing Radiation held its fifteenth meeting at the Pavillon de Breteuil, Sèvres, on 23–25 May 2001.

Professor G. Moscati, President of the CCRI, opened the meeting by introducing the new Chairman of Section I, Dr P. Sharpe. Professor Moscati also expressed the thanks of all the participants for the exemplary service of the previous Chairman, Dr K. Hohlfeld. Dr P.J. Allisy-Roberts conveyed a welcome to the participants on behalf of Dr T.J. Quinn, who was in Japan at a CIPM meeting, and introduced the new facilities in which the meeting was being held.

The following were present: A.H.L. Aalbers (NMi-VSL), A. Allisy (ICRU), L. Büermann (PTB), B. Chauvenet (BNM-LNHB), I. Csete (OMH), S. Duane (NPL), S.A. Fedina (VNIIM), C. Grover (NRC), H.-M. Kramer (PTB), A. Merta (GUM), G. Moscati (President of the CCRI), D. Rogers (NRC), S.M. Seltzer (NIST), N. Takata (NMIJ/AIST), D. Webb (ARPANSA), J. Witzani (BEV), Tian Zhongqing (NIM).

Observers: F. Luhana (CSIR-NML), A. Meghzifene (IAEA), J.G.P. Peixoto (LNMRI/IRD).

Invited: B.R.S. Simpson (Chairman of Section II), G. Stucki (METAS).

Attending all or part of the meeting from the BIPM: P. Giacomo (Director Emeritus), P.J. Allisy-Roberts (Executive Secretary of the CCRI, BIPM), D.T. Burns, G. Ratel, C. Michotte, C. Thomas (BIPM).

Apologies were received from: A. Brosed (CIEMAT), J.-E. Grindborg (SRPI), R.F. Laitano (ENEA-INMRI).

Absent: IOMP and IRPA.

Before beginning formal business, Dr Sharpe conveyed his personal welcome to the participants and invited the members around the table to introduce themselves. He indicated the rather full agenda, emphasizing the need to address a number of important issues, such as approval of the entries to the BIPM key comparison database with the appropriate degrees of equivalence and the wall corrections involved in ^{60}Co air-kerma standards.

Mr Seltzer was appointed Rapporteur.

No significant changes to the agenda were suggested.

2 REPORT OF THE SIXTEENTH MEETING OF THE CCRI

The Chairman called attention to the published report of the sixteenth meeting previously mailed to all participants which includes the report of the fourteenth meeting of Section I. Professor Moscati reminded the participants that the three Sections of the CCRI meet in contiguous sessions, followed by a short meeting of the CCRI, comprised of the President, the Section chairmen and the Director of the BIPM, to agree on common conclusions. The President and the chairmen are thus invited to all Section meetings to improve communication.

The agreement at the previous meeting on the early submission of official CCRI(I) documents was recalled, and the participants were thanked for largely adhering to the 9 April 2001 deadline in submitting their documents. On this topic, attention was called to the move to electronic versions of the working documents that greatly facilitated their current distribution among the participants, and to Dr Quinn's proposal that the working documents be web-accessible and password-restricted to the delegates, without bound paper volumes as in the past. It was proposed and agreed that a CD-ROM containing the working documents be distributed some time after the meeting so that the documents would be available to the staff of the national metrology institutes. All of the documents submitted to the fifteenth meeting of the CCRI(I) were formally adopted.

3 COMPARISONS OF MEASUREMENT STANDARDS (X- AND γ-RAYS)

3.1 BIPM and CCRI comparisons

Dr Allisy-Roberts presented a summary of the current status of dosimetry comparisons and calibrations (CCRI(I)/01-1). Since the last meeting, twelve comparisons and twenty-one calibrations of secondary standards have been carried out. It was noted that this number is below that of the previous two-year period because of improvements being made to the BIPM facilities. However, it is clear that a significant increase in such work is required of the BIPM to help the national metrology institutes meet the requirements of the MRA for the BIPM key comparison database. Document CCRI(I)/01-1 also indicates the age of the most recent comparisons and calibrations, highlighting those outside the recommended ten-year limit, and proposes a schedule for 2001 to 2003 to bring the comparisons and calibrations up to date.

Dr Sharpe expressed the thanks of the Section for the effective and hard work of the BIPM in carrying out the comparisons and calibrations. Dr Rogers pointed out the need to have at least one additional, permanent scientific staff member in the radiation dosimetry group of the BIPM. This was felt necessary to handle the increased workload and responsibilities in completing timely comparisons and reports in the areas approved at the last meeting. In addition there were new areas of work considered by the Section as important for the future at the BIPM (e.g., high-energy photon beams, mammography, therapeutic beta sources, and electron beams). A formal proposal to that effect was approved by the Section, with final wording to be prepared for submission to the CCRI and the CIPM.

3.2 MRA Appendix B key comparison reports

Dr Allisy-Roberts introduced this topic with a demonstration from another measurement area on the BIPM Appendix B key comparison database website. She showed the table comparing NMI values to the reference value, the table giving the matrix of the degrees of equivalence between any two NMIs, and the brief explanatory material accompanying the tables. Dr Burns pointed out that in the proposed matrices for Section I comparisons, the analyses of the uncertainty of the difference takes into account the correlation of common factors used in the standards, but that the value of the correlation

coefficient, although reasonable, is an educated estimate. From the discussions of specific CCRI(I) key comparisons, actions on a number of general issues were decided:

1. It was agreed that the text accompanying the tables in the KCDB should read approximately as follows. "Under the terms of the MRA the values listed in the tables are the basis for establishing the degrees of equivalence among the standards. The first column of the second table gives the relationship between the laboratory standard and the key-comparison reference value, and the uncertainty on this relationship. The remainder of the table gives the relationship between any pair of NMI standards and the uncertainty on this relationship. The stated uncertainty is an expanded uncertainty (with a coverage factor of $k = 2$)." Professor Allisy stressed the importance of making clear that the differences and uncertainties in the tables were in terms of parts per thousand.
2. Upon the recommendation of Dr Rogers, and with particular reference to NRC/NIST ^{60}Co absorbed-dose comparisons that appeared to be inconsistent with those conducted through the BIPM, it was agreed that bilateral comparisons would be included in the KCDB tables through footnotes on the following basis. An existing bilateral key comparison can be submitted to the CCRI(I) by the end of June 2001, the information will be circulated electronically, and the members will have two months in which to approve its inclusion. Any proposed new bilateral key comparison should be submitted to the CCRI(I) for approval of the protocol. The CCRI(I) will seek advice from the Key Comparison Working Group on how to include the results of a bilateral key comparison as a footnote.
3. It was agreed that results of a key comparison must be published to be included in the KCDB. If a key comparison is more than ten years old, the NMI will be consulted on the validity of that comparison. If declared still valid, the result will be included in the KCDB with the proviso that a new comparison takes place within the next two years. If a new comparison is planned, the entry for that NMI will be marked with an asterisk (*). If a new comparison is not conducted during that time, the results of the old comparison will expire at the next CCRI(I) meeting; i.e., this is the last period in which such older results will be included.
4. It was agreed that the following procedure would apply when a NMI changes its standard: either a document that can be referenced is prepared, or a new comparison with the BIPM is conducted. The results

are submitted for approval by the CCRI(I), and – if approved – are then used to update the data in Appendix B.

3.2.1 Absorbed dose (^{60}Co) key comparison (BIPM.RI(I)-K4)

The discussion of specific comparisons started with that conducted through the BIPM of standards of absorbed dose to water from therapy-level ^{60}Co gamma-ray beams (BIPM.RI(I).K4). Dr Allisy-Roberts summarized the material presented in document CCRI(I)/01-12 that lists the results of BIPM comparisons for eight NMIs using transfer standards, the treatment of uncertainties for these comparisons, and the expression of the degrees of equivalence. The correlated components in these comparisons include the ratios of photon mass energy-absorption coefficients and of electron stopping powers for the conversion of absorbed dose in graphite calorimeters to that in water, and the heat defect in water calorimeters. Mr Seltzer referred to document CCRI(I)/01-14 which explained an increase in the stated uncertainty of the NIST standard owing to a problem discovered in the field-size reproducibility, that could have affected the previous sealed-water calorimeter measurements. With the understanding that the stated uncertainty for the NIST standard be accordingly revised, the data in CCRI(I)/01-12 were approved for inclusion in Appendix B.

3.2.2 Air kerma (medium energy x-rays) key comparison (BIPM.RI(I)-K3)

Dr Burns summarized the BIPM comparisons of medium-energy x-ray air-kerma standards (BIPM.RI(I)-K3) as described in document CCRI(I)/01-9. Eleven comparisons are available, for which six have proper published reports, three have reports in preparation, one (NIST-1991) has been reported but with no required formal documentation, and one (BEV-1982) has no reference. In addition, a recent comparison with the PTB is at the draft stage and could be included before the next CCRI(I) meeting. The correlated components in these comparisons include values for the density of air, for W/e, for the humidity correction, and for the correction for radiative losses by electrons in air. It was agreed that a consistent application of rule 3 above requires that the BEV 1982 and the NIST 1991 comparisons with no appropriate references be dropped from the proposed table in the KCDB. The NIST has planned a new BIPM comparison during 2001-2002 and can include an older, documented comparison in the interim if it wishes to do so. It was agreed to accept the proposed comparison data subject to revision and circulation among the members.

3.2.3 Air kerma (low energy x-rays) key comparison (BIPM.RI(I)-K2)

The BIPM comparisons for low-energy x-ray air-kerma standards (BIPM.RI(I)-K2), described in document CCRI(I)/01-11, were summarized by Dr Burns. Ten comparisons are available, eight of which are direct and two are indirect based on transfer free-air chambers. Seven comparisons have published reports, one report is in preparation, and two (ETL/NMIJ-1972 and CIEMAT-1979) have no reference. Dr Takata indicated that the NMIJ is building a new free-air chamber and the old standard is no longer in use. Of these comparisons, six are within the last ten years. Of the four that are older, the OMH has already participated in a recent comparison. Recent comparisons with the BEV, OMH, PTB and the VNIIM are at the draft stage. The correlated components are the same as for medium-energy x-ray beam standards. On the basis of the agreed rules, the results of old comparisons will be included in the KCDB until the next meeting of the CCRI(I). It was stressed that the BIPM staff should complete the necessary reports of recent comparisons for publication as soon as possible so that they can be included in the KCDB. The remaining unpublished comparison reports would be finalized as soon as possible. In this respect, the exemplary work of the BIPM staff was recognized and the Section re-expressed the necessity for at least one additional permanent staff member.

Dr Rogers proposed a CCRI comparison of the dissemination of air-kerma standards in low-energy and medium-energy x-ray beams by the primary standards laboratories. Professor Allisy stressed the need when presenting such results to distinguish between degrees of equivalence of primary standards and degrees of equivalence of calibration capabilities. The proposal was endorsed as a possible key comparison, using BIPM/CCEMRI beam qualities and circulating an ionization chamber for the measurements. The Section agreed on a strong request to the CCRI that such a comparison be undertaken.

Dr Burns presented results of extensive Monte Carlo calculations of correction factors for free-air chambers used as the BIPM and NMI primary standards for x-ray beam air kerma. The results, summarized in documents CCRI(I)/01-32 and -36 (revised), give electron-loss, photon-scatter, fluorescence-absorption, and bremsstrahlung-absorption corrections for NMI chambers at CCRI reference beam qualities. The last two, newer corrections account for the ionization current produced by the absorption of fluorescence photons emitted after photoelectric absorption and by absorption of bremsstrahlung photons from secondary electrons, respectively. Both of these contributions should be subtracted for the realization of air kerma; the

first can be significant (from 0.2 % to 0.5 %) for low-energy x-ray beams and the second is very small (less than 0.015 %). It was agreed that the BIPM will implement these new results for their standards before publication of Appendix B, and that the NMIs will notify the CCRI(I) through the BIPM when similar corrections are implemented in their standards.

3.2.4 Absorbed dose (^{60}Co) key comparison (CCRI(I)-K4)

Dr Allisy-Roberts reported on the status of the comparison regarding the dissemination of ^{60}Co absorbed-dose-to-water standards approved at the sixteenth meeting of the CCRI. It was pointed out that this was the first CCRI(I) key comparison. Conducted differently from the standards comparison BIPM.RI(I)-K4, the goal of this comparison (CCRI(I)-K4) is to assess the agreement of absorbed-dose calibrations delivered by primary standards laboratories using routine calibration procedures. The comparison is based on the calibration of three transfer-standard ionization chambers (NE 2571, NE 2611A and ND 1006), hand carried to each participating laboratory. So far measurements have been made at the ARPANSA, BEV, BNM, ENEA, NIST, NPL, NRC, PTB, and at the BIPM before and after measurement at each NMI to ensure consistency of the chambers. The initial results generally reflect the same differences as those determined in the standards comparisons, i.e., if the degrees of equivalence are taken into account, the ratios of calibrations are very close to unity. The current schedule is to complete final measurements at the BIPM in June 2001, circulate first a draft report to participants in July, then an amended draft for approval to all members of CCRI(I) in September, and – if approved – include it in Appendix B in October.

The following actions were approved regarding this comparison: The results will be given only in terms of relative values so that use of the chambers could be continued and the comparison extended to other laboratories. The NMi will be included in the comparison with no significant changes in the proposed schedule. On the recommendation of Dr Rogers, it was agreed that the results be published in *Physics in Medicine and Biology*, as it was in this journal that an earlier publication reported some significant differences in chamber calibration factors from a number of calibrating laboratories.

3.2.5 Absorbed dose (^{60}Co) comparison (CCRI(I)-S1)

The discussion on the status of the supplementary comparison on absorbed dose to water from ^{60}Co gamma-ray beams at radiation-processing dose levels (CCRI(I)-S1) indicated that the report had not yet been written. Mr Seltzer referred to document CCRI(I)/01-16, pointing out that the NIST had completed an extensive recalibration of its high-dose reference fields, resulting in a reduction of absorbed dose to water by 1.8 % for the NIST GammaCell 220-232 in the alanine-vial geometry, effective 31 March 2000. This effectively eliminates a discrepancy between the NIST and the NPL, the two transfer-dosimeter issuing laboratories in the comparison, for which it was found (CCRI(I)/99-17) that the mean value of the ratio of $D_{w,NIST}/D_{w,NPL}$ was 1.015. It was agreed that the report be written and submitted to *Radiation Physics and Chemistry* for publication, based on the original results of the comparison with a note on the change in the NIST calibration.

3.3 Air kerma (^{60}Co) key comparison

Although the subject of a key comparison, this topic was considered as a separate agenda item owing to the long-term concern about the wall corrections for graphite-walled Bragg-Gray-cavity ionization chambers used as primary standards.

3.3.1 Estimations of $k_{att}k_{sc}k_{CEP}$ and their uncertainties

Dr Aalbers, Chairman of the Working Group on Monte Carlo Calculations of Correction Factors for ^{60}Co Air-kerma Standards established at the last meeting, summarized the status of new work (CCRI(I)/01-38). Drs Kramer and Csete made presentations based on their recent direct comparisons of the primary standards of the PTB and the OMH (CCRI(I)/01-17) in which close agreement was found using wall corrections from Monte Carlo calculations with the EGSnrc code. In particular, their collaborative experimental tests of calculated versus extrapolated wall corrections (CCRI(I)/01-18) provided clear evidence that the calculated wall corrections produced consistent agreement using four differently shaped cavity chambers at various orientations whereas traditional extrapolated wall corrections would produce highly discrepant results. The OMH had already declared a new value for their standard (CCRI(I)/01-03), which they were disseminating, and the PTB was keen to do so from a date to be specified, probably 1 January 2002.

Dr Rogers called attention to documents CCRI(I)/01-25 and -39 that indicate the insensitivity of the Monte Carlo results for the wall correction both to

details of the electron transport algorithms and to the assumed incident photon spectra. Mr Seltzer referred to document CCRI(I)/01-33, which describes Monte Carlo calculations for the NIST chambers using the Integrated Tiger Series code with preliminary results that essentially agree with EGS results developed by Rogers and co-workers at the NRC.

In the absence of Dr Laitano, Dr Allisy-Roberts called attention to document CCRI(I)/01-30 (revised). This report describes work at the ENEA involving experiments, analytical calculations and Monte Carlo calculations to determine the wall corrections. As a result, Italy will adopt the Monte Carlo corrections from EGSnrc calculations (CCRI(I)/01-40). The BIPM indicated a programme of work based on Monte Carlo calculations with EGSnrc and with PENELOPE, coupled with experimental measurements. When completed, this work on wall and beam non-uniformity corrections will form the basis of new correction factors for the BIPM standards, with the approval of the CCRI.

3.3.2 Other Monte Carlo calculated corrections

A discussion on Monte Carlo calculations of other corrections included the statement by Dr Rogers (referring to document CCRI(I)/01-23) that their calculations of $\overline{g}$, the fraction of secondary electron kinetic energy lost in radiative processes, essentially agree with those given by Seltzer in 1993 when including energy-loss straggling. The values for ^{60}Co are from 2 % to 3 % larger than the commonly used 1985 values of Boutillon obtained in the continuous-slowing-down approximation. However, because $1-\overline{g}$ is the quantity of interest, and $\overline{g}$ has a value of about 0.003, the effect on air-kerma standards is negligible. Dr Takata presented results (see CCRI(I)/01-31) of the NMIJ determination of $1-\overline{g}$ made to facilitate the change in Japan from exposure to air-kerma standards, and of calculations of ionization caused by the acceleration and deceleration of electrons in the electric field of free-air chambers. The results indicate rather small effects, particularly for parallel-plate chambers.

3.3.3 Consistent use of uncertainties of *W/e* and stopping power ratios

On the subject of *W/e* and stopping-power ratios, Dr Rogers reiterated his concern over the accuracy of adopted electron stopping powers from ICRU Report 37, particularly for graphite for which there has been a more recent experimental determination of the mean excitation energy. In further discussion the Section agreed to recommend that the ICRU convene the

appropriate expertise to revisit the evaluation of electron stopping powers, especially for graphite and water. Mr Seltzer, with concurrence by Prof. Allisy, will communicate the CCRI(I) request to the ICRU. Dr Allisy-Roberts recalled the agreement at the fourteenth meeting of CCRI(I) to apply the usual uncertainty when using the product of W/e and the graphite-to-air stopping-power ratio, and to use a larger uncertainty for W/e if used alone.

3.3.4 Key comparison progress report (BIPM.RI(I)-K1)

Dr Allisy-Roberts summarized the progress on the key comparison of air-kerma standards for ^{60}Co gamma-ray beams (BIPM.RI(I)-K1). This comparison is subject to ongoing changes being made by NMIs on wall corrections and on uncertainties for W/e and stopping-power ratios. It was agreed that each NMI would notify the BIPM of any changes in its standard and uncertainties to update the KCDB. Drs Aalbers and Allisy-Roberts agreed to prepare a summary report on wall corrections and uncertainties for W/e and stopping-power ratios to circulate among the members and to the participants in this key comparison.

3.4 Current and future regional comparisons

The comparison APMP.RI(I)-K3 for air kerma from 100 kV to 250 kV x-ray beams is in progress. Dr Takata indicated that three countries have completed measurements, with a fourth scheduled for October 2001; the plan is to complete a report by Spring 2002. All measurements in the comparison APMP.RI(I)-K4 for absorbed dose to water in ^{60}Co gamma-ray beams have been completed. Dr Webb indicated that the report has gone to the APMP for review. There is nothing in the KCDB regarding comparisons for EUROMET. Dr Aalbers indicated that he knew of no proposals yet, but that there is in progress a European comparison for air kerma from mammography x-ray beams that perhaps could become a supplementary comparison. Dr Rogers indicated that a SIM comparison for air kerma and absorbed dose to water from ^{60}Co gamma-ray beams, coordinated by Dr Shortt at the NRC, was under way, involving the CNEA (Argentina), IAEA, ININ (Mexico), LNMRI/IRD, NIST, NRC, and Venezuela. It was advised that protocols for regional comparisons obtain prior CCRI(I) approval to avoid possible arguments after the fact. Dr Sharpe suggested that formal channels of communication be established with the RMOs, and the Section recommended that the CCRI should request reports from the regional coordinators.

4 PROGRAMME AT THE BIPM

Drs Allisy-Roberts and Burns reported on the extensive refurbishment and upgrade of the BIPM dosimetry facilities, including the repair of storm damage to the building and consequent redecoration, as well as the installation of new air-conditioning systems for all the laboratories. The latter has resulted in control of relative humidity in the measurement laboratories to (50 ± 1) %, control of air temperature to ± 50 mK and of water temperature to $\pm$ 10 mK. In addition, all control and data acquisition systems are now computer-based.

4.1 Air kerma beams

Dr Burns summarized the status of the low-energy x-ray facility that has been completely upgraded, including a new high-voltage generating system, a new x-ray tube, and a new data-acquisition/control system (see document CCRI(I)/01-7). The matching and characterization of the low-energy beam qualities have been completed. Consistency with previous comparisons should be within the BIPM measurement uncertainty (except for the 10 kV beam for which improved air-attenuation corrections could result in a change of 0.1 % for an extreme value of air pressure). Once the new voltmeters have been constructed, testing will continue of the BIPM medium-energy x-ray facility for which the high-voltage generators have been replaced. Dr Allisy-Roberts explained that the protection-level ^{60}Co source had been relocated to make room for the new therapy-level source and would be recommissioned, and that the physical damage to the ^{137}Cs facility during redecoration had been repaired satisfactorily.

There was no clear agreement in Section I regarding the implementation of ISO x-ray beam qualities at the BIPM, IEC qualities being perhaps more important. The discussion on the possible addition at the BIPM of mammography x-ray beam qualities, based on Mo- and/or Rh-anode tubes, elicited mostly positive comments indicating the importance of the application and the growing implementation of NMI standards and calibration laboratories.

4.2 New cobalt source installation

Dr Allisy-Roberts indicated that the BIPM has finally had installed a new 250 TBq ^{60}Co source and container. The radiation shielding has been improved, radiation security systems and safety barriers have been installed, and the installation of an exposure bench and positioning system is under way. Work on determining correction factors, both experimentally and by Monte Carlo calculation, will need to be undertaken for the new source.

4.3 Development of a graphite calorimeter

Dr Allisy-Roberts pointed out that the BIPM is developing a new graphite calorimeter and suggested it would perhaps be well advanced by the next meeting.

5 DEVELOPMENT OF NATIONAL STANDARDS FOR PHOTON DOSIMETRY

5.1 Diagnostic radiology

Diagnostic x-ray beam qualities can be different from those established by primary standards laboratories and also from the ISO beam qualities that address radiation-protection dosimetry. Dr Aalbers referred to document CCRI(I)/01-34, which summarizes comparisons of air-kerma standards for diagnostic-radiology x-ray beam qualities, made under EUROMET Project 364. The participants included the BIPM, ENEA, NMi and the NPL, who had established beam qualities according to the IEC 1267 standard, and the BEV and PTB who had available diagnostic-radiology x-ray beam qualities. Dr Kramer pointed out that the PTB has implemented the IEC beam qualities. Dr Webb indicated that ARPANSA is looking at HVL interpolation to help reduce the number of beam qualities they maintain, and that such a procedure should apply to calibrations for diagnostic-radiology x-ray beam qualities. It was mentioned that the IEC standard was under revision. Dr Duane intimated that the NPL would develop any new IEC beam qualities.

5.2 Mammography

The BNM, NIST, NMi, NPL, and the PTB have primary standards for air kerma from mammography x-ray beams. Responding to a request for BIPM support, Dr Allisy-Roberts suggested that the BIPM could start a two-year project to develop mammography beams using funding for a research fellow. Dr Rogers proposed that if this were to be successful, a longer-term commitment would be necessary. Dr Witzani mentioned that EUROMET Project 01-10 aims to compare the response of various detectors in the spectra produced by pure Mo tubes with the response at other qualities. It was suggested that other NMIs await the outcome of this project before setting up special calibration facilities.

5.3 Brachytherapy

Dr Kramer described the development at the PTB of two extrapolation chambers to serve as standards for absorbed dose to water from beta sources (CCRI(I)/01-20). The first, for a field of 1 cm^2 from extended sources, should be in use sometime in 2001. The second employs multiple electrodes as small as 1 mm × 1 mm with only 2 μm gaps, and is intended for use with seed-train sources used in intravascular brachytherapy.

Referring to document CCRI(I)/01-35, Dr Aalbers indicated that the NMi is developing an extrapolation chamber with small collecting-electrode areas to serve as the primary standard for therapeutic beta sources.

Mr Seltzer called attention to document CCRI(I)/01-15 which outlines the NIST standard for absorbed dose to water from beta brachytherapy sources and the NIST primary standard for low-energy photon-emitting (^{125}I and ^{103}Pd) brachytherapy sources, and lists the prostate seeds and intravascular sources that are traceable to NIST standards.

Dr Rogers pointed out that document CCRI(I)/01-23 refers to a NRC paper recently published that establishes the validity of Spencer-Attix cavity theory to 0.6 % and hence the use of graphite cavity chambers for the absolute measurement of air kerma from ^{192}Ir sources.

5.4 Radiation protection

Dr Meghzifene suggested that traceability to primary standards for radiation protection quantities is not as well established as that for therapy-level dosimetric quantities. Dr Rogers indicated that in Canada only air kerma is traceable to the NRC. Dr Kramer suggested that if instrument manufacturers

are really traceable to primary standards in NMIs, their calibrations should be acceptable. Dr Allisy-Roberts stated that the BIPM provides ambient dose equivalent comparisons and calibrations in ^{60}Co and ^{137}Cs gamma-ray beams for NMIs.

5.5 Radiation processing

Dr Sharpe pointed out that alanine-EPR dosimetry has enjoyed much development and now has applications also at therapy-level doses. Dr Webb indicated that ARPANSA was in the process of re-establishing their alanine-EPR dosimetry service, which will be used also at therapy levels (CCRI(I)/01-22). Mr Seltzer remarked on the NIST "e-Calibration" program for the remote, web-based alanine-EPR measurement service being developed at the NIST. Professor Allisy commented that such procedures were really high-class, quality assurance measurements but could not be considered as independent calibrations. Dr Sharpe added that there were also quality assurance aspects associated with the remote dosimetry concept that needed to be addressed.

6 DEVELOPMENT OF NATIONAL STANDARDS FOR CHARGED-PARTICLE DOSIMETRY

6.1 Electron beams

Dr Rogers, referring to document CCRI(I)/01-23, indicated the development at the NRC of water calorimetry for electron beams. Dr Duane pointed out (CCRI(I)/01-21) that the NPL standard for absorbed dose to water for electron beams is a graphite calorimeter. Dr Stucki indicated that METAS is using total absorption in Fricke solution for their measurement standard, which they hope to have ready by the end of the year 2001. The BNM is working with graphite calorimetry and Fricke solution to look at the G value for high-energy electrons. Dr Sharpe commented that a number of NMIs are now involved with electron-beam dosimetry, and wondered about a BIPM role in coordinating comparisons. Dr Allisy-Roberts replied positively and suggested it be considered at the next meeting bearing in mind the high priority for photon beam dosimetry comparisons.

6.2 Beta-ray fields

There was no discussion, as this topic is largely covered under other agenda items.

6.3 Proton beams

Dr Aalbers indicated that the NMi was doing some very limited dosimetry studies with a water calorimeter, and Dr Burns stated that Belgium was measuring proton beams also with a water calorimeter. It was acknowledged that the ENEA was undertaking considerable work for proton-beam dosimetry, and Dr Simpson referred to the long-standing proton-beam programme at the National Accelerator Centre in South Africa.

6.4 Other radiations

Dr Burns referred to heavy-ion-beam therapy and pointed to the supporting dosimetry work in Japan and to the inclusion of dosimetry for heavy ions in the new IAEA Code of Practice.

7 CALIBRATION AND MEASUREMENT CAPABILITIES

7.1 Dissemination of $N_{D,w}$ and N_K calibration factors

Dr Allisy-Roberts reminded the participants of the agreement at the last meeting that all NMIs would report at the present meeting ratios of $N_{D,w}/N_K$ along with the numbers and types of chambers. Only one laboratory had supplied the data. It was then agreed that the request to collect $N_{D,w}/N_K$ data would be carried forward to the next meeting, and that Dr Rogers would coordinate its collection. A number of participants pointed out that not all NMIs routinely do both calibrations for a submitted chamber; some give only what is requested and a few disseminate only one of the two.

After a few brief comments by participants regarding the fact that some countries had no protocols based on $N_{D,w}$ and some that did were experiencing confusion on the point of measurement, Dr Rogers brought attention to the controversy on the beam-quality specifier for high-energy photon beams. North America has adopted the use of %dd(10) and most

other protocols use $TPR_{20,10}$. Referring to the work described in document CCRI(I)/01-26, Dr Rogers concluded that water-to-air stopping-power ratios for clinical beams form a curve as a function of $TPR_{20,10}$ that can be different from that for the non-clinical beams. On the other hand, %dd(10) produces consistent results for all beams including the non-clinical beams used at a few NMIs.

7.2 Submissions to MRA Appendix C

Drs Allisy-Roberts and Meghzifene referred to the CMC submission in Appendix C from the IAEA (CCRI(I)/01-29). The IAEA is not a member of an RMO but is global and supports secondary standard dosimetry laboratories (SSDLs) in every RMO. Dr Sharpe pointed out that the CCRI(I) cannot approve the submission, but can review it prior to it being sent to the JCRB for approval. It was agreed that the CCRI(I) reviewers should be the BIPM, the PTB and the NIST, to which laboratories the IAEA standards are listed as traceable, and that the review should be completed in the next two months with comments sent to the IAEA. Dr Kramer agreed to coordinate the response as he was familiar with the EUROMET review process.

Dr Allisy-Roberts drew attention to the proposed JCRB statement to be included on certificates under the CIPM MRA: “This certificate has been issued under the provisions of the MRA drawn up by the International Committee for Weights and Measures (CIPM). All participating institutes recognize the validity of each other’s calibrations and measurement certificates for the quantities, ranges and uncertainties specified in Appendix C of the MRA.” (for details see www.bipm.org).”

7.3 Supporting supplementary comparisons

Discussion of supporting supplementary comparisons had been included under other agenda items. A reporting form would be sent to members and RMO coordinators to request information on other comparisons which may be appropriate for the KCDB.

8 REPORTS FROM MEMBER LABORATORIES

Representatives of the member laboratories briefly introduced their submitted written reports describing the work of their institutes. Additional comments given are indicated below.

- ARPANSA (CCRI(I)/01-22): Dr Webb emphasized their efforts to resolve a discrepancy between their low-energy and medium-energy x-ray free-air chambers and the role of new correction factors calculated by Dr Burns in this respect.
- BEV (CCRI(I)/01-10): Dr Witzani called attention to their participation in the EUROMET comparison of mammography x-ray beam dosimeter calibrations and in the inter-laboratory comparison of radiation-protection calibrations in terms of personal dose equivalent Hp(10).
- BNM (CCRI(I)/01-5): Dr Chauvenet mentioned the change in status of the BNM-LCIE and that consequently the low- and medium-energy x-ray standards would be transferred to the BNM-LNHB. On the scientific side, he described the following projects: the development of the 4 °C water calorimeter, the characterization of the linear accelerator, standards for ^{192}Ir dosimetry, and ambient dose equivalent calibrations.
- GUM: Dr Merta reported that there had been little activity in the 1999-2001 period owing to low budget and staff levels. They have acquired a new Pantek 160 kV x-ray unit, and expect things to be better in the future.
- NIM: Dr Tian Zhongqing stated that there was not much to report for the last two years. They have acquired a new 740 TBq (20 kCi) ^{60}Co source, and are planning the reconstruction of a low-energy x-ray beam free-air chamber and of a graphite calorimeter. There is particular concern in his laboratory about the dosimetry of narrow beams of photons used in computer-assisted tomography (CT) and in the GammaKnife. He reported that China will change from the quantity exposure to air kerma in two to three years.
- NIST (CCRI(I)/01-13): Mr Seltzer spoke of the new ^{60}Co source, a new water calorimeter being built under contract and a new project in tooth enamel dosimetry after radiological accidents, using EPR. There was also ongoing work on fundamental calculations on elastic and Compton scattering to obtain a consistent data set.

- NMi (CCRI(I)/01-35): Dr Aalbers remarked on their prototype development of a Domen-type water calorimeter, and of an extrapolation chamber with 1 mm and 4 mm diameter collecting electrodes and 0.06 mm gaps for use in dosimetry measurements for therapeutic beta-ray sources.
- NMIJ (CCRI(I)/01-31): Dr Takata mentioned the new laboratory administration (ETL now being part of the NMIJ, which in turn is part of the AIST). His scientific contributions indicated that calculated wall corrections are consistent with the experimental response of their cylindrical graphite standard chamber in ^{60}Co beams but not for ^{137}Cs.
- NPL (CCRI(I)/01-21): Dr Duane indicated that the disrupting move to new laboratories should be completed by the end of 2001. He indicated that the NPL is developing a water calorimeter, also a portable graphite calorimeter as a transfer standard, and is re-evaluating the calculated wall corrections for their graphite cavity chambers.
- NRC (CCRI(I)/01-23, -24, -27 and -28): Dr Rogers called attention to their work showing the necessity of pre-conditioning the NE 2571, on their calculations of the electric field lines in an free-air chamber, and on new calculations of the heat defect in water.
- OMH (CCRI(I)/01-3 and -6): Dr Csete said that in spite of staff reductions and the need for new facilities, he was hoping to obtain a new cobalt source and make a new key comparison.
- PTB (CCRI(I)/01-19 and -20): Dr Kramer reported the development of a Domen-type sealed-water calorimeter, operated at 4 °C, for their primary standard of absorbed dose for photon beams. The problem of replacement factors in transferring measurements from graphite extrapolation chambers to in-phantom absorbed dose to water had largely been resolved.
- VNIIM (CCRI(I)/01-2): Dr Fedina referred to the work at the VNIIM on soft- and medium-energy x-rays and the use of spectrometry.

9 REPORTS FROM INTERNATIONAL MEMBERS AND OBSERVERS

9.1 ICRU

Professor Allisy reported on current ICRU activities. The ICRU Report 64 "Dosimetry of High-Energy Photon Beams Based on Standards of Absorbed Dose to Water" is at the publisher. The ICRU has entered into an agreement with Nuclear Technology Publishing to begin publishing ICRU Reports as a serialized publication. Other Report Committees developing documents of interest to the CCRI(I) include those on Dosimetry Systems for Radiation Processing and on Dosimetry of Beta Rays and Low-Energy Photons for Brachytherapy with Sealed Sources. Professor Allisy recalled his forty-three years of work and reminded the participants that he would no longer be representing the ICRU. Dr Sharpe expressed the great appreciation on behalf of the CCRI(I) for Professor Allisy's contributions to the CCRI and to the ICRU. Dr Rogers added that the contributions made by Professor Allisy to the field of dosimetry and the role of the BIPM had been mammoth. These sentiments were endorsed by the meeting.

9.2 IAEA

Dr Meghzifene introduced the report from the IAEA (CCRI(I)/01-8). He mentioned a few highlights of interest to the Section, including: publication of the new Code of Practice TRS-398; the new calibration service for mammography x-ray beams; the development of a new code of practice for x-ray dosimetry in diagnostic radiology; the reduction of effort in the radiation-processing dosimetry service; the planned new efforts in activity measurements for nuclear medicine; the plans to extend efforts into radiation-protection operational quantities; and the International Symposium on Standards and Codes of Practice in Medical Radiation Dosimetry planned for 25-28 November 2002.

9.3 IOMP and IRPA

There were no representatives present from either the IOMP or the IRPA and no written reports had been submitted. It was suggested that the organizations be approached to appoint formal liaisons with the CCRI(I) rather than to invite the Presidents as has been customary.

10 PUBLICATIONS

10.1 Bibliographies from NMIs

Attention was drawn to the BIPM website that now offers the publications of the NMIs for the last two years. The participants were asked to keep their bibliographies up-to-date and to submit them in a workable electronic form.

10.2 CCRI(I) web pages

The participants were reminded of the new procedures for the electronic submission of working documents that are then web-accessible and password-restricted to the delegates. Any changes to the working documents for the fifteenth meeting should be sent by 15 June 2001.

11 FUTURE MEMBERSHIP

NMI requests for membership of the CCRI are submitted to the Director of the BIPM or to the President of the CIPM. To be eligible, each NMI must provide national measurement standards even if not a primary standards laboratory, and fulfil the criteria determined by the CIPM. It was suggested that the Swedish Radiation Protection Institute might be transferred to observer status as they no longer fulfilled the criteria for membership, and that perhaps it might be appropriate to invite the METAS and the STUK to apply for membership.

12 TRENDS AND FUTURE NEEDS IN IONIZING RADIATION METROLOGY: RECOMMENDATIONS TO THE CCRI, CIPM AND THE CGPM

Professor Moscati summarized information on a CIPM review of needs in metrology. He pointed out that many tasks described in the1998 report had been completed. There are important changes in the way the NMIs and the BIPM will work in the future, and technological advancements and developments will affect international metrology, such as moving into the areas of chemistry and biotechnology. Changes should reflect societal needs, including removal of barriers to trade, protection of the environment and consideration of problems in human health and safety, all of which require more reliable and accurate, traceable and comparable measurements. He brought attention to a questionnaire sent to all NMIs on national and international needs in metrology that called for forward-looking suggestions on changes that might be expected in our international metrology system. These suggestions are needed for the preparation of a draft report to be discussed at the CIPM meeting in October 2001 and to be presented to the CGPM in 2003, so all representatives were encouraged to participate in their NMIs' efforts to prepare the suggestions.

13 DATE OF NEXT MEETING

It was agreed that a meeting in Spring 2003 was necessary and that it should be coordinated with those of Sections II and III. Based on available information on the needs of Section II, a tentative date of 21 May to 23 May 2003 was suggested. Members were reminded that the deadline for submission of working documents would be six weeks before the meeting.

The Chairman concluded the meeting by remarking on the significant progress that has been made on activities required by the MRA. He reminded the participants of a number of important action items approved at the meeting: submission of bilateral data to be included in Appendix B; the formal notification of changes in standards, including documented values of correction factors, uncertainties and effective date, particularly in regard to

the very useful discussions at the meeting on wall and fluorescence-absorption corrections; and the advance approval required for future bilateral and regional comparison protocols.

Finally he thanked the BIPM for its hospitality, the visit to the dosimetry laboratories and for the new modern meeting facilities from which the meeting had benefited.

S.M. Seltzer, Rapporteur

September 2001

Revised October 2001

APPENDIX R(I) 1.
Working documents submitted to Section I of the CCRI at its 15th meeting

Open working documents of Section I of the CCRI can be obtained from the BIPM in their original version, or can be accessed on the BIPM website (http://www.bipm.org). The complete list of documents is given on page 67.

Consultative Committee
for Ionizing Radiation

Section II: measurement of radionuclides
Report of the 16th meeting
(21-23 May 2001)

Agenda

1 Opening of the meeting; approval of the agenda; appointment of a rapporteur.

2 Report of the sixteenth meeting of the CCRI.

3 CCRI(II) key comparisons of activity measurements:

- 3.1 ^{192}Ir trial comparison;
- 3.2 ^{204}Tl comparison;
- 3.3 ^{152}Eu comparison results;
- 3.4 ^{89}Sr comparison results;
- 3.5 ^{238}Pu comparison progress;
- 3.6 ^{75}Se comparison publication;
- 3.7 ^{90}Sr comparison publication;
- 3.8 Future CCRI(II) comparisons.

4 International Reference System (SIR):

- 4.1 Status report on the ionization chamber system;
- 4.2 SIR Monograph;
- 4.3 Efficiency curves;
- 4.4 Systematic analysis of the SIR.

5 Extension of the SIR:

- 5.1 Status report on the BIPM liquid scintillation counting system;
- 5.2 Report of the ICRM Working Group on Liquid Scintillation Counting;
- 5.3 Extension of the SIR to beta emitters with the liquid scintillation counting system;
- 5.4 Extension to short-lived radionuclides.

6 MRA-associated matters:

- 6.1 Standards equivalence;
- 6.2 Results of regional key comparisons reviewed by the Standards Equivalence Working Group;
- 6.3 Regional comparisons proposed to the CCRI(II);

6.4 CMC status reports from the regions;

6.5 BIPM key comparison database.

7 Reports from the other working groups:

7.1 High-efficiency detection systems;

7.2 Realization of the becquerel at the basic level.

8 NMI project reports.

9 BIPM programme development.

10 Trends and future metrological requirements: recommendations to the CCRI for the CGPM.

11 NMI laboratory reports.

12 CCRI(II) web pages.

13 Membership of CCRI(II).

14 Any other business.

15 Date of the next meeting.

Abstract

Section II (Measurement of radionuclides) of the Consultative Committee for Ionizing Radiation (CCRI) held its sixteenth meeting at the Pavillon de Breteuil, Sèvres, on 21, 22 and 23 May 2001. The principal discussions centred on two main issues: the establishment of the key comparison reference values (KCRV) and equivalence data for radioactivity standards, and the extension of the International Reference System (SIR) for the comparison of pure-beta emitters. Agreement was reached on a majority of those radionuclides that had been compared previously and the population of the database will begin in the summer. A new Key Comparison Working Group was established to coordinate the work of the former SIR and equivalence working groups. One of the main tasks for this group will be to re-examine those radionuclides for which problems are still unresolved and, in particular, to produce a mechanism for identifying and dealing with outliers. For the extension of the SIR, a timetable has been approved to produce recommended measurement procedures, sample preparation protocols and standard scintillants. Following trials at the BIPM, it is intended to introduce an operational system, using both the CIEMAT-NIST and triple-to-double coincidence ratio (TDCR) methods, by the autumn of 2002. A significant expansion in the key comparison programme is planned with six exercises scheduled for the next two-year period. Advances have been made in the characterization of the BIPM SIR ionization chambers and further work, both theoretical and experimental, is planned particularly to provide information on other factors which influence the detection efficiency for individual radionuclides.

1 OPENING OF THE MEETING; APPROVAL OF THE AGENDA; APPOINTMENT OF A RAPPORTEUR

Section II (Measurement of radionuclides) of the Consultative Committee for Ionizing Radiation held its sixteenth meeting at the Pavillon de Breteuil, Sèvres, on 21, 22 and 23 May 2001.

The following members were present: D. Alexiev (ANSTO), R. Broda (RC), N. Coursol (BNM-LNHB), C. Grover (NRC), Y. Hino (NMIJ/AIST), H. Janβen (PTB), L.R. Karam (NIST), J.M. Los Arcos (CIEMAT), G. Moscati (President of the CCRI), T.S. Park (KRISS), D.F.G. Reher (IRMM), S. Sepman (VNIIM), B.R.S. Simpson (Chairman of Section II, CSIR-NML), L. Szücs (OMH), M.J. Woods (NPL), Yang Yuandi (NIM).

Personal members: J.-J. Gostely (IRA/METAS), G. Winkler (IIK).

Observers: A. Allisy (ICRU), P. Dryák (CMI), P. De Felice (ENEA-INMRI), C.J. da Silva (LNMRI/IRD), W. de Vries (NMi VSL).

Also attending the meeting from the BIPM: P. Giacomo (Director Emeritus of the BIPM), P.J. Allisy-Roberts (Executive Secretary, BIPM), D.T. Burns, C. Michotte, G. Ratel and C. Thomas (BIPM).

Apologies were received from the invited guests: H. Klein and P. Sharpe.

Absent: IOMP and IRPA.

Dr P.J. Allisy-Roberts presented apologies for his absence on behalf of the Director of the BIPM, Dr T.J. Quinn, and opened the meeting by welcoming the participants to the meeting room in the new Pavillon du Mail.

Dr B.R.S. Simpson, the Chairman, commenced by welcoming the participants and, in particular, the new delegate from the NRC (Canada), Dr C. Grover. Members then introduced themselves. In addition to the regular participants, Dr C. Thomas (BIPM) was in attendance in her role as coordinator of the BIPM key comparison database (KCDB). The Chairman stressed the important tasks of the CCRI(II) and noted that much of the work of the Section was conducted via the various working groups whose lifetimes ceased when their tasks were completed. He noted that a particular function of the Section was the conduct of key comparisons, as was also the case for the other two Sections of CCRI. It was the responsibility of Prof. Moscati to inform the CIPM of the work conducted by the three CCRI Sections and to

advise that body of those matters of particular concern in the area of ionizing radiations.

It was reaffirmed that the Section was seeking to place more emphasis on, and provide more time for, discussion on technical matters via oral presentations and, to that end, had agreed that the reports of the national metrology institutes should be provided as written documents prior to the meeting, which had indeed occurred.

The Section delegates were reminded of the various actions that had been placed upon them at the previous meeting. Most of these would be addressed at appropriate points on the agenda.

The meeting confirmed the appointment of Mr M.J. Woods as Rapporteur.

The agenda was approved with the inclusion of an additional item on the membership of CCRI(II). It was noted that Dr P. Cassette (BNM-LNHB and coordinator of the ICRM Liquid Scintillation Working Group) had been invited to address the Section on the agenda item relating to the extension of the SIR. The discussion on the agenda item relating to the working group report on the ^{204}Tl comparison would also be postponed to that time. There was a late inclusion of a presentation and discussion relating to the extension of the SIR to short-lived radionuclides. It was agreed to accept the other late documents (CCRI(II)/01-25 to -31).

2 REPORT OF THE SIXTEENTH MEETING OF THE CCRI

Professor Moscati pointed out that the full details of the meeting are contained in the relevant CCRI report. He would meet (at the CCRI) with the three CCRI Section chairmen after their respective meetings and report back to the CIPM. Professor Moscati informed the meeting that the General Conference would be reviewing the document on *National and International needs relating to Metrology: International collaborations and the role of the BIPM* which had been produced in 1998 and was available from the BIPM website (see also item 10).

3 CCRI(II) KEY COMPARISONS OF ACTIVITY MEASUREMENTS

Regarding the discussion on key comparisons it was noted that the CCRI(II) and RMO key comparisons provide a snapshot at a specified time for a given value of activity of a particular radionuclide whereas the SIR provides ongoing key comparisons of different values of activity measurements for the same given radionuclides. The CCRI(II) has previously decided that the SIR data are the basis for degrees of equivalence for the KCDB. The CCRI(II) and RMO key comparisons are linked to the SIR values so that each NMI has a unique set of degrees of equivalence for a given radionuclide. The KCRV for a CCRI(II) or RMO key comparison is the activity value derived from the equivalent activity of the SIR KCRV. The degrees of equivalence will be the same between pairs of NMIs in this comparison as they are in the equivalent SIR key comparison because the CCRI(II) data are also transferred to the SIR dataset. Thus, all NMIs who participate in the CCRI(II) or RMO key comparison will see their degrees of equivalence in graphical and tabular form compared with the other participants. They will also see the same data expressed as equivalent activities within the SIR comparison in which other NMIs have participated.

3.1 ^{192}Ir trial comparison (Coordinator: Y. Hino)

Dr Y. Hino reported on the second trial comparison that had been conducted during 1997-1998 and which involved the CMI-IIR, ETL (now NMIJ), LNMRI/IRD, VNIIM, and Nagoya University. The dispersion of the results was less than in the first comparison and agreed well with the existing SIR reference value. It was notable that the extrapolations using a gamma gate set on the 316 keV photopeak showed a significant upturn as the proportional counter efficiency exceeded about 95 %. It was pointed out that the SIR value needed to exclude values from NMIs which had now been superseded. The reasons for the improvement in the agreement were not clear and it was proposed that the Working Group on ^{192}Ir should examine this issue. To this end, Dr H. Janβen, Dr G. Ratel and Mr D. Reher agreed to supplement the existing working group: it was tasked to produce a report on their findings before the new CCRI(II) comparison begins. It was also stressed that if the comparison results are to be submitted to the CCRI(II) Equivalence Working Group (now the Key Comparison Working Group see item 4.4) for their

recommendation, they should be included in the SIR database as key comparison data and results submitted adopting the same reporting protocol as used for BIPM key comparisons.

3.2 ^{204}Tl comparison (Coordinator: G. Ratel)

Consideration of this item took place during the discussions on the extension of the SIR. The ^{204}Tl Working Group, with members P.J. Allisy-Roberts, T. Altzitzoglou, P. Cassette, N. Coursol. C. Michotte, G. Ratel (coordinator), D. Reher and M.J. Woods, had met in February 2000 and had agreed to conduct a range of further investigations. These were essentially now complete. The principal problems lay with the high carrier concentration of the comparison material and its effect on the self-absorption for solid sources. Investigations at the BNM-LNHB had not identified any problems arising from the photo-sensitivity of thallium. It was agreed that this working group be disbanded and a new comparison conducted.

3.3 ^{152}Eu comparison results

Dr G. Ratel reported on the results of the key comparison. The sources had been prepared by the PTB and measured in the BIPM SIR ionization chamber prior to their distribution to the participants. A trial comparison had been conducted amongst five NMIs (BNM-LNHB, NMIJ, NRC, OMH, PTB) and, following the successful conclusion of this exercise, sources had been sent to the other eighteen participants in December 1999. A large variety of standardization methods was employed and the arithmetic mean of all results was 582.0 ± 1.4 kBq g^{-1}. Two results from $4\pi\gamma$ measurements showed large deviations from the mean value and Dr G. Winkler noted that this method was hindered by the poor uncertainties associated with the x-ray emission probabilities. There was an asymmetric distribution of results ranging from +1.5 % to –2.5 % from the mean value. There appeared to be a slight difference in the means from the various standardization techniques and the spread of results seemed to be somewhat larger than those from previous submissions to the SIR. During the general discussion of the results, it was suggested that the declared uncertainties were smaller than warranted by the overall distribution: it was stated that another Consultative Committee had examined their standardization methods and had constructed a “state-of-the-art” uncertainty budget. It was agreed that CCRI(II) should conduct a similar exercise using the ^{152}Eu comparison as an example and the Uncertainties Working Group was established to do this, comprising H. Janβen

(coordinator), R. Broda, N. Coursol, J.M. Los Arcos, G. Ratel, D. Reher and M.J. Woods. A further examination of the problems surrounding the standardization of ^{152}Eu would be held in abeyance until the new working group had reported. Concern was expressed that in the presentation, the individual results were not attributed to the participants; it was pointed out that the exercise was still at the draft A stage. Dr G. Ratel agreed to produce the draft A report by October 2001 and, in addition, would provide the Equivalence Working Group with the reporting forms for the ^{152}Eu and ^{192}Ir exercises together with the SIR data relating to these radionuclides.

3.4 ^{89}Sr comparison results

This radionuclide had been chosen for a comparison because of its importance to the medical community. Dr Ratel reported that twenty-three ampoules were prepared at the PTB from a dilution of a stock solution as 30 mg g^{-1} $SrCl_2$ in 0.1 mol HCl. At the reference time, ^{85}Sr and ^{90}Sr were identified as the major contaminants at 0.172 % and 0.20 % by activity, respectively. Insignificant quantities of ^{84}Rb (0.000 88 %) and ^{86}Rb (0.000 112 %) were also detected. Because of the low response per unit activity in the SIR ionization chambers, six ampoules were also prepared at the PTB from the undiluted solution and sent to the BIPM for SIR assay. The contribution of the contaminants to the ionization chamber response amounted to about 30 % of the total response. The nineteen participants used ten different standardization methods. Of these, five measurements were made by the efficiency tracer 4πβ-γ-coincidence technique using ^{60}Co as the tracer. Of these results, three were clearly identified as outliers and confirmed that the use of this tracer is not appropriate, as may be deduced from its beta decay characteristics. A draft A report is being produced by Dr Ratel. It was recommended that the Equivalence Working Group should consider not including these results in the determination of the KCRV although they would still be entered into the BIPM key comparison database. Some examples of the stability problems experienced by those participants using liquid scintillation counting were presented and demonstrated that stability depended on such factors as the aqueous/scintillant volume ratios and the nature of the scintillant.

3.5 ^{238}Pu comparison progress

This comparison is still under way with six NMIs so far having provided eleven results to Dr Ratel. Mr Woods reported that, because plutonium is

designated as an IAEA safeguards material, some significant problems had arisen regarding the transport of samples to participants. Additional authorizations are required for transport arrangements and this had still not been resolved in a few cases. As a warning it was noted that isotopes of Am and Np may have similar restrictions imposed in the future. Because of the transport problems, it was agreed that the deadline for reporting results should be extended to 1 September 2001.

3.6 ^{75}Se comparison publication

The amendments suggested by the Chairman and by CCRI(II) have been incorporated in the report of the ^{75}Se comparison which was submitted to *Nuclear Instruments and Methods*. The paper has been accepted and is awaiting publication.

3.7 ^{90}Sr comparison publication

The results of the ^{90}Sr comparison had been presented at the Liquid Scintillation Conference at Karlsruhe during May 2001. A paper will be produced by Dr G. Ratel and submitted for publication. Consideration will also be given to publishing a summary in *Metrologia*.

3.8 Future CCRI(II) comparisons

A questionnaire had been distributed to delegates listing twenty-four radionuclides as candidates for future comparisons and the responses were detailed in the working document, CCRI(II)/01-20. In addition, a discussion paper (CCRI(II)/01-21) had been submitted which differentiated between the requirements from separate user communities. From the candidate radionuclides, only three (^{32}P, ^{186}Re and ^{235}U) did not have entries in the SIR database. Three radionuclides (^{109}Cd, ^{125}I and ^{137}Cs) had been the subject of key comparisons in the previous twenty-year period. It was noted that three comparisons are still ongoing (^{89}Sr, ^{152}Eu and ^{238}Pu) and that working groups were examining previous comparisons (^{192}Ir and ^{204}Tl). Fifteen delegates had responded to the questionnaire and six radionuclides had commanded over 50 % support as candidates for comparison. Some delegates had remarked that they had been dissuaded from nominating some radionuclides because of their short half-lives. The remaining candidate radionuclides (^{32}P, ^{54}Mn, ^{65}Zn, ^{85}Sr and ^{241}Am) were then considered.

Delegates were reminded of some of the considerations that should be taken into account in selecting comparison radionuclides, such as:

- the number of CCRI(II) comparisons that could be conducted each year;
- the number of existing SIR entries;
- the demands of the SIR efficiency curves;
- the level of interest;
- the need for pilot laboratories.

For longer-lived radionuclides, it was agreed that it would be desirable to provide a longer period for the reporting of results, thereby allowing NMIs to organize their work programmes in a more satisfactory way.

Following extensive discussions, the following comparison programme was agreed.

Nuclide	Provide Source	Provide / solution	Distribution	Start date	Finish date
^{204}Tl	BNM-LNHB + BIPM		BIPM	Oct. 2001	May 2002
^{241}Am	NPL		NPL/BIPM	Dec. 2001	Dec. 2003
^{65}Zn	IRMM		IRMM/BIPM	Feb. 2002	Feb. 2003
^{32}P	PTB		PTB/BIPM	Feb. 2002	May 2002
^{54}Mn	PTB		PTB/BIPM	Apr. 2002	Apr. 2003
^{192}Ir	NMIJ		NMIJ/BIPM	Oct. 2002	Feb. 2003

The response rate to the questionnaire and its subsequent outcome indicated that this format was useful in determining future comparison programmes and should be repeated before the next CCRI(II) meeting.

The problem of publication of individual results before the deadline was raised, a situation which can occur when papers are submitted for publication or presentation at conferences such as at the ICRM. It was agreed that the comparison protocol be revised to remind participants that results should not be released before an agreed deadline.

4 INTERNATIONAL REFERENCE SYSTEM (SIR)

4.1 Status report on the ionization chamber system

Since the previous CCRI(II) meeting, NMIs had continued to provide the SIR with an increasing number of radionuclides. In particular cases, e.g. ^{177}Lu and ^{89}Sr, special care was taken to determine the presence of potential impurities and to quantify them with precision by means of Ge spectrometers. The contribution of bremsstrahlung to the response of the ionization chamber had also been investigated. In addition, a careful analysis had been carried out to characterize more fully the efficiency of the ionization chamber. Two ampoules filled with radioactive gas (^{133}Xe and ^{222}Rn) have been measured. Moreover, the ININ had participated for the first time. In total, seventy-three ampoules were measured in the period concerned. Full details of the submissions were presented in working document CCRI(II)/01-18.

4.2 SIR Monograph

The list of contents for the proposed SIR Monograph was presented. This included:

- Introduction
- Description of method
- Description of experimental set-up, including new developments
- Some relevant formulae:
  a) to calculate equivalent activity with its uncertainty
  b) to correct for the equivalent activity of an impurity with its uncertainty
- Periodic checks of sources from 1976 to 31 December 2000
- Periodic checks of chambers
- Photon efficiency curve of SIR chamber as at 31 December 2000
- Beta efficiency curve of SIR chamber as at 31 December 2000
- Recalculation of the lower and upper limits for the acceptable activity of ampoules to be submitted
- Details for submission of ampoules (including customs requirements)

For each radionuclide, a table of results as at 31 December 2000 will be presented together with a plot with estimators (arithmetic mean, weighted mean, median and uncertainties) where there are at least two entries. The software used to acquire data and to calculate the equivalent activity will also be given in an appendix.

Proposals were made and approved concerning the availability of data in the KCDB. These were:

1. The SIR degrees of equivalence will be in the database; N.B.: KCDB data cannot be downloaded as EXCEL files.
2. The SIR "Mother file" should be available on the web as a CCRI(II) document with restricted access. [It was proposed that these EXCEL files be available to the new Key Comparison Working Group (see 4.4).]
3. The SIR Monograph should be available as a BIPM publication and also be capable of being downloaded from the BIPM website.
4. As the SIR Monograph is effectively the "Final report" of all the BIPM key comparisons up to 31 December 2000, it should contain the KCRV for each radionuclide and the results of each NMI including the degrees of equivalence as they will appear in the KCDB (see also 4.4).
5. Once approved by the CCRI(II), updates after 1 January 2001 should be published in *Metrologia*.

4.3 Efficiency curves

Dr C. Michotte presented several improvements and additional measurements that related to the efficiency curves for the SIR ionization chamber. These included the adoption of revised half-life values for ^{111}In and ^{125}I, and the effect of more accurate half-life and impurity values for ^{177}Lu^{m}.

The rules for the selection of radionuclides to be used for the determination of the photon efficiency curves were described and included:

- more than one SIR entry for the radionuclide;
- no gases;
- no high-energy beta emitters;
- no positron emitters with a positron emission probability greater than 10 %;
- median values used;

- restricted ranges of chemical and density compositions for low-energy gamma emitters.

A sixth-order polynomial was used for the fitted efficiency curve and coherence of the fit was determined by comparing actual and theoretical values for the forty radionuclides used in the fit data. The fitted curve also agreed well with the curve computed by Rytz in 1984 for energies above 60 keV. The computed curve was used to predict the efficiencies for the other radionuclides in the SIR database and satisfactory agreement was achieved with only one exception (^{243}Am).

The beta efficiency curve (ln(eff) v. mean beta energy) was also presented. It is based on the following radionuclides: ^{85}Kr, ^{89}Sr, ^{204}Tl, ^{32}P, ^{90}Sr, ^{144}Ce, ^{106}Ru; all except ^{32}P are first-forbidden transitions. It was suggested that cubic spline fitting should be examined using least-squares analysis.

It was noted that theoretical A_e values for all SIR entries are available. The theoretical response for ^{204}Tl was calculated for the BIPM ampoules which had been used in the comparison and these agreed with the measured values within the uncertainties.

For ^{124}Sb, one of the three results appeared to be an outlier. However, the application of the efficiency curves suggested that the outlier assumption was not warranted and that the real problem was the underestimation of the uncertainties of the submitted values.

It was remarked that the calculated and measured equivalent activities may often be strongly correlated and that caution should be observed.

The conclusions were that the photon efficiency curve was accurate to better than 1 % above an energy of 65 keV and that the beta efficiency curve was still under investigation. There is a need for more data at low energies and Monte Carlo simulations were needed to provide improved data on effects arising from density, gaseous formats, effects of annihilation gamma rays, etc.

4.4 **Systematic analysis of the SIR** (Coordinator: D.F.G. Reher)

The working group had held several meetings since the last CCRI(II) meeting and these had been conducted jointly with the Equivalence Working Group. The principal concerns had been the examination of the SIR "Mother" database and the subsets that produced the KCRV and data for the degrees of equivalence. A number of recommendations had been approved for submission to CCRI(II) for its approval and these were detailed in

working document CCRI(II)/01-15. These recommendations were discussed and the following decisions approved:

1. The corrected SIR KCRV and equivalence files would be placed on the CCRI(II) website with access restricted to CCRI(II) delegates. Comments are to be sent to G. Ratel (who will forward copies to D. Reher and M.J. Woods). Subject to any amendments, the data will be used to populate the KCDB.
2. A number of radionuclide entries need further consideration because of the need to agree to a system for identifying outliers (and excluding them from the KCRV file) and to clarify whether the standardization method is direct or non-direct, etc.
3. Those radionuclides with no ambiguities and for immediate inclusion in the databases are: ^{24}Na, ^{46}Sc, ^{47}Sc, ^{56}Co, ^{56}Mn, ^{58}Co, ^{59}Fe, ^{60}Co, ^{85}Sr, ^{88}Y, ^{95}Nb, ^{95}Zr/^{95}Nb, ^{99}Mo, ^{99}Tc^{m}, ^{103}Ru, ^{111}In, ^{123}I, ^{124}Sb, ^{131}I, ^{133}Xe, ^{140}Ba/^{140}La, ^{141}Ce, ^{144}Ce/^{144}Pr, ^{152}Eu, ^{153}Gd, ^{153}Sm, ^{154}Eu, ^{166}Ho^{m}, ^{169}Yb, ^{182}Ta, ^{192}Ir, ^{195}Au, ^{201}Tl, ^{203}Hg, ^{203}Pb, ^{228}Th, ^{241}Am and ^{243}Am.
4. Those radionuclides that require further consideration are: ^{22}Na, ^{51}Cr, ^{54}Mn, ^{57}Co, ^{65}Zn, ^{67}Ga, ^{75}Se, ^{106}Ru/^{106}Rh, ^{109}Cd, ^{110}Ag^{m}, ^{113}Sn, ^{125}I, ^{133}Ba, ^{134}Cs, ^{137}Cs, ^{139}Ce and ^{207}Bi.
5. Only one entry per NMI is allowed in the KCDB and in the KCRV and equivalence databases.
6. For the KCRV calculation, the arithmetic mean and the standard deviation of the mean are to be used.
7. The rules for the determination of outliers are to be reconsidered after advice from Dr M. Cox (NPL) has been received and after the Uncertainties Working Group has considered the results of the ^{152}Eu comparison.
8. For the reporting of uncertainties, two significant digits will be stated if the first significant digit is a 1 or a 2; only one significant digit will be reported if the first significant digit is greater than 2.
9. A list of acronyms, to be approved by the CCRI(II), will be produced for the different standardization methods and will be entered in a column in the SIR database.
10. An additional column will be included in the SIR database to indicate whether the standardization method is direct/absolute or non-direct/non-absolute.

11. Two additional columns will be included in the SIR database to indicate (a) whether the entry is for inclusion in the KCRV calculation and (b) whether it is a pilot study or for the key comparison database (MRA/Equivalence).
12. An additional column will be included in the databases for comments.
13. The ^{134}Cs (1974), ^{137}Cs (1978) and ^{139}Ce (1976) comparison data are to be included in the databases.
14. Regional key comparison data should be submitted to the Key Comparison Working Group for analysis and subsequent recommendation to the CCRI(II).
15. When the Key Comparison Working Group has concerns about the quality of the submitted data from an NMI for a key comparison, these concerns should be discussed with reference to the NMI and any non-resolution should be transmitted to the CCRI President.
16. A standardized form for the presentation of uncertainty budgets is to be produced for SIR submissions. The uncertainty budget in the SIR database will have ten additional columns for the commonly used uncertainty components with an additional column for the total uncertainty of method specific components and a further additional column describing the method specific components.
17. The extended SIR is not sufficiently mature at this stage to be considered as a key comparison facility.
18. The results of the ^{125}I comparison (1986), which is not linked to the SIR, are to be used for KCRV evaluation and the KCDB; the previous SIR results will not be used.
19. The ^{241}Am comparison (1963) was considered too old and will not be used; only the SIR values will be used.

It was agreed that the SIR and Equivalence Working Groups should be disbanded and replaced by a Key Comparison Working Group. The coordinator is M.J. Woods and the other members are N. Coursol, J.-J. Gostely, Y. Hino, H. Janβen, L. Karam, G. Ratel and D. Reher.

5 EXTENSION OF THE SIR

5.1 Status report on the BIPM liquid scintillation counting system

The BIPM liquid scintillation (LS) counting system had been used for participation in the ^{89}Sr comparison and for other measurements but no further work had been done to extend the SIR, partly because of the relocation of the radioactivity laboratory. The ^{90}Sr comparison results were presented at the Liquid Scintillation Conference at Karlsruhe in May 2001. The conclusion stated at that time was that the ^{90}Sr results indicated that the extension of the SIR via CIEMAT-NIST LS counting is reliable and now operational. However, concerns had been raised, particularly with regard to the reproducibility of LS cocktails and the need to identify a long-lived radionuclide in a chemically stable form in a suitable cocktail that could be used to confirm the long-term stability of the system. A protocol is required for the routine operation of the extended SIR and an option would be for the BIPM to supply LS cocktail and empty, glass containers to those wishing to submit samples. The participant would fill the container with the cocktail and radioactive solution in recommended ratios, seal the container and submit it to the BIPM for measurement. This would have several advantages including the use of a standard scintillant, the minimization of the effort required from the BIPM and the removal of uncertainties that would result from any additional sample preparation at the BIPM. It was clear that additional investigations are required for the extension of this system to non-pure-beta emitting radionuclides (the discussion continued under agenda item 5.3).

5.2 Report of the ICRM Working Group on Liquid Scintillation Counting

Dr P. Cassette reviewed the problems of liquid scintillation counting and addressed a variety of issues. It was pointed out that in the determination of the ionization quench function the Birks formula was generally used and this relied on the Bethe formula for the estimation of $\mathrm{d}E/\mathrm{d}x$ values. However, it is known that this formula does not provide accurate values at low energies because of the assumption that the linear energy transfer (LET) is zero at zero energy and that there is a linear relationship from zero energy to 100 eV. A new approach was needed. There is also insufficient data to determine the dependence of the kB factor on such parameters as chemistry, counter characteristics, cocktail composition, LET, etc. and there needs to be a better evaluation of the influence of the kB factor on CIEMAT-NIST

measurements. Both the CIEMAT-NIST and the TDCR methods are relatively insensitive to the kB factor when the beta energy is greater than 150 keV but the former is very sensitive to the kB factor for electron capture radionuclides whilst the TDCR method is not. There is a need to reach a consensus on a good LET model and for a physical evaluation of the kB factor by a study of scintillator responses. Further investigations are required on cocktails, water content, etc. A call was made for a comparison of the codes used to study the kB effect since other experiences suggested much lower effects than those presented.

The wall effect is also of concern and the existing data are not very useful as they were produced from studies in gas counters. Simulations are required using a code such as PENELOPE, although the evidence to date suggests that there are significant effects only for highly quenched, high-energy beta sources.

Better data are also required about shape factors for non-unique transitions that would improve the estimations of uncertainties for this factor.

There was some discussion about the definition of the TDCR method and a new comparison is being designed to compare the two approaches that have different definitions of the double coincidences.

Concern was also expressed about the variability between different cocktails and there is a requirement to share experiences on this. For the highest level of standardizations, there is a need for a reference LS cocktail, with some options being, for example, a commercial supply, a toluene-based mixture of PPO+POPOP+Triton, or something better.

Dr J.M. Los Arcos felt that a single cocktail would not be suitable for all situations and that perhaps three or four standard cocktails would be required. It was argued that advice should also be sought from people with chemistry backgrounds and Dr Los Arcos agreed that this would be welcomed in his working group.

Dr P. Cassette would be asked to provide a summary of his presentation for circulation to delegates.

5.3 Extension of the SIR to beta emitters with the liquid scintillation counting system (Coordinator: J.M. Los Arcos)

The coordinator referred to the working document CCRI(II)/01-29 which recorded the results of progress since the previous meeting. In particular, the

monograph by A. Grau Malonda had been published, *Free parameter models in liquid scintillation counting* (CIEMAT, 1999).

It was agreed that the working group should meet in the near future to analyse the previous work, produce a new monograph focused on the extension of the SIR to beta emitters by liquid scintillation techniques and to implement and test these procedures with the BIPM LS counting systems. The main concern had related to the accuracy of the ionization quench function (see item 5.2) and a compilation is being produced of papers together with values and databases of interest to be analysed within the working group tasks. As expressed above, three or four scintillators may be required and it was proposed that advice could be provided in an annex to the new monograph giving details of sample preparation and stability checks for specific radionuclides such as ^{89}Sr, ^{90}Sr, ^{204}Tl and ^{241}Am.

Dr P. De Felice also presented his working document, CCRI(II)/01-28. This suggested that the requirements to extend the SIR should include objective results, transparent data management, long-term operation, measuring system stability, stable procedures (unaffected by future knowledge development), openness to future re-evaluation and low effort required from the BIPM. The options would be (a) for the NMI to send a standardized solution to the BIPM where scintillant would be added or (b) for the BIPM to send empty vials and scintillant to the NMI which would then send ready-to-measure sources to the BIPM. In both events, the BIPM would count the sample, measure the quench factor and derive the corresponding efficiency value. The NMI entries would be considered to be in agreement if the efficiency values lay on the same quench curve. For each radionuclide there would be one scintillant. Compensations for instabilities of the measurement system would be based on the CIEMAT-NIST method using fixed models and parameters.

In the discussion it was suggested that the TDCR method could be used and that this would not need the chemical quench to be determined independently.

It was agreed that both methods should be used in parallel and that the BIPM would supply scintillants (as recommended by the working group) and vials to NMIs together with a recipe for the sample preparation. To achieve this end, the working group would complete the actions as detailed in the working document CCRI(II)/01-29 and would include a trial measurement at the BIPM by 10 January 2002. The dates in the working document should be postponed by about two months with the BIPM system becoming available to NMIs by the first week in August 2002.

5.4 Extension to short-lived radionuclides

Mr M.J. Woods presented the current progress on an ICRM project that was looking at the possible alternatives for those radionuclides with half-lives which are too short to allow transportation of samples to the SIR. The system under investigation uses the NPL secondary standard radionuclide calibrator that is available in many NMIs. The procedure is to provide reference sources in SIR ampoules from a stock solution of a suitable radionuclide, with all samples being assayed in the NPL chamber before dispatch. These sources would allow normalization of the responses in the individual NMI chambers. The NMIs would standardize the short-lived radionuclide, dispense aliquots into SIR ampoules at their own laboratories and measure them in their own chambers. The results are then collated and analysed at the NPL. ^{18}F (half-life equal to two hours) was chosen for the pilot study with ^{68}Ge/^{68}Ga as the reference source. Because of the reproducibility of the response of the chambers, it is also possible to make corrections for contaminants. To date, five NMIs had returned six results and four others are awaited. The first results look promising with corrections for one result to be made for ^{48}V contamination. In order for this system to be suitable, some improvements will need to be made, in particular with respect to the reporting format. In addition, a mechanism is required to transfer the results to the SIR using an NMI that is located close enough to the BIPM to allow the transport of short-lived radionuclide samples. The BNM-LNHB agreed to undertake this in September 2001. A further comparison is planned, possibly with ^{67}Ga.

6 MRA-ASSOCIATED MATTERS

6.1 Standards equivalence (Coordinator: M.J. Woods)

The report from this working group had been covered in the discussions under item 4.4. The only additional item to add to the agenda of the new Key Comparison Working Group is to establish a list of radionuclides that have similar decay schemes and are standardized by the same technique. This is required for those CMC entries where the particular radionuclide has not been the subject of a key comparison. Reference to participation in a key

comparison for another radionuclide in the same grouping would allow a supporting comparison entry to be made.

6.2 Results of regional key comparisons reviewed by the Standards Equivalence Working Group

No results had been submitted.

6.3 Regional comparisons proposed to the CCRI(II)

The APMP wishes to make additional comparisons but these have still to be decided. It is possible that these might include a comparison of large-area reference sources used for the calibration of contamination monitors.

The EUROMET has a similar proposal and it was recommended that the two groups should liaise with the possibility of an NMI from each group participating in both exercises as a link.

The APMP will submit the results of its comparisons with ^{58}Co, ^{88}Y and ^{166}Ho^{m} to the CCRI(II) via the Key Comparison Working Group after consultation with the participants. The same procedure will apply to the EUROMET comparisons of ^{47}Sc, ^{123}I and ^{237}Np (the SIR results of this last comparison were presented by Dr G. Ratel).

6.4 CMC status reports from the regions

The JCRB has proposed a statement for use with certificates issued under the MRA and a decision is awaited on its acceptability.

Dr N. Coursol is now the Ionizing Radiation Technical Coordinator for the EUROMET, replacing Mr D. Reher. There are now almost two thousand entries proposed and it is hoped that these will be submitted to the JCRB in October 2001. The inter-regional review will take place after this date.

Dr T.S. Park is the Chairman of the Technical Committee for Ionizing Radiation (TCRI) for the APMP. To date, five NMIs have provided data that are now being processed. It is hoped to finish this by the end of 2001 and to send the data to the JCRB in 2002.

No report was available for the SIM.

No report was available from COOMET but no CMC tables have been prepared yet.

In SADCMET, only CSIR-NML (South Africa) maintains measurement standards in ionizing radiation. Appendix C submissions have been proposed

and reviewed by COOMET and the SIM. Some issues still need to be resolved.

6.5 BIPM key comparison database

Delegates were reminded of the need to keep the Executive Secretary informed of the status of comparisons relating to the MRA.

A letter from Prof. G. Moscati to the editor of *Metrologia* was circulated. Delegates were reminded that the refereeing process cannot change comparison results.

7 REPORTS FROM THE OTHER WORKING GROUPS

Each working group had submitted annual reports showing the progress made. These had been distributed to all the participants in 2000 and in 2001. It was agreed to maintain these annual reports.

7.1 High-efficiency detection systems (Coordinator: G. Winkler)

Dr G. Winkler presented the current status on the development of the review of high-efficiency detection systems. He discussed the principles of the method, pointing out that if there are direct transitions to the ground state then a knowledge of the branching probability needs to be known if an accurate activity determination is to be achieved. There is a need to consider contributions from bremsstrahlung radiation and internal conversion events as well as those from the photons. He demonstrated the approach by regrouping the decay scheme transitions into a format that is primarily centred on level transitions.

Results of measurements using experimentally determined efficiencies have been compared with Monte Carlo simulations conducted at Lausanne by M. Décombaz. Generally agreement was achieved to within ± 0.1 % to ± 0.2 % for ^{51}Cr, ^{54}Mn, ^{60}Co, ^{75}Se, ^{137}Cs, ^{152}Eu and ^{192}Ir although the uncertainties for ^{152}Eu were about ± 0.5 %, rising to ± 1.7 % for thick sources. The uncertainty determination was also described.

An amended version of the related working document CCRI(II)/01-13 was submitted which represents the first page of the summary paper for publication.

7.2 Realization of the becquerel at the basic level

(Coordinator: D.F.G. Reher)

The progress to date was presented. The major effort had concentrated on determining the allowable variations in components arising from the need to achieve reproducibility between chambers of better than 0.1 %. Most of the drawings and dimensions have been completed and the next step is to produce prototypes at the IRMM and the NPL. All critical parameters will be traceable to the SI. The preferred system for sample containment has still to be resolved in order to overcome the inability to reproduce ampoules with sufficient accuracy.

8 NMI PROJECT REPORTS

Details of these had been circulated to delegates prior to the meeting.

Mr J.-J. Gostely presented the results of a calculation of the response of his IG11/A20 ionization chamber for radon gas ampoules. This was based on the efficiency curve of the chamber. Further work is under way to account for the differences between the gaseous and solution formats.

Dr N. Coursol presented the new organizational structure at the BNM-LNHB. She also showed the results of some simulations of ionization chamber responses using the PENELOPE Monte Carlo code. The simulations demonstrated reasonable agreement with the measured responses, with the code overestimating all radionuclides used to date by 6 % with the exception of ^{125}I which was underestimated by 10 %.

9 BIPM PROGRAMME DEVELOPMENT

The Ge(Li) spectrometer had been used for a range of measurement and impurity checks. It was noted that the ^{152}Eu comparison activity had been measured using the spectrometer efficiency curve and this agreed with the mean comparison value with a similar level of uncertainty as for the primary measurements.

Measurements with the HPGe spectrometer (type XtRa) have indicated a resolution of 1.9 keV at ^{60}Co photon energies reducing to better than 1 keV at 60 keV.

New scalers, operating under Labview, have been installed on the 4πβ-γ-primary measurement system and timing has been checked by direct comparison with a Cs clock.

The digital command control (DCC) system on loan from ANSTO/NPL had been tested with ^{152}Eu and ^{241}Am. In addition, a comparison had been conducted with ^{60}Co using the DCC and BIPM data acquisition systems in parallel. The ratio of DCC to BIPM results was 0.9986 (u_A = 0.0010).

A paper on *Mutual Recognition and Equivalence in Radioactivity. How can the International Reference System be used?* had been presented by G. Ratel at the *5th Workshop on the theme of mathematical and computational tools in metrology* held at the Portuguese Institute for Quality, Caparica, Portugal in May 2000. The paper is in the proceedings, published as *Advanced Mathematical and Computational Tools in Metrology V*, pp. 291-297.

Future work includes the efficiency calibration of the HPGe spectrometer, Monte Carlo simulations using GEANT for the efficiency curves for the SIR ionization chamber for photons, betas and positrons, and the effects of solution density and gaseous sources. Simulations will also be conducted using PENELOPE and the Svec/Schrader method as presented at ICRM 2001. A project in association with Dr M. Cox (NPL) is being developed to replace the iterative curve fitting currently used for the SIR efficiency curves.

10 TRENDS AND FUTURE METROLOGICAL REQUIREMENTS: RECOMMENDATIONS TO THE CCRI FOR THE CGPM

Professor Moscati explained that a report had been produced in 1998 by the CIPM and presented to the General Conference on the subject of future requirements in metrology. The CIPM had decided that this report should be reviewed because of the significant changes that had taken place since that time. These included the fact that some of the tasks originally approved had been completed, there were rapid technological and scientific developments, and new areas of metrology had been opened such as chemistry and biotechnology. In addition there are some pressing societal needs such as the need for the removal of barriers to trade; protection of the environment; protection of human health and safety, especially food safety; the need for more reliable, accurate, traceable and comparable measurements; and the existence of international networks not linked to NMIs.

Resolution 4 of the twenty-first CGPM had emphasized the need to use SI units in studies of Earth resources, the environment, human well-being and related issues. Moreover, governments are questioning the economic impact of publicly funded metrology. It is important therefore that NMIs and the BIPM review their priorities. A questionnaire had been sent to NMIs requesting responses to a number of questions relating to the review.

A particular concern to the CCRI(II) has been the increasing difficulties in respect of the ability to transport even the relatively low-activity radioactive materials that are necessary for the conduct of comparisons needed to support the MRA. Professor Moscati was asked to convey these concerns to the CIPM. The agreed form of words was:

"The CCRI(II) notes the development of international transport regulations which are becoming increasingly restrictive regarding the movement of even small amounts of radionuclide activity. The CCRI(II) is concerned that this in turn is restricting the ability of NMIs to compare their activity measurements. These comparisons are needed to provide the SI traceability necessary to ensure that the regulations can be observed. The CCRI(II) proposes that the CIPM discusses this issue with the IAEA to identify whether special transport procedures may be introduced for the exchange of radionuclide sources between NMIs for comparison purposes."

11 NMI LABORATORY REPORTS

These had been circulated to delegates prior to the meeting as working documents of the CCRI(II) and no oral presentations were requested or questions raised.

12 CCRI(II) WEB PAGES

A practical demonstration was given for access to the working documents on the restricted access web pages for CCRI(II) delegates.

13 MEMBERSHIP OF CCRI(II)

The proposal was agreed that ENEA should be encouraged to become a full member of the CCRI(II).

14 ANY OTHER BUSINESS

Dr C. Grover gave the background to the current status of radioactivity standards in Canada. A strategic review had proposed that a minimum number of four staff members were required to maintain a viable activity in this area and a response is awaited.

A proposal from Dr Quinn for paperless meetings was tabled. The principal points were that:

- Documents submitted for meetings should be in electronic form.
- These documents will be posted on the BIPM website in the section related to the relevant Consultative Committee; access will be restricted as below.
- The member institutes' delegates, when nominated, will be given a password allowing them access to these documents to read and to download as desired.
- Delegates will be alerted when documents first become available on the web. Paper copies will not normally be available for distribution.
- Short documents arriving on the day of the meeting or just before will, with the approval of the President of the Committee, be made available as paper copies.
- After the meeting, the working documents will remain on the BIPM website with the same access code; the bound volumes of working documents will no longer be made and distributed.

A request was made that documents should be available as Word files as well as PDF files so that they may be downloaded and used easily. It was noted that there would need to be agreement beforehand from the authors that such access should be available.

15 DATE OF THE NEXT MEETING

It was stated that it was preferable for the CCRI(II) meeting to be held before the ICRM meeting so that CCRI(II) decisions could be transmitted to the ICRM and that a back-to-back arrangement would reduce the inconvenience to those delegates with long distances to travel. The next ICRM meeting in 2003 is likely to be in the first week of June 2003 in Dublin. A preferred time for the CCRI(II) would be the last week of May 2003 starting on the Tuesday. A suggestion had also been made that it would be conducive to the progress of business if CCRI(II) meetings could be held yearly when the demand arose.

The Chairman of the CCRI(II) closed the meeting by offering thanks to the delegates for their participation, to the Rapporteur and, in particular, the Executive Secretary and all BIPM staff for their support during the meeting.

M.J. Woods, Rapporteur

September 2001

Revised October 2001

APPENDIX R(II) 1.
Working documents submitted to Section II of the CCRI at its 16th meeting

Open working documents of Section II of the CCRI can be obtained from the BIPM in their original version, or can be accessed on the BIPM website (http://www.bipm.org). The complete list of documents is given on page 101.

Consultative Committee for Ionizing Radiation

Section III: Neutron measurements

Report of the 14th meeting

(28-29 May 2001)

Agenda

1 Opening of the meeting; approval of the agenda; appointment of a rapporteur.

2 Report of the sixteenth meeting of the CCRI.

3 Minutes of the thirteenth meeting of the CCRI(III).

4 CCRI(III) key comparisons:

- 4.1 Fast neutron fluence measurement: Bonner sphere comparisons at 24.5 keV, CCRI(III)-K1;
- 4.2 Neutron fluence rate: thermal neutrons CCRI(III)-K8.B-10;
- 4.3 Neutron emission rate CCRI(III)-K9-AmBe;
- 4.4 Neutron fluence rate CCRI(III)-K10;
- 4.5 Future measurement comparisons.

5 RMO comparisons:

- 5.1 Comparison of neutron survey meter calibrations EUROMET project 608;
- 5.2 Other RMO comparisons.

6 The Mutual Recognition Arrangement:

- 6.1 Appendix B submissions;
- 6.2 Appendix C submissions.

7 Exchange of information on work in progress at the participants' laboratories.

8 Trends and future needs in neutron metrology (including subjects for the CGPM report).

9 Future membership of CCRI(III).

10 Other business.

11 Date of the next meeting.

12 Visit to the BIPM laboratories.

Abstract

Section III (Neutron measurements) of the Consultative Committee for Ionizing Radiation (CCRI) held its fourteenth meeting at the Pavillon de Breteuil, Sèvres, on 28 and 29 May 2001. This was the first meeting of Section III since the signing of the mutual recognition arrangement (MRA) in Paris on October 1999 and the first meeting under the leadership of the new Chairman of Section III, Dr H. Klein of the PTB. A more rapid pace of key comparisons in support of the MRA is already underway in Section III. Dr T.J. Quinn, the Director of the BIPM, presented guidance for the publications of key comparisons, including proposed checklists for the preparation of final reports of key comparisons and related publications in *Metrologia*. The submission of a *Metrologia* publication of the completed comparison of 24.5 keV neutron fluence measurements was discussed in detail along with the entry of these results, the reference value, and equivalence statements into Appendix B of the MRA database. Three comparisons in progress were discussed, involving measurements of fast neutron fluences for four monoenergetic neutron sources in the keV and MeV energy ranges, measurement of neutron source emission rate, and measurement of thermal neutron fluence rates. Finally, there was an exchange of information on the status of neutron metrology at the participants' laboratories, outlining the resources, facilities, instruments, current applications and future needs.

1 OPENING OF THE MEETING; APPROVAL OF THE AGENDA; APPOINTMENT OF A RAPPORTEUR

Section III (Neutron measurements) of the Consultative Committee for Ionizing Radiation held its fourteenth meeting at the Pavillon de Breteuil, Sèvres, on 28–29 May 2001.

The following were present: T. Bolognese (BNM), D.M. Gilliam (NIST), H. Klein (Chairman of Section III, PTB), K. Kudo (NMIJ/AIST), N.N. Moisseev (VNIIM), G. Moscati (President of the CCRI), A.J.M. Plompen (IRMM), T.J. Quinn (Director of the BIPM), D.J. Thomas (NPL).

Observers: A. Allisy (ICRU), Chaofan Rong (CIAE).

Guests: M. Kralik (CMI), B.R.S. Simpson (Chairman of CCRI Section II, CSIR-NML).

Members of the BIPM who attended all or part of the meeting: P.J. Allisy-Roberts (Executive Secretary of the CCRI, BIPM), C. Michotte, G. Ratel, C. Thomas (BIPM).

Apologies: P. Sharpe (Chairman of CCRI Section I, NPL), J. Zoetelief (TNO).

Absent: IAEA, NIM.

The Director of the BIPM welcomed the participants of Section III to the conference room of the new Pavillon du Mail.

Dr H. Klein, Chairman of Section III, began the meeting with an expression of gratitude to Dr V.E. Lewis (NPL), for his long and excellent service as a member and the former Chairman. Since there were several persons attending the Section III meeting for the first time, all present were invited to introduce themselves.

Dr Klein thanked Prof. Moscati for entrusting him with the Chairmanship, but noted that it was his intention to serve only two or possibly three terms as Chairman before his retirement. Dr Klein thanked Dr P.J. Allisy-Roberts for her preparations for the meeting, and welcomed Dr B.R.S. Simpson, Chairman of Section II (Measurement of radionuclides).

Dr D. Gilliam accepted the task of rapporteur.

Under the heading "Other business" Dr Allisy-Roberts proposed to discuss the change to paperless distribution of the working documents of the meeting.

2 REPORT OF THE SIXTEENTH MEETING OF THE CCRI

Professor Moscati welcomed the attendees and expressed his appreciation to Dr V. Lewis for a job well done as former Chairman and his best wishes to Dr H. Klein as the new Chairman. Professor Moscati commented that the published proceedings of the sixteenth meeting of the CCRI contained the details of that meeting and the associated meetings of the three Sections.

3 MINUTES OF THE THIRTEENTH MEETING OF THE CCRI(III)

No changes were suggested to the published minutes.

4 CCRI(III) KEY COMPARISONS

Dr Quinn reviewed the document "Guidance for the publication of the results of key comparisons" (CCQM/01-1), and proposed checklists for draft B reports of key comparisons and for preparation of a brief summary report in *Metrologia* (CCEM/00-18).

He noted that draft A reports go only to the participants. Draft B reports must contain all the information required for inclusion in Appendix B of the MRA database, including proposed reference values and degrees of equivalence. When approved by the Consultative Committee, the draft B report becomes

the final report of the comparison and goes into Appendix B. On the basis of this final report for Appendix B of the BIPM key comparison database, a partially shortened scientific report may be prepared and submitted for publication in *Metrologia** or any other scientific journal. In drafts A and B, the final report, and the one- or two-page summary report in *Metrologia,* uncertainties are stated with $k = 1$ (corresponding to one standard deviation), except that the reference value and the degrees of equivalence will be stated with $k = 2$.

4.1 Fast neutron fluence measurement: Bonner sphere comparisons at 24.5 keV, CCRI(III)-K1

The NPL took over as the pilot laboratory for this comparison when neutron metrology closed at the BIPM. Dr Lewis had prepared a draft A report giving two options for weighting the participants' results to determine a weighted mean as a reference value. One option is to use the stated uncertainties from the participants, but Dr Klein argued that the stated uncertainties are not justified unless sufficiently detailed uncertainty budgets and explanations of assessments of the individual uncertainty components become available. The other option is to use an equal weighting for the results from most of the participants, except for those of the NIST, which estimates a much larger uncertainty for its results in this comparison, or to use the median in order to overcome the problems with an apparent outlier (NIST) and those with exceptionally low uncertainties (CIAE and VNIIM). The CCRI(III), however, favoured the weighted mean value if generally accepted uncertainties can be applied. An important point was noted that only one value for the degree of equivalence can be attributed to each participating laboratory, i.e. if different neutron sources or methods were used by one participant, a mean value and the associated uncertainty budget will be reported.

It was noted further that there is no discussion of the measurement procedures, reference instruments or standards used to determine the neutron fluence in the report, nor is there a discussion of the reported uncertainty budgets. Dr Klein proposed that he would obtain further explanations of the uncertainties from the participants and make a recommendation to Dr Lewis within three months. The draft B may then be submitted to Section III by e-mail or conventional mail for approval.

---

* *Metrologia* now proposes publishing full final reports of key comparisons in an electronic Technical Supplement.

4.2 Neutron fluence rate: thermal neutrons CCRI(III)-K8.B-10

The NIST is the pilot laboratory for the thermal neutron comparison CCRI(III)-K8.B-10. A transfer instrument system was shipped from the NIST to the NPL in December 2000 for a trial run. Owing to some difficulties with the laboratory conditions, the NPL will require until the end of June 2001 to complete these measures. The comparison protocol has been distributed to Section III, and comments will be accepted until the end of July 2001.

A tentative schedule for participation of other laboratories was made:

- CIAE: September – November 2001;
- NIST: December 2001 – February 2002;
- NMIJ/AIST: after June 2002;
- IRMM: autumn 2002 to spring 2003.

The BNM would take part perhaps in two years when a new accelerator source is ready. The VNIIM prefers to wait until it finds a partner laboratory with a reactor. The PTB was unable to make a commitment at this time. It was agreed that results from the CIAE and the NPL should be held or sent to Dr Ratel (BIPM), who will keep them confidential, until the NIST results have been sent to the BIPM, since the NIST is acting as both a participant and the evaluator of the results.

4.3 Neutron emission rate CCRI(III)-K9-AmBe

The NPL is the pilot laboratory for the neutron emission rate comparison CCRI(III)-K9-AmBe, although Dr Lewis will not be available to compile and evaluate the results. The measurements have been completed by the CMI, the NPL and the VNIIM. The AmBe source currently at the KRISS will be sent by the Korean laboratory to the CIAE by the end of May 2001. The NIST is ready and scheduled to receive the source in August 2001. Dr Bolognese will contact the BNM-LNHB to see if they wish to be included in this comparison. The comparison is expected to be completed by the spring of 2002. Dr Klein or possibly Dr J. Adams (NIST) will serve as the evaluator of the results, depending on the availability of Dr Adams when the measurements are completed.

4.4 Neutron fluence rate CCRI(III)-K10

The PTB is the pilot laboratory for this comparison of fast neutron fluences for four monoenergetic sources: 144 keV, 1.2 MeV, 5 MeV, and 14.8 MeV. For the first time, the key comparison of neutron fluence rate measurements CCRI(III)-K10 was performed in the same field during the same period by all of the participants, using primary (or secondary) standard instruments. In March 2001, seven laboratories performed their measurements at the accelerator facility of the PTB. The following protocol and schedule for analysing and reporting data were approved:

- selection of the best neutron monitor rates corrected for dead-time losses and for in-scattering from the instruments inserted in the field;
- selection of calculated spectral neutron fluence, divided into spectra of uncollided and target-scattered neutrons for correction by the PTB, to be sent to all participants by the end of June 2001;
- determination of the fluence of uncollided neutrons at 1 m distance in vacuum and calculation of the calibration factor of the monitor selected for this comparison; evaluation of the uncertainty budget; final report to be written by the national metrology institute (final reports to be sent to Dr Klein who will act as the evaluator, on request by the end of October 2001); and
- compilation and evaluation of the results by Dr Klein (draft A report by the end of 2001).

4.5 Future measurement comparisons

Dr Klein mentioned the need for a future comparison in neutron spectrometry, but also noted a major obstacle. The need arises because many survey instruments have a significant energy response for certain ranges of neutron energies which requires that the energy distribution in these neutron fields be characterized. However, for the Bonner sphere spectrometer the difficulty arises in the estimation of uncertainties in the unfolding of the spectrum, as is the case for all other spectrometers for which the response matrix is calculated by Monte Carlo simulation and experimentally adjusted, e.g. proton recoil spectrometers. A working group is discussing this problem and it was agreed that a comparison was not appropriate at present.

Dr A. Plompen suggested a comparison of neutron fluence measurements at 19 MeV, but only one other laboratory, the PTB, supported this suggestion.

Therefore, it was concluded that a bilateral comparison between the IRMM and the PTB would be the best course of action.

In the past, Section III has made a comparison of dose equivalent only at therapy levels and not at radiation protection levels. The possibility of a comparison of ambient dose equivalent measurements was discussed (see 5.1).

5 RMO COMPARISONS

5.1 Comparison of neutron survey meter calibrations EUROMET project 608

The EUROMET project 608 comparing neutron survey meters at radiation protection levels is scheduled to begin at the end of 2001 and to run for two years. The pilot laboratory for this comparison is the BNM-IPSN. This comparison is planned as a supplementary comparison, rather than as a key comparison. As such, references to this comparison will be cited in the MRA database Appendices B and may be referenced in the calibration and measurement capabilities (CMCs) of Appendix C. The comparison results will not normally be displayed. In addition to the BNM-IPSN, six other European laboratories intend to participate in this comparison. The CIAE (China), the IRD (Brazil) and the NIST (United States) have also expressed interest in participating and this appears to be welcomed by the EUROMET.

5.2 Other RMO comparisons

No other regional metrology organizations (RMO) comparisons in neutron metrology were reported.

6 THE MUTUAL RECOGNITION ARRANGEMENT

6.1 Appendix B submissions

Appendix B currently lists nineteen comparisons approved for provisional equivalence, all of which were made prior to 1990. The present comparisons in progress or planned, namely CCRI(III)-K1 (24.5 keV fast neutron fluence), CCRI(III)-K8.B-10 (thermal neutron fluence rate), CCRI(III)-K9.AmBe (neutron emission rate), CCRI(III)-K10 (neutron fluence rate at 0.144 MeV, 1.2 MeV, 5.0 MeV and 14.8 MeV), as discussed in 4.1–4.4, are already cited in Appendix B and the results will be added as they become available and are approved by the CCRI(III), which should be within the next three years.

The period of validity for the degrees of equivalence in Appendix B has been decided by Section III to be ten years, so that the comparisons all need to be repeated within ten years provided they remain of interest.

Dr Quinn commented that almost all the final results submitted to Appendix B had contained some numerical errors and suggested that the comparison data should be checked for internal consistency very carefully by at least two other laboratories in addition to the pilot laboratory.

6.2 Appendix C submissions

Dr Klein commented on the submission of CMC information by the RMOs such as the EUROMET and the SIM. He noted that there is much more activity within some RMOs than others, as may be seen in section 5 above. Dr Allisy-Roberts cautioned that the agreed service categories should be used in the CMC submissions so that the search engine of the BIPM key comparison database will work properly. Dr Thomas pointed out that one or two additional comment fields may be added to Appendix C to give further information such as the identity of a designated secondary laboratory which may have actually performed the measurements for the corresponding NMI, and links to web pages of such (secondary) laboratories. In response to a question from Dr Simpson as to how the user community would be made aware of the MRA database, Dr Quinn replied that the BIPM had plans for some advertising efforts and that each NMI should also advertise this source of information to their user community.

Dr Allisy-Roberts called the attention of the meeting to a statement proposed for use with calibration certificates issued under the CIPM MRA. This statement had been proposed by the JCRB as: "This certificate has been issued under the provisions of the MRA drawn up by the International Committee for Weights and Measures (CIPM). All participating institutes recognize the validity of each other's calibrations and measurement certificates for the quantities, ranges and uncertainties specified in Appendix C of the MRA (for details see www.bipm.org)."

The JCRB was awaiting comments from the NMIs on this proposal. Section III made no recommendation with regard to this statement.

7 EXCHANGE OF INFORMATION ON WORK IN PROGRESS AT THE PARTICIPANTS' LABORATORIES

The Chairman had asked in advance of the meeting that all the participants report on their current activities and future plans concerning neutron metrology. The participants in turn described their resources, instruments and methods used for reference measurements, various applications and the requests of their customers. Some of this information had been included in working documents submitted to the CCRI(III). The Chairman requested that summaries of the additional information presented be sent to him. Dr Klein proposed to include all this information in a summary report on the status and future needs of neutron metrology which Prof. Moscati had requested from the NMIs. The draft report would be distributed through e-mail for comments. The final version may then be approved at the next meeting.

8 TRENDS AND FUTURE NEEDS IN NEUTRON METROLOGY (INCLUDING SUBJECTS FOR THE CGPM REPORT)

Professor Moscati presented the background to his request for information from the NMIs on trends and future needs in neutron metrology. The report *National and international needs relating to metrology* produced in 1998 by Dr Blevin for the CIPM, was being updated by Dr Kaarls in preparation for the next CGPM. It was noted that the report published in 1998 is available on the BIPM website. Dr Kaarls will be taking into account the views of the directors of the NMIs to whom he had circulated a questionnaire for a response by the end of June, a first draft of which will be presented to the CIPM in October 2001. Professor Moscati asked CCRI(III) members to make an input to their directors as appropriate. Professor Moscati will also be making a report to the CIPM, in addition to which he has to prepare a report and presentation for the CGPM in 2003 on the future needs in ionizing radiation metrology. As this report would need to be ready before the next CCRI, Dr Klein agreed to keep Prof. Moscati informed during the drafting of his summary report (see item 7).

9 FUTURE MEMBERSHIP OF CCRI(III)

The possibility of adding new members to the CCRI(III) was discussed. The CIAE and the LNMRI/IRD are interested in becoming members or observers of Section III. For this purpose, each of these laboratories must reach an agreement with its corresponding NMI in order to be nominated as the national standards laboratory for neutron metrology. These laboratories and also the CMI are encouraged to apply to their NMIs for nomination and then to the Director of the BIPM for membership. The criteria for membership and details on how to apply are given on the BIPM website.

The Chairman will also contact those NMI laboratories engaged in neutron metrology and already participating in a comparison, e.g. the KRISS, to encourage them in active cooperation within the framework of the CCRI(III).

10 OTHER BUSINESS

Dr P. Allisy-Roberts informed Section III that following a decision of the Director of the BIPM, all the working documents submitted by the NMIs for discussion at future meetings should be submitted in electronic form for publication in the restricted-access BIPM web pages. The documents can be accessed with a username and password which are available from the CCRI Executive Secretary. These code words were announced to the meeting for access to the current meeting's working documents*. In the future, the draft agenda, list of participants, and the working documents of the CCRI meeting will be available only electronically.

11 DATE OF THE NEXT MEETING

The next meeting of Section III is proposed to be held on 26–27 May 2003 (a.m.). Section I will meet 21–23 May 2003 (a.m.), and Section II will meet 28–30 May 2003 (a.m.), with the CCRI meeting 30 May 2003 (p.m.). It was noted that this proposal has yet to be approved by the CIPM.

12 VISIT TO THE BIPM LABORATORIES

Tours of the BIPM radiation dosimetry and radioactivity laboratories were provided for Dr Moisseev from the VNIIM and Mr Kralik from the CMI, who were both making their first visit to the BIPM.

---

* On the request of the CCRI(I), all the working documents for the May 2001 meetings are now available on CD-ROM. These have been distributed to the participants.

The Chairman closed the meeting with thanks to the participants for their contributions and to the BIPM for its organization of the meeting and hospitality arrangements.

D.M. Gilliam, Rapporteur

September 2001

APPENDIX R(III) 1.
Working documents submitted to Section III of the CCRI at its 14th meeting

Open working documents of Section III of the CCRI can be obtained from the BIPM in their original version, or can be accessed on the BIPM website (http://www.bipm.org). The complete list of documents is given on page 121.

LIST OF ACRONYMS USED IN THE PRESENT VOLUME

1 Acronyms for laboratories and committees

ANSTO	Australian Nuclear Science and Technology Organisation, Menai (Australia)
APMP	Asia/Pacific Metrology Programme
APMP/TCRI	Asia/Pacific Metrology Programme, Technical Committee on Ionizing Radiation
ARL*	Australian Radiation Laboratory, Yallambie (Australie), see ARPANSA
ARPANSA	(formerly the ARL) Australian Radiation Protection and Nuclear Safety Agency, Victoria (Australia)
BEV	Bundesamt für Eich- und Vermessungswesen, Vienna (Austria)
BIPM	International Bureau of Weights and Measures/Bureau International des Poids et Mesures
BNM	Bureau National de Métrologie, Paris (France)
BNM-LCIE	Bureau National de Métrologie, Laboratoire Central des Industries Électriques, Fontenay-aux-Roses (France)
BNM-LNHB	(formerly the BNM-LPRI) Bureau National de Métrologie, Laboratoire National Henri Becquerel, Gif-sur-Yvette (France)
BNM-LPRI*	Bureau National de Métrologie, Laboratoire Primaire des Rayonnements Ionisants, Saclay (France), see BNM-LNHB
CC	Consultative Committee of the CIPM
CCEMRI*	Consultative Committee for Standards of Ionizing Radiation Comité Consultatif pour les Étalons de Mesure des Rayonnements Ionisants, see CCRI
CCRI	(formerly the CCEMRI) Consultative Committee for Ionizing Radiation/Comité Consultatif des Rayonnements Ionisants
CGPM	General Conference on Weights and Measures/Conférence Générale des Poids et Mesures
CIAE	Chinese Institute of Atomic Energy, Beijing (China)

* Organizations marked with an asterisk either no longer exist or operate under a different acronym.

CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, Madrid (Spain)
CIPM	International Committee for Weights and Measures/Comité International des Poids et Mesures
CMI	Český Metrologický Institut/Czech Metrological Institute, Prague (Czech Rep.)
CMI-IIR	Český Metrologický Institut/Czech Metrological Institute, Inspectorate for Ionizing Radiation, Brno (Czech Rep.)
CNEA	Comisión Nacional de Energía Atómica, Buenos Aires (Argentina)
COOMET	Cooperation in Metrology among the Central European Countries
CSIR-NML	Council for Scientific and Industrial Research, National Metrology Laboratory, Cape Town and Pretoria (South Africa)
ENEA-INMRI	Ente per le Nuove Tecnologie, l'Energia e l'Ambiente, Istituto Nazionale di Metrologia delle Radiazioni Ionizzanti, Rome (Italy)
ETL*	Electrotechnical Laboratory, Tsukuba (Japan), see NMIJ/AIST
EUROMET	European Collaboration in Measurement Standards
GUM	Glówny Urzad Miar/Central Office of Measures, Warsaw (Poland)
IAEA	International Atomic Energy Agency
ICRM	International Committee for Radionuclide Metrology
ICRU	International Commission on Radiation Units and Measurements
IEC	International Electrotechnical Commission
IIK	(formerly the IRK) Institut für Isotopenforschung und Kernphysik, Vienna (Austria)
ININ	Instituto Nacional de Investigaciones Nucleares, Mexico (Mexico)
INMRI	see ENEA
IOMP	International Organization for Medical Physics
IPSN*	Institut de Protection et de Sûreté Nucléaire, Fontenay-aux-Roses (France), see IRSN
IRA	Institut de Radiophysique Appliquée, Lausanne (Switzerland)
IRD*	see LNMRI
IRI-TNO	Institute of Applied Radiobiology and Immunology, Centre for Radiological Protection and Dosimetry, Rijswijk (The Netherlands), see TNO

IRK*	Institut für Radiumforschung und Kernphysik, Vienna (Austria), see IIK
IRMM	Institute for Reference Materials and Measurements, European Commission
IRPA	International Radioprotection Association
IRSN	(formerly the IPSN) Institut de Radioprotection et de Sûreté Nucléaire, Fontenay-aux-Roses (France)
ISO	International Organization for Standardization
JAERI	Japan Atomic Energy Research Institute, Tokyo (Japan)
JCRB	Joint Committee of the Regional Metrology Organizations and the BIPM
KRISS	Korea Research Institute of Standards and Science, Daejeon (Rep. of Korea)
LCIE*	Laboratoire Central des Industries Électriques, Fontenay-aux-Roses (France), see BNM-LCIE
LNHB*	Laboratoire National Henri Becquerel, Gif-sur-Yvette (France), see BNM-LNHB
LNMRI/IRD	Laboratório Nacional de Metrologia das Radiaçoes Ionizantes, Instituto de Radioproteção e Dosimetria, Rio de Janeiro (Brazil)
LPRI*	Laboratoire Primaire des Rayonnements Ionisants, Saclay (France), see BNM
METAS	(formerly the OFMET) Office Fédéral de Métrologie et d'Accréditation, Wabern (Switzerland)
MRA	Mutual Recognition Arrangement
NAC	National Accelerator Centre, Faure (South Africa)
NIM	National Institute of Metrology, Beijing (China)
NIST	National Institute of Standards and Technology, Gaithersburg (United States)
NMi VSL	Nederlands Meetinstituut, Van Swinden Laboratorium, Delft (The Netherlands)
NMI	National Institute of Metrology
NMIJ/AIST	(formerly the ETL) National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology, Tsukuba (Japan)
NPL	National Physical Laboratory, Teddington (United Kingdom)
NRC	National Research Council of Canada, Ottawa (Canada)
OFMET*	Office Fédéral de Métrologie, Wabern (Switzerland), see METAS
OMH	Országos Mérésügyi Hivatal, Budapest (Hungary)

PTB	Physikalisch-Technische Bundesanstalt, Braunschweig (Germany)
RC	Radioisotope Centre, Otwock (Poland)
RMO	Regional Metrology Organization
SADCMET	SADC Cooperation in Measurement Traceability
SIM	Sistema Interamericano de Metrologia
SRPI	Swedish Radiation Protection Institute, Stockholm (Sweden)
SSDL	Secondary Standard Dosimetry Laboratory
STUK	Säteilyturvakeskus, Helsinki (Finland)
TCRI*	Technical Committee on Ionizing Radiation, see APMP/TCRI
TNO	TNO Medical Biological Laboratory, Rijswijk (The Netherlands)
VNIIM	D.I. Mendeleyev Institute for Metrology, Gosstandart of Russia, St Petersburg (Russian Fed.)

2 Acronyms for scientific terms

CMC	Calibration and Measurement Capabilities
CT	Computer-assisted Tomography
DCC	Digital Command Control
EGS	Electron Gamma Showers
EPR	Electron Paramagnetic Resonance
FRS	Facility of Radiation Standards
HVL	Half-value Layer
KCDB	BIPM Key Comparison Database
KCRV	Key Comparison Reference Value
LET	Linear Energy Transfer
LS	Liquid Scintillation
SI	International System of Units
SIR	International Reference System for gamma-ray emitting nuclides
TDCR	Triple-to-Double Coincidence Ratio