Comité consultatif pour les étalons de mesure des rayonnements ionisants (CCEMRI)

Consultative Committee for Standards of Ionizing Radiation (CCEMRI)

Rapport de
la 15e session
(juillet 1997)
Report of
the 15th Meeting
(July 1997)

Bureau international des poids et mesures

Organisation intergouvernementale de la Convention du Mètre

Comité consultatif pour les étalons de mesure des rayonnements ionisants ▮ **15e session (juillet 1997)**

Consultative Committee for Standards of Ionizing Radiation ▮ **15th Meeting (July 1997)**

Comité consultatif pour les étalons de mesure des rayonnements ionisants
15e session (7-8 juillet 1997)

Bureau International des Poids et Mesures

Consultative Committee for Standards of Ionizing Radiation (CCEMRI)

15th Meeting (July 1997)

Note on the use of the English text

To make its work more widely accessible the Comité International des Poids et Mesures 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.

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THE BIPM AND THE METRE CONVENTION

The Bureau International des Poids et Mesures (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 co-ordination of corresponding measurement techniques;
- carry out and co-ordinate measurements of the fundamental physical constants relevant to these activities.

The BIPM operates under the exclusive supervision of the Comité International des Poids et Mesures (CIPM) which itself comes under the authority of the Conférence Générale des Poids et Mesures (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) and to time scales (1988). 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 and in 1984 for the laser work. In 1988 a new building for a library and offices 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, published in the *Procès-Verbaux des Séances du Comité International des Poids et Mesures*, 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 co-ordinating 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 chairman 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 nine 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.

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

- *Comptes Rendus des Séances de la Conférence Générale des Poids et Mesures*;
- *Procès-Verbaux des Séances du Comité International des Poids et Mesures*;
- *Reports of Meetings of Consultative Committees*.

The BIPM also publishes monographs on special metrological subjects and, under the title *Le Système International d'Unités (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 *Procès-Verbaux* of the CIPM.

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 STANDARDS OF IONIZING RADIATION

as of 7 July 1997

President

G. Moscati, Member of the Comité International des Poids et Mesures; Instituto de Fisica, Universidade de São Paulo, São Paulo.

Executive secretary

M. Boutillon, Bureau International des Poids et Mesures [BIPM], Sèvres.

Members

The Chairman of Section I.
The Chairman of Section II.
The Chairman of Section III.
A. Allisy, International Commission on Radiation Units and Measurements.
G. Dietze, Physikalisch-Technische Bundesanstalt, Braunschweig.
A. Dutreix, University Hospital St Rafael, Leuven.
A.M. Kellerer, Institut für Strahlenbiologie, Gesellschaft für Strahlen- und Umweltforschung mbH, Neuherberg.
G.F. Knoll, University of Michigan, Ann Arbor.
The Director of the Bureau International des Poids et Mesures [BIPM].

Section I (X- and γ-rays, electrons)

Chairman

J.-P. Simoën, Bureau National de Métrologie: Laboratoire Primaire des Rayonnements Ionisants [BNM-LPRI].

Members

Australian Radiation Laboratory [ARL], Yallambie.
Bureau National de Métrologie: Laboratoire Primaire des Rayonnements Ionisants [BNM-LPRI], Saclay.

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

Electrotechnical Laboratory [ETL], Tsukuba.

Glówny Urzad Miar [GUM], Warsaw.

International Commission on Radiation Units and Measurements [ICRU].

National Institute of Metrology [NIM], Beijing.

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

National Physical Laboratory [NPL], Teddington.

National Research Council of Canada [NRC], Ottawa.

Nederlands Meetinstituut: Van Swinden Laboratorium [NMi-VSL], Bilthoven.

Országos Mérésügyi Hivatal [OMH], Budapest.

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

Swedish Radiation Protection Institute [SRPI], Stockholm.

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

The Director of the Bureau International des Poids et Mesures [BIPM].

Section II (Measurement of radionuclides)

Chairman

B.R.S. Simpson, National Accelerator Centre, Faure.

Members

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

Bureau National de Métrologie: Laboratoire Primaire des Rayonnements Ionisants [BNM-LPRI], Saclay.

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

National Accelerator Centre [NAC], Faure.

National Institute of Metrology [NIM], Beijing.

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

National Physical Laboratory [NPL], Teddington.

National Research Council of Canada [NRC], Ottawa.

Országos Mérésügyi Hivatal [OMH], Budapest.

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

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

G. Winkler, Institut für Radiumforschung und Kernphysik [IRK], Vienna.

The Director of the Bureau International des Poids et Mesures [BIPM].

Section III (Neutron measurements)

Chairman

V.E. Lewis, National Physical Laboratory, Teddington.

Members

Bureau National de Métrologie: Laboratoire Primaire des Rayonnements Ionisants [BNM-LPRI], Saclay.

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

Electrotechnical Laboratory [ETL], Tsukuba.

National Institute of Metrology [NIM], Beijing.

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

National Physical Laboratory [NPL], Teddington.

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

J.J. Broerse, TNO Medical Biological Laboratory [TNO-MBL], Rijswijk.

The Director of the Bureau International des Poids et Mesures [BIPM].

CONSULTATIVE COMMITTEE FOR STANDARDS OF IONIZING RADIATION

REPORT OF THE 15th MEETING

(7-8 July 1997)

TO THE COMITÉ INTERNATIONAL DES POIDS ET MESURES

Agenda

1 Opening of the meeting; designation of a rapporteur.

2 Draft mutual recognition agreement for national measurement standards and calibration certificates issued by national metrology institutes.

3 Reports of the three sections of CCEMRI and related work of the BIPM:
- 3.1 Section I: x-and γ-rays, electrons;
- 3.2 Section II: measurement of radionuclides;
- 3.3 Section III: neutron measurements.

4 Programme of future work.

5 Membership in CCEMRI sections:
- 5.1 Section I: x-and γ-rays, electrons;
- 5.2 Section II: measurement of radionuclides;
- 5.3 Section III: neutron measurements.

6 Role of the CCEMRI meeting.

7 Information on ICRU activities.

8 Date of next meeting.

Abstract

The Consultative Committee for Standards of Ionizing Radiation (CCEMRI) held its fifteenth meeting at the BIPM in July 1997. The Committee discussed the draft mutual recognition agreement for national measurement standards and calibration certificates issued by national metrology institutes distributed to member institutes by the Director of the BIPM. The CCEMRI agreed with and supported the ideas contained in this paper. Reports were presented by the Chairmen of the three sections. Section I (X- and γ-rays, electrons) reported on comparison measurements of air kerma standards in x-ray fields, ^{137}Cs and ^{60}Co γ-rays, on the schedule for future comparisons and on other activities. Section II (Measurement of radionuclides) described completed and ongoing comparisons of radionuclide standards and the role of the International Reference System (SIR). Various working group activities were also mentioned. Section III (Neutron measurements) reported on progress in the evaluation of comparisons and on plans for future comparisons. BIPM staff members presented the results of their recent work, and plans for future work were discussed. The role of the CCEMRI was discussed, the membership of its sections was reviewed and new members were proposed.

1 OPENING OF THE MEETING; DESIGNATION OF A RAPPORTEUR

The fifteenth meeting of the Consultative Committee for Standards of Ionizing Radiation (CCEMRI)* was held at the Pavillon de Breteuil, in Sèvres, on 7 and 8 July 1997.

The following were present: A.Allisy (ICRU), K. Debertin (former Chairman of CCEMRI Section II, PTB), G. Dietze (PTB), A. Dutreix (University Hospital St Rafael, Lewen), V.E. Lewis (Chairman of CCEMRI Section III, NPL), G. Moscati (Member of the CIPM, President of the CCEMRI), T.J. Quinn (Director of the BIPM), J.-P. Simoën (Chairman of CCEMRI Section I, BNM-LPRI), B.R.S. Simpson (Chairman of CCEMRI Section II, NAC).

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

Prof. A.M. Kellerer and Prof. G.F. Knoll were unable to attend.

The President, Prof. Moscati, opened the meeting and welcomed Committee members and the staff of the BIPM. Dr Quinn welcomed Committee members to the BIPM.

Dr Dietze was appointed rapporteur.

The draft agenda circulated prior to the meeting was discussed and two items were added:

1. Membership of CCEMRI sections and the role of the CCEMRI;
2. Report on the activities of ICRU by Prof. Allisy.

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* See list of acronyms on page 225.

2 DRAFT MUTUAL RECOGNITION AGREEMENT FOR NATIONAL MEASUREMENT STANDARDS AND CALIBRATION CERTIFICATES ISSUED BY NATIONAL METROLOGY INSTITUTES

Dr Quinn introduced the draft of an agreement for establishing mutual recognition of national measurement standards. During the previous twelve months this draft had been sent to national laboratories and to all Consultative Committees with a request for comments. Many such comments had already been received and Dr Quinn remarked that it was his intention to prepare a revised draft by September 1997.

Dr Quinn explained the role of the proposed key comparisons and the way in which a "key comparison reference value" obtained by an averaging procedure from the results of the comparisons may become an international reference value for an SI unit. In each case, it will be the task of the Consultative Committee to specify the details.

All three sections had already discussed the proposal and replies from Sections I and II had been circulated in the form of documents CCEMRI(I)/97-35 and CCEMRI(II)/97-26 bis. These sections had each set up a working group to develop detailed proposals for key comparisons for consideration at their next meetings.

Sections I and III agree, in general, that a small set of suitably specified comparisons should be sufficient to provide a basis for the metrological equivalence over the whole range of radiation energies to be considered. For Section II, however, reference values must be established for a large number of radionuclides; an important point for discussion is how the already established International Reference System for activity measurements (SIR) could be included in the new system.

The general conclusion of the meeting was that the CCEMRI and its three sections support the proposal to establish metrological equivalence by following the procedures described in the draft.

3 REPORTS OF THE THREE SECTIONS OF CCEMRI AND RELATED WORK OF THE BIPM

The Chairman of each section summarized the section´s activities and presented new results.

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

Dr Simoën presented the report on the activities of Section I which had held its thirteenth meeting in April 1997.

As usual, the results of comparisons of measurement standards performed since the previous meeting in 1995 were presented. At the BIPM, six air kerma comparisons were carried out using γ-radiation from ^{137}Cs and ^{60}Co. It was noted that the results for ^{137}Cs show larger deviations than those for ^{60}Co: they are consistent with the stated uncertainties, which are also larger. The results of comparisons repeated after twenty years show the stability of the standards is good. No comparison in terms of absorbed dose to graphite or water had been made since the previous meeting.

The results of some comparisons not organized by the BIPM were presented. Three bilateral comparisons and two EUROMET comparisons had been performed. The quantities considered were air kerma (for mammographic x-rays, low- and medium-energy x-rays, ^{60}Co γ-rays) and absorbed dose to water (for ^{60}Co γ-rays and high-energy photons). With the intention of establishing metrological equivalence, the results of some COOMET and APMP comparisons were compared with values obtained during international comparisons.

Section I noted the increasing role of the BIPM in calibrating national secondary standards. Forty-three such calibrations were reported concerning air kerma, absorbed dose to water and ambient dose equivalent. For ^{60}Co γ-rays, the calibration factors in terms of air kerma and absorbed dose to water

have been shown to be stable over several years. The experimental relationship between these factors may now be used to assess chamber response. These results were also used to check the validity of protocols used to derive absorbed dose from an air kerma calibration.

Further reports were given on the work of the BIPM. Dr Burns presented preliminary results from calculations, using the EGS4 Monte Carlo code, of the electron loss and photon scatter corrections for free-air chambers. These should improve the consistency of measurements made with the BIPM standard at different beam qualities.

Mme Boutillon presented data describing the recombination of ions, using two free-air chambers operating close to the saturation region. The influence of air density and humidity was also investigated. This work allows an accurate value of the recombination coefficient to be deduced.

DrAllisy-Roberts outlined the project for absorbed dose to water comparisons using the BIPM transfer system for high-energy photons. She reported that the BIPM had bought two chambers (NACP and NE 2611 A) which, together with a waterproof parallel-plate chamber (Roos type, donated by the PTB), will constitute the transfer system. All three chambers will be subject to periodic calibration in terms of absorbed dose to water in the BIPM ^{60}Co beam.

To establish the procedure which will be used in the transfer system between national laboratories, time has been reserved in the linear accelerator beam at a local hospital. Measurements on the three chambers will be made at five photon beam qualities between 10 MV and 25 MV.

The BIPM will shortly fit a new 170 TBq source in its ^{60}Co unit, and so may now consider making measurements with a graphite calorimeter. Measurements of this kind will serve as a preliminary step leading to the establishment of absolute measurements of absorbed dose for high-energy photon and electron beams.

Several reports were presented on the development and improvement of national primary standards:

- In a discussion of air kerma standards, the ETL reported work on the diffusion loss of ions in ionization chambers (parallel-plate, cylindrical and spherical chambers) and NRC summarized its investigations of chamber wall correction for ^{137}Cs γ-rays.

- When considering absorbed dose standards the ENEA reported the development of a "sealed water" calorimeter and the NRC and PTB presented their work on the heat defect in water calorimeters.
- In considering the development of brachytherapy standards the NIST presented its work on β-emitting sources (^{32}P and ^{90}Sr) and described the establishment of a calibration service for ^{125}I seeds in terms of air kerma.

In a discussion of radiation dosimetry, it was proposed that the BIPM organize a comparison at 15 kGy and 50 kGy, based on a system using mailed dosimeters supplied by participating laboratories (e.g. alanine/ESR dosimeters). Seven national laboratories are interested in such a comparison.

When discussing the new role of comparison measurements, four key comparisons were identified: three for air kerma (low energy x-rays, medium-energy x-rays and ^{60}Co γ-rays) and one for absorbed dose to water (^{60}Co γ-rays). It was agreed that a working group will advise the BIPM on the content of a questionnaire to be sent to the national institutes of metrology (NMIs) regarding their air kerma comparisons in ^{60}Co with the BIPM. The working group, chaired by Dr A. Aalbers, will submit a preliminary air kerma reference data set to Section I at least two months before the next meeting (scheduled for 1999).

3.2 **Section II: measurement of radionuclides** (Chairman: B.R.S. Simpson, former Chairman: K. Debertin)

Dr Debertin presented a report on the activities of Section II which held its fourteenth meeting in April 1997.

Comparisons continue to play a key role in the work of Section II, although the number of comparisons has declined over the last ten years. It was generally agreed that this number will now increase in view of the new challenge to demonstrate equivalence, although the existing International Reference System (SIR) would become the basis for this demonstration.

Section II is presently concerned with five comparisons:

1. ^{204}Tl *trial comparison.* The ^{204}Tl nuclide is very suitable for testing the BIPM's new liquid scintillation counter system (LSC). The solution and the ampoules were prepared and distributed by the BIPM. Results from five of the six participants agree within 1.6 %, but one result was low by 2.5 %. Further measurements, made by the outlier laboratory using a new ampoule, produced a value consistent with the others; the total spread of the data is now 1.6 %.

2. ^{204}Tl *full-scale comparison*. The ^{204}Tl full-scale comparison was delayed as problems were experienced with the trial comparison. The BIPM has now distributed 30 ampoules to 24 laboratories and is evaluating the results. Section II agreed that Dr Ratel should be given support in the evaluation of the data in order to reduce his workload.

3. ^{192}Ir *trial comparison*. ^{192}Ir is widely used in industry and medicine and was chosen as the subject of a comparison because of discrepancies in SIR measurements which show distinct groupings in the data. The results of the comparison obtained with five independent methods show a large spread, about 2 %. Potential problems related to the electron capture branch, mainly when using coincidence techniques, were discussed. For this radionuclide the $4\pi\gamma$ method appears to be superior to those based on coincidence measurements. Section II will not continue with a full-scale comparison until the remaining unresolved problems in the coincidence measurements have been considered by a new working group.

4. ^{90}Sr *comparison*. In early 1997 twelve participants submitted appropriate solutions (4 kBq to 790 kBq) of ^{90}Sr to the extended SIR and measurements were made using the LSC system. The spread in the results is approximately 1 %. This demonstrates that the extended SIR is ready for routine operation.

5. ^{152}Eu *comparison*. While in 1995 Section II did not support a proposal to undertake a comparison of the ^{152}Eu radionuclide, a comparable proposal was accepted at the 1997 meeting. A large set of ampoules will be produced by the PTB but, as a first step, only a few of them will be distributed to four laboratories. If no problems emerge, the rest of the ampoules will be dispatched and the full-scale comparison will begin.

The radionuclides ^{55}Fe, ^{85}Sr, ^{90}Sr, ^{153}Gd, ^{192}Ir, which play an important role in medicine and industry, were considered as potential candidates for future comparisons.

The SIR continues to be the most important system providing a measure of equivalence between NMIs. In contrast to organized comparisons, an NMI can send any radionuclide solution at any time. About 500 independent results for some 55 radionuclides are available. Originally intended for γ-ray emitters only, the SIR has been successfully extended to β-particle emitters. The BIPM now offers this extended service for general use, although the long-term stability of the liquid-scintillation counting system is still under investigation.

Mr Reher and Mr Woods (CCEMRI(II)/97-24) pointed out that the unit of activity is currently maintained through the calibration of reference ionization chambers such as the SIR. If this system were to fail, many decades of international effort could be lost. In order to prevent this, it was proposed that a reproducible ionization chamber be developed. A working group was established to study this project in close collaboration with the BIPM.

At the 1995 CCEMRI(II) meeting a working group was charged with the analysis of the ionization chamber SIR data. This analysis should provide a reference equivalent activity for each radionuclide. Such an evaluation allows the current performance of the NMIs to be assessed. Selection criteria for the data are given in CCEMRI(II)/97-26 bis and can also be found in the report of Section II.

Concerning the proposal on equivalence, Section II decided that:

- the working group on equivalence will establish the metrological equivalence of the activity values A_{lab} of NMIs for individual radionuclides with reference activity values A_{ref};
- metrological equivalence will be defined as the difference between A_{lab} and A_{ref} and the uncertainty associated with this value;
- metrological equivalence will be established primarily by the submission of samples to the SIR;
- data from the BIPM and other international comparisons may be included in the evaluation of equivalence provided it satisfies certain conditions;
- results will be published in a systematic manner.

The basis for metrological equivalence shall be the “key comparisons” defined for each radionuclide:

- SIR results (equivalence activity values);
- extended SIR results (activity ratios NMI/BIPM);
- results from classical comparisons (activity values).

Reports were also given from the following working groups of Section II.

- *Extension of the SIR to β-emitters with the liquid-scintillation method*. The group’s task are to support the BIPM in the extension of the SIR to β-emitters and to examine any liquid-scintillation source preparation procedure, which presents some difficulties. It was noted that the computer codes currently used in liquid-scintillation counting show problems, particularly in the case of electron capture nuclides (the Q value

is not known sufficiently well). Dr Grau Malonda suggested that a BIPM monograph on liquid-scintillation counting be produced, and he was appointed co-ordinator of a writing group.

- *Future comparisons*. As usual, Dr Szörenyi distributed a questionnaire, this time to 28 laboratories, asking for suggestions on the radionuclides that should be selected for the next comparisons. Many radionuclides were proposed, but no reasons for their selection were given. It was decided that a list of criteria should be circulated to members and observers for their consideration prior to the next CCEMRI(II) meeting.

- *Ionization chamber monograph*. The excellent *Monographie BIPM*-4 entitled "Activity measurements with ionization chambers" is complete. The Committee expressed its gratitude to Dr Schrader for this comprehensive work on the basic method for maintaining the unit of activity.

- *High-efficiency detector systems for activity measurements*. Dr Winkler has collected material for the production of a review paper "4π NaI and CsI detectors for high-efficiency counting". Dr Winkler hopes to finish the paper by the end of 1997. It will be submitted for publication in *Applied Radiation and Isotopes.*

The work of the working groups on systematic analysis of SIR results and standards equivalence has already been mentioned above.

Since no further interest was expressed in the joint procurement of radionuclides, the working group on joint procurement of radionuclides was disbanded.

In the discussion of this report on the activities of Section II three items were raised:

1. Dr Simoën asked for ideas concerning comparison measurements of α-emitting radionuclides. There was the suggestion that liquid-scintillation counting may be a good measurement technique for a comparison, but this has not yet been discussed in Section II.

2. Dr Dietze asked about standardization methods for short-lived radionuclides. It was recommended that Section II look at this task in the future.

3. With respect to the increasing importance of comparisons, it was emphasized that the Sections should take care to arrange that comprehensive results of comparisons are published in *Metrologia.*

3.3 **Section III: neutron measurements** (Chairman: V.E. Lewis)

Dr Lewis reported on the activities of Section III which held its twelfth meeting in April 1997.

- *Comparison of measurements of* 24.5 keV *fluences*. Dr Lewis reported on the results of neutron fluence measurements which he had received from five participating laboratories (CIAE, NIST, NPL, PTB, VNIIM). Four different types of neutron sources (filtered beam, Sb/Be, ^{7}Li(p,n), ^{45}Sc(p,n)) were employed. The comparisons will be completed with the participation of ETL in the summer of 1997. Dr Ratel of the BIPM reviewed the normalization steps that were carried out at the BIPM to overcome the failure of one of the ^{3}He proportional counters employed in the comparisons. Dr Klein described the highly detailed model of the ^{3}He counter and polyethylene spheres which was analyzed at the PTB by applying the Monte Carlo method to correct the response of these transfer instruments for the small differences in the energies of the various neutron sources employed by the different laboratories.

When discussing the problem of equivalence of national measurement standards, Section III was asked to identify the "key comparisons" which should be carried out and to decide how frequently they should be repeated so as to maintain or improve the degree of equivalence of the measurements at member institutes.

Dr Klein stated that he considered the key comparisons for Section III to be those concerning neutron fluence measurements in the energy range 0.1 MeV to 15 MeV and at thermal energy ($\approx$ 0.025 eV). He suggested that these comparisons be repeated every five to eight years. He recommended that the energy values already identified by the International Organization for Standardization (ISO) should be accepted by Section III as the key comparison energies. These neutron energies are 0.144 MeV, 0.565 MeV, 2.5 MeV, 5.0 MeV, 14.8 MeV, and thermal energy. All these energies are of equal priority. Dr Klein suggested that the time needed to accomplish most of these comparisons would be greatly reduced if, rather than circulate a transfer instrument around the world, all participants brought their measuring instruments to one site where most of these energies can be realized conveniently, e.g. at the PTB.

Dr Kudo (ETL) suggested that neutron source emission rate comparisons should be included among the key comparisons. Dr Kharitonov (VNIIM) expressed the opinion that ten years would an adequate interval for repetition

of the key comparisons. He suggested that, because of its longer half-life, a ^{244}Cm source from the VNIIM would be superior to a ^{252}Cf source for circulation to participating laboratories.

There was an agreement that these proposals should be followed up, but some uncertainty remained about what may be done to improve the pace of the comparisons.

- *Thermal neutron fluence measurement comparison.* At the 1995 meeting of Section III, Dr Gilliam reported an apparent problem with loss of boron from the active deposits of the intended ionization chamber transfer instruments. Since that time, a special set of very thin boron deposits had been supplied to the NIST by the IRMM for testing with various flow gases and humidity combinations. Some of the deposits are covered by thin graphite coatings with the objective of reducing any loss of boron. The IRMM will also provide a set of ^{235}U deposits as a supplement and/or substitute for the boron deposits. With the 24.5 keV comparison almost complete Dr Gilliam remarked that a greater sense of urgency seemed now to be attached to the thermal neutron comparison. The BNM-LPRI has asked to be included in the review of the protocol for this comparison.
- *BIPM standard neutron sources*. The BIPM standard neutron sources have been transferred to the NIST for maintenance following the termination of the experimental neutron programme at the BIPM. It was shown that calibration checks on these sources at the NIST agree very well with previous calibrations at the BIPM. These sources are available on loan to other laboratories. The uncertainties given for one standard deviation are less than 2 %.

Dr Klein initiated a discussion of the re-evaluation of the H(n,n) angular distribution (ENDF/B-VI code). Both Dr Klein and Dr Lewis expressed scepticism about the new evaluation, which does not appear to take account of measurements made at 14 MeV under the auspices of the CCEMRI. These measurements did not indicate a need for the change that was made between versions V and VI of ENDF/B. Dr Klein asked that the NIST help him to obtain a copy of the report by D.C. Dodder and G. Hale which documents the re-evaluation.

4 PROGRAMME OF FUTURE WORK

Because the work of the CCEMRI is performed entirely within its three sections, it was agreed that the programme of future work had already been addressed by the Chairmen of the sections in their reports.

5 MEMBERSHIP IN CCEMRI SECTIONS

The membership in the three sections of the CCEMRI was discussed on the basis of the new criteria distributed by the CIPM.

5.1 Section I: x- and γ-rays, electrons

Dr J.-P. Simoën is retiring and will be replaced by Dr K. Hohlfeld as Chairman.

The two following laboratories were proposed for membership:

- Ente per le Nuove Tecnologie, l´Energia e l´Ambiente [ENEA], Rome;
- Österreichisches Forschungszentrum Seibersdorf GmbH [ÖFS], Seibersdorf.

It was agreed that the following laboratories should be invited as observers:

- International Atomic Energy Agency [IAEA];
- International Organization for Medical Physics [IOMP];
- International Radioprotection Association [IRPA];
- Laboratório Nacional de Metrologia das Radiaçoes Ionizantes [LNMRI], Rio de Janeiro.

5.2 Section II: measurement of radionuclides

The following laboratories were proposed for membership:

- Centro de Investigaciones Energéticas Medioambiantales y Tecnológicas [CIEMAT], Madrid;
- Electrotechnical Laboratory [ETL], Tsukuba;
- Institute for Reference Materials and Measurements [IRMM], European Commission;
- Korea Research Institute of Standards and Science [KRISS], Taejon;
- Radioisotope Centre [RC], Otwock/Swierk.

It was agreed that the following laboratories should be invited as observers:

- Czech Institute of Metrology, Brno;
- Ente per le Nuove Technologie, l'Energia e l'Ambiente [ENEA], Rome;
- International Commission on Radiation Units and Measurements [ICRU];
- International Organization for Medical Physics [IOMP];
- Laboratório Nacional de Metrologia das Radiaçoes Ionizantes [LNMRI], Rio de Janeiro;
- Nederlands Meetinstituut: Van Swinden Laboratorium [NMi-VSL], Delft.

5.3 Section III: neutron measurements

No new members were proposed.

The following laboratories should be invited as observers:

- International Atomic Energy Agency [IAEA];
- Institute of Atomic Energy [IAE], Beijing;
- International Commission on Radiation Units and Measurements [ICRU].

6 ROLE OF THE CCEMRI MEETING

In detail, the role of the separate CCEMRI meeting was discussed. The Committee agreed that the meetings of the three sections are most important for the actual work and collaboration of the BIPM and the national laboratories. Much information given at the CCEMRI meeting was a repetition of that presented at the section meetings. It would be more efficient if the President of the CCEMRI and the Chairmen of the three sections could all participate in the three section meetings and in a short meeting together to agree on common conclusions. An independent CCEMRI meeting with additional members seems to be unnecessary. The Committee proposed to follow this suggestion. The next CCEMRI section meetings should take place within a period of about two weeks.

7 INFORMATION ON ICRU ACTIVITIES

Prof. Allisy informed the Committee on recent and future ICRU activities. The next ICRU meeting would be in Madison, Wisconsin (United States) in August 1997. The aim was to complete four ICRU Reports (No. 56, 57, 58 and 59).

Seminars to be given during this meeting point to new directions of future activities:

- quantities and units in non-ionizing radiation;
- computational human models;
- imaging in nuclear medicine.

8 DATE OF NEXT MEETING

The next section meetings will be in 1999. A proposal for the section meetings is:

Section III	24-25 May 1999
Section I	26-28 May 1999
Section II	1-3 June 1999
Chairmen´s meeting	4 June 1999

On closing the meeting, the President thanked the members and the staff of BIPM for their participation and their interesting contributions. He expressed the thanks of the Committee to BIPM for its hospitality.

G. Dietze, Rapporteur
September 1997
revised June 1998

CONSULTATIVE COMMITTEE FOR STANDARDS OF IONIZING RADIATION

SECTION I: X- AND γ-RAYS, ELECTRONS REPORT OF THE 13th MEETING

(14-16 April 1997)

Agenda

1 Opening of the meeting; designation of a rapporteur.

2 Comparisons of measurement standards.

3 Agreement on metrological equivalence.

4 Schedule of comparisons.

5 International and regional comparisons.

6 Present and future work of the BIPM.

7 Development and improvement of national standards for photon dosimetry.

8 Dissemination of $N_{D,\mathrm{w}}$ calibration factors.

9 Standards for brachytherapy.

10 Standards for radiation protection.

11 Standards for radiation processing.

12 Development and improvement of national standards for charged particle dosimetry.

13 Reports from member laboratories.

14 Report from the IAEA.

15 Other business.

Abstract

Section I of the Consultative Committee for Standards of Ionizing Radiation (CCEMRI) held its thirteenth meeting at the Pavillon de Breteuil, Sèvres, in April 1997. The recent work of the BIPM was reviewed and, after discussion of the points raised in the meeting and of the reports of the member laboratories, the programme for future work was agreed. The results of several international comparisons, involving the BIPM or carried out independently between standards laboratories, were reported. The CCEMRI Section I was asked to consider the draft report on agreement for metrological equivalence of standards distributed by the Director of the BIPM to member institutes. A working group was charged with identifying the key comparisons concerning x- and γ-rays and electrons, and with providing a plan and timetable which will allow Section I to consider a reference value for air kerma for ^{60}Co γ-rays at its next meeting. Progress on water calorimetry for absorbed dose to water measurements was described. Standards for brachytherapy, radiation protection and radiation processing were discussed. Progress in facilities, staffing and research, and approaches to implementing ISO *Guide 25* for calibration laboratories were discussed in reports from member laboratories.

1 OPENING OF THE MEETING; DESIGNATION OF A RAPPORTEUR

Section I (X- and γ-rays, electrons)* of the Consultative Committee for Standards of Ionizing Radiation (CCEMRI)** held its thirteenth meeting at the Pavillon de Breteuil, Sèvres, on 14, 15 and 16 April 1997.

The following were present: A.H.L. Aalbers (NMi-VSL), J. Boas (ARL), A. Brosed (CIEMAT), B.M. Coursey (NIST), J. Csete (OMH), K. Hohlfeld (PTB), W.A. Jennings (ICRU), L. Lindborg (SRPI), Z. Referowski (GUM), D.W.O. Rogers (NRC), P.H.G. Sharpe (NPL), J.-P. Simoën (Chairman of Section I, BNM-LPRI), N. Takata (ETL).

Observers: P. Andreo (IAEA), R.F. Laitano (ENEA).

Attended all or part of the meeting: P. Giacomo (Director Emeritus of the BIPM), A. Allisy (member of the CCEMRI); P.J. Allisy-Roberts, M. Boutillon, D.T. Burns, C. Michotte and G. Ratel (BIPM).

Apologies were received from: NIM and VNIIM.

The Director of the BIPM was unable to attend the meeting so Dr Simoën, Chairman of Section I, welcomed the participants. He explained the purpose of the meeting for those not familiar with the work of Section I, namely to discuss the work performed at the BIPM and to give guidance on future activities, normally in close co-operation with the national laboratories. He noted that the meetings may result in the submission of recommendations to the CIPM, but also serves a useful forum for the exchange of information on the work in progress at the various laboratories. Recently designated members of CCEMRI Section I were introduced.

* For the list of members, see on page 131.

** For the list of acronyms mentioned in this report, see on page 225.

Dr Simoën asked Dr Coursey to serve as rapporteur for the meeting.

He then invited discussion of the draft agenda which was adopted without change.

2 COMPARISONS OF MEASUREMENT STANDARDS

2.1 Comparisons with the BIPM

Direct or indirect comparisons in terms of air kerma had been made (97-2)* with the BEV (Austria), BNM-LPRI (France), GUM (Poland), LNMRI (Brazil), NIST (United States), NMi (Netherlands) and as a EUROMET project. The results for ^{60}Co are in agreement within the uncertainties with previous comparisons involving the same laboratories, over periods exceeding fifteen years. The standard deviation of the comparisons in ^{137}Cs is 0.35 %, which is higher than that for ^{60}Co but is consistent with the higher individual uncertainties for ^{137}Cs. No comparisons of absorbed dose have been made since the last meeting.

Forty-three calibrations of secondary standards in terms of the quantities air kerma, absorbed dose to water and ambient dose equivalent were reported, and collaboration has continued with the IAEA on thermoluminescent dosimeter (TLD) irradiations. An analysis of past calibration factors has identified problems with early calibrations in terms of absorbed dose to water ($N_{D,\mathrm{w}}$) of secondary standards of the type NE 2561, made at the BIPM between four and six years ago. Since that time, the calibration factors have remained stable within the uncertainties and the experimental relationship between $N_{D,\mathrm{w}}$ and the air kerma calibration factor N_K is now used to assess a chamber response. For some laboratories, the most recent calibration in terms of air kerma dates from twelve years ago and there are five laboratories with calibrations older than five years.

* Documents submitted by the participants are listed in Annexe R(I) 1, and are referred to in the text in the form 97-1, 97-2, etc.

2.2 Other comparisons

Dr Laitano reported on a comparison between the ENEA and NIST on air kerma standards for medium energy x-rays and ^{60}Co (97-9). The NIST carried two 3.6 cm^3 transfer ionization chambers (Shonka and Exradin A3) to the ENEA. For x-rays the beam qualities used were those adopted at the BIPM for free-air chamber comparisons in the energy region from 100 kV to 250 kV.

Dr Boas reported on the results of a comparison of absorbed dose to water in high-energy photon beams between the ARLand NPL (97-25). The ARLuses a 21 MeV Vickers electron accelerator to establish absorbed dose standards at x-ray beam energies comparable with those used in radiotherapy. At the ARL, x-ray beam qualities were established at 16 MV and 19 MV to match those used by the NPL calibration service. The ARL uses a graphite calorimeter in a graphite phantom to measure the absorbed dose.

Dr Coursey reported on a comparison between the NISTand PTB on air kerma standards for mammographic x-ray beam qualities (97-21). The NIST has recently introduced a calibration range dedicated to mammographic x-ray instrument calibrations. This uses molybdenum and rhodium anode tubes. Air kerma is measured with a cylindrical free-air ionization chamber. The comparison involved measurements with a Exradin A11 ionization chamber at six beam qualities, all of which involved an anode and filtration in molybdenum.

Dr Lindborg summarized the results of a EUROMET comparison in which several national laboratories with primary or secondary standards compared ^{60}Co standards both for air kerma and absorbed dose to water (97-26). Measurements were made with two Farmer ionization chambers (NE 2571 and NE 2561) and one Capintec chamber (PR 06C). A formula and correction factor were supplied to participants to allow conversion of the air kerma calibration factor to the absorbed dose to water calibration factor.

Dr Aalbers presented a progress report (97-33) on EUROMET Project 364, a comparison of primary air kerma standards involving six laboratories (including the BIPM). A Keithley ionization chamber with a flat energy response was used. Five beam qualities, ranging from 50 kV to 150 kV, were selected corresponding to the IEC 1297 recommendations.

3 AGREEMENT ON METROLOGICAL EQUIVALENCE

Paragraph 4 of the Director's draft document on metrological equivalence, presented by Dr Allisy-Roberts, lists seven responsibilities for delegation to the Consultative Committees. A working group was convened, comprising: Drs Aalbers, Allisy-Roberts, Coursey, Hohlfeld, Laitano, Rogers and Sharpe. Their deliberations were presented on the last morning of the meeting. Their draft response to the seven points was discussed by the full committee and the agreed version circulated as document 97-35. It was agreed that the working group will advise the BIPM on the content of a questionnaire to be sent to the national metrological institutes regarding their air kerma comparisons with the BIPM. The working group will be chaired by Dr Aalbers and will submit a first air kerma reference data set to CCEMRI Section I at least two months before the 1999 meeting.

4 SCHEDULE OF COMPARISONS

The BIPM gave the current schedule for comparisons of air kerma: for x-rays with the ENEA and NPL; for ^{137}Cs with the VNIIM and possibly ENEA; for ^{60}Co with the ARL, ENEA, NPLand VNIIM. For absorbed dose to water, the ARL and NPL had arranged dates. For some national laboratories, it was noted that the most recent comparison for air kerma dates from twenty years ago and there are nine whose last relevant comparison was more than ten years ago. Members accepted the responsibility of comparing their standards with BIPM standards at least every ten years.

5 INTERNATIONAL AND REGIONAL COMPARISONS

In the light of the discussion on equivalence, Mme Boutillon presented the results of the workshop on regional and international comparisons (Aalbers, Boutillon, Hargrave, Referowski). The results of three sets of regional comparisons (Asia/Pacific, COMECON and EUROMET) were analysed and compared with those of international comparisons. They concern air kerma determinations in x- and γ-ray fields. At energies higher than 100 kV the loss of accuracy is small whereas at x-ray energies below 50 kV the uncertainty in regional comparisons is about twice that in international comparisons. This is probably due to the use of transfer instruments in this energy range for which, as already shown at the BIPM, the calibration factor measured at the same quality in different beams can vary appreciably. The workshop results will be published in *Metrologia* after submission to members of Section I.

Dr Aalbers discussed the EUROMET project on ^{192}Ir wires used in interstitial brachytherapy. This work involves air kerma rate measurements on Amersham ^{192}Ir wires. Some of the participants have also dissolved the sources and made activity measurements. A discussion of activity measurements of ^{192}Ir is given in the report of CCEMRI Section II.

6 PRESENT AND FUTURE WORK OF THE BIPM

6.1 Electron loss and photon scatter correction

Dr Burns presented preliminary results of calculations of the electron loss and photon scatter correction factors for free-air chambers using the EGS4 Monte Carlo code. The method used allows values to be derived for any chamber of circular or rectangular cross section. When applied to international comparisons for medium-energy x-rays, there is a significant improvement in the consistency of the results obtained at different beam qualities. Work is continuing for low-energy x-rays. Dr Burns thanked the NMi for the recent measurements which they had made of several BIPM spectra.

In the discussion which followed, Dr Andreo suggested that EGS4 may not be the best code for low-energy calculations and stressed the importance of repeating the calculations using a different code. Both Dr Rogers and DrAalbers reported on EGS4 calculations made specifically for the standards held at their own institutions. Dr Hohlfeld presented recent results of similar calculations for two PTB free-air chambers (97-16).

6.2 Recombination coefficient

Mme Boutillon presented experimental results on the determination of the volume recombination coefficient m^2, by measurements made in conditions as close as possible to those required for the strict application of the basic equations, using two free-air chambers. In normal conditions, the recombination coefficient is $m^2 = 3.97 \times 10^{14}$ s m^{-1} C^{-1} V^2 ($s = 8 \times 10^{12}$ s m^{-1} C^{-1} V^2), close to the value previously obtained at the ETL. The influence of the air density and humidity was also investigated using several chambers of different types. The coefficient m^2 varies with the air density as $\rho^{2.46}$ and changes by 3 % for a change in the relative humidity of 10 %.

6.3 High energy x-ray absorbed dose

Dr Allisy-Roberts outlined the project agreed at the last CCEMRI Section I meeting for absorbed dose to water comparisons using the BIPM transfer system for high x-ray energies and reported on progress. The BIPM had bought one NACP chamber and one NE 2611Achamber which, together with a waterproof plane-parallel chamber recently donated by the PTB, made a group of three chambers for this high-energy project. Dr Hohlfeld was kindly thanked for his role in obtaining the PTB chamber. All three chambers would have measurements in water made periodically in the BIPM ^{60}Co beam; a graph illustrating the stability of the NE chamber over a period of 3 months (standard deviation of the normalized calibration factor, 4×10^{-4}) was shown. During the summer of 1997 it is planned that a series of measurements will be made in two linear beams at a local hospital. Five qualities will be chosen in the range 10 MV to 25 MV to establish a procedure for the transfer system to be used at the national laboratories. Measurements will begin at the PTB, NPL and NRC once the laboratories have agreed on the procedure to be used. It was agreed to re-issue the details on calibration conditions to the three laboratories for confirmation of their current validity. The NPL reported that it is now in a position to donate a NE 2561 chamber to the transfer system. This commitment was gratefully acknowledged.

The BIPM will fit its ^{60}Co unit with a 170 TBq source in 1998 and has plans to build a graphite calorimeter for use at ^{60}Co and at high energy. Dr Hohlfeld remarked that portable water calorimeters may be worth investigating as transfer standards.

7 DEVELOPMENT AND IMPROVEMENT OF NATIONAL STANDARDS FOR PHOTON DOSIMETRY

7.1 Air kerma reports

Dr Takata presented a report (97-6) on two solutions for calculating the diffusion loss of ions in parallel-plate, cylindrical, and spherical ionization chambers. One is an exact solution derived from equations governing the behavior of ions in electric fields. The other is based on the supposition that ions are produced by back diffusion if they are lost in the vicinity of an electrode where the electrostatic potential is less than kT/e.

Dr Rogers presented data (97-29) which test the theories concerning the point of measurement and appears to be in closer agreement with the anisotropic theory than with the alternatives. He also presented the results of measurements in ^{137}Cs using a spherical graphite-walled ionization chamber to which additional shells can be added. The results are reported to confirm a previous NRC suggestion that the linear extrapolation made by most of the laboratories is inappropriate for deriving k_{wall} correction factors.

7.2 Absorbed dose reports

Dr Laitano presented the design and preliminary data (97-8) on a “sealed water” calorimeter intended for reference dosimetry in photon and proton beams. The calorimeter was designed to work in horizontal beams at a range of measurement depths (2 cm to 25 cm) in water. Heat flow calculations were made to assess properly the glass ampoule dimensions and other operational parameters. Convection effects have been modelled using a three-dimensional (finite element) thermal diffusion code developed by colleagues at a thermodynamics institute in Turin.

Dr Hohlfeld presented experimental results (97-16) on heat defect measurements in a sealed water calorimeter which indicate zero heat defect at

high doses (greater than 300 Gy) for water loaded with 76 mmol L^{-1} O_2 and 800 mmol L^{-1} H_2. A pre-irradiation was required to burn off O_2, for which there is a substantial heat defect. Dr Rogers presented Dr Klassen's results (97-29) on calculations of thermal defect and remarked that the NRC assigns an uncertainty of 0.5 % to the correction for the heat defect.

Dr Rogers reported that the NRC disseminates absorbed dose to graphite calibrations based on Dr W. Henry's early results (1977). In particular, no gap correction is applied, an arrangement which minimizes changes for the user community.

The NRC and NPL both reported results suggesting that the product eG (where e is the molar extinction coefficient, and G is the yield, that is the number of species produced per 100 eV of energy deposited) for Fricke dosimeters is not constant over the energy range from 1.25 MeV to 20 MeV. Dr Sharpe pointed out that the principles of radiation chemistry can be invoked to explain why the yield is energy dependent.

8 DISSEMINATION OF $N_{D,w}$ CALIBRATION FACTORS

Dr Andreo (97-1) pointed out that the direct calibration of ionization chambers in terms of absorbed dose to water presents clear advantages over the indirect method commonly in use. Better international coherence in the dissemination of calibration factors to users, however, seems to be desirable.

Dr Andreo also suggested that national laboratories should disseminate the international mean of absorbed dose to water determinations in their calibration certificates. After some discussion, the members rejected this possibility, at least until there is an agreed procedure for determining such a mean.

9 STANDARDS FOR BRACHYTHERAPY

Dr Coursey described the expanding uses of brachytherapy in cancer treatment and in the prevention of restenosis following balloon angioplasty procedures (97-20). In future comparisons of brachytherapy sources for cancer therapy the most important sources will be ^{125}I and ^{192}Ir. Although EUROMET is taking action on ^{192}Ir, the NIST is the only laboratory which offers air kerma rate calibrations for ^{125}I seeds. After a long period of development, the NIST has introduced a Wide Angle Free Air Ionization Chamber (WAFAC), designed and built by Dr R. Loevinger, for the specific purpose of measuring the air kerma rate of ^{125}I seeds. The WAFAC may also be used for the low-energy x-rays from ^{103}Pd.

A new application of mainly β-emitting brachytherapy seeds is in the prevention of restenosis. This will call for the development of new standards of absorbed dose rate and radioactivity from the primary standards laboratories. The NIST is already using methods previously developed for ^{90}Sr ophthalmic applicators to measure surface absorbed dose rate for brachytherapy sources of ^{32}P and ^{90}Sr.

10 STANDARDS FOR RADIATION PROTECTION

Dr Rogers reported on protection level standards (97-29). It is widely recognized that there is a problem associated with the calibration of LiF thermoluminescent dosimeters for air kerma in ^{137}Cs and ^{60}Co beams. Table 1 of his report summarizes air kerma measurements made with LiF TL dosimeters in different TL dosimeter holders. The difference can be as large as 6 % for some holders. Two effects which contribute to this difference are discussed in the report.

11 STANDARDS FOR RADIATION PROCESSING

Dr Sharpe suggested that CCEMRI Section I follow up a previous suggestion by the IAEAto arrange a comparison of absorbed dose at 15 kGy and 50 kGy using a mailed dosimetry system. The BNM-LPRI, ENEA, IAEA, NIST, NPL, NRC and PTB agreed to participate. Several of these institutes also offered to supply alanine/ESR dosimeters. The BIPM agreed to organize the project.

12 DEVELOPMENT AND IMPROVEMENT OF NATIONAL STANDARDS FOR CHARGED PARTICLE DOSIMETRY

The NPLreported on modifications to improve the performance of their linear accelerator. Electron energies from 3 MeV to 22 MeV are now available and the dose rate can be varied from less than 0.1 Gy min^{-1} to greater than 20 kGy min^{-1}. A new gun system is being installed which will increase the dose rate by a factor of five. Trials of a new calibration service for electron beams at the NPL are now complete. Eighteen NACP and Markus chambers were calibrated for fourteen therapy centres. Following the development of alanine/ESR dosimetry for use at therapy levels in photon beams, it is hoped to extend this service to electron beams. Results at high energies indicate that alanine/ESR dosimeters show no energy dependence.

The PTB reported on a comparison between the NIST and PTB on a ^{204}Tl protection level source from Amersham-Buchler. The PTB will develop a solid state absorbed dose rate detector for ^{90}Sr ophthalmic applicator type sources.

The ENEApresented results on the role of nuclear inelastic scattering in water and tissue equivalent materials for 200 MeV protons. The ENEAis using the “sealed water” calorimeter for measurements of absorbed dose to water in proton beams.

13 REPORTS FROM MEMBER LABORATORIES

The ENEA reported a problem with accrediting bodies that require strict separation of calibration and certification activities from other laboratory activities. Other laboratories acknowledged that they may also have to deal with this problem in the future. It was noted that the metrology institutes are under pressure to conform to ISO *Guide 25* for calibration laboratories. The NMi and NPL have prepared quality manuals for their calibration services along the lines of this guide. The NIST reported that it has identified seven services (five calibration services and two standard reference materials programmes) that should meet ISO *Guide 25*, and it has prepared a quality manual for the high-dose calibration service. The BNM-LPRI (97-12) and NMi (97-28) reported on new procedures when using absorbed dose to water standards for high-energy photons. The CIEMAT (97-18) presented data on the ratio of air kerma and absorbed dose to water obtained in measurements using 3.6 cm^3 Shonka ionization chambers at a ^{60}Co teletherapy unit in a local hospital. The measured D_w/K_{air} ratio is in good agreement with that obtained at the BIPM.

The ARL presented preliminary results of comparison of absorbed dose to water with the ANSTO and NPL (97-24 and 25).

The NRC (97-29) suggested that members share world wide web site information with the CCEMRI. Dr Rogers also mentioned the activities of Task Group 61 of the American Association of Physicists in Medicine on recommended guidelines for kilovoltage dosimetry. The NRC conducted a survey and found from over 100respondents that the clinics were not using in-phantom dosimetry methods for orthovoltage x-rays. A central issue for this Task Group is whether to continue recommending the in-phantom measurement for peak potentials exceeding 100 kV, or to recommend in-air calibration throughout the low- and medium-energy region.

The GUM (97-30) reported on the installation of new x-ray sources using Mo and W anode tubes for low energies. A new ^{60}Co source will be installed.

14 REPORT FROM THE IAEA

Dr Andreo (97-17) drew attention to the quality audits involving the IAEA/WHO Secondary Standards Dosimetry Laboratories (SSDLs) in Figures 3 and 4 of his paper. At least four of the laboratories that provide calibration services have confused the $N_{D,w}$ factors with $N_{D,air}$ and have issued calibrations in error by up to 10 %. The problem of chamber positioning – effective point of measurement with respect to the centre of the instrument – also arises at SSLDs. Figure 5 of the IAEA paper reports on results obtained using mailed TLD IAEA/WHO dosimeters. In this study the response was only 60 % and among those responding only 60 % provided data lying within ± 5 % of the test value.

Dr Andreo presented an analysis of different protocols (AAPM, TRS-277, etc.) for the calculation of $N_{D,w}$ from the air kerma calibration factor. The *Code of Practice for plane parallel chambers in electron and photon beams* has been published (IAEA Report 381). This is intended as a intermediate step to link air kerma and absorbed dose standards. A new edition of the IAEAprotocol for absorbed dose determinations in photon and electron beams (TRS-277) is ready for issue. Dr Rogers reported that, for the new AAPM protocol, the centre of the chamber is still the point of measurement.

15 OTHER BUSINESS

The members of the section agreed to hold their next meeting in two years' time.

Dr Simoën thanked members of the section for their support and the BIPM staff for their hospitality.

Mme Boutillon reported that Dr Simoën intends to retire before the next meeting. She thanked him on behalf of the BIPM and the members of CCEMRI Section I for his ten years service as Chairman of Section I. He was warmly applauded.

B.M. Coursey, Rapporteur
August 1997
revised June 1998

APPENDIX R(I) 1.

Working documents submitted to Section I of the CCEMRI at its 13th meeting

(see the list of documents on page 65)

ANNEXE R(I) 1.
Documents de travail présentés à la 13e réunion de la Section I du CCEMRI

Ces documents de travail peuvent être obtenus sur demande adressée au BIPM.

Document
CCEMRI (I)/

97-1 BIPM, AIEA. — Some thoughts on the dissemination of $N_{D,w}$ calibration factors in ^{60}Co gamma radiation, M. Boutillon, P. Andreo, 2 p.

97-2 BIPM. — Comparisons and calibrations at the BIPM, P.J. Allisy-Roberts, M. Boutillon, 8 p.

97-3 BIPM. — Calculation of electron loss and photon scatter correction factors for free-air chambers, D.T. Burns, 2 p.

97-4 OMH (Hongrie). — Progress report on the radiation dosimetry at OMH, I. Csete, 2 p.

97-5 ETL (Japon). — Report of ETL to the CCEMRI Section I, N. Takata, K. Sakihara, Y. Koyama, H.I. Sekiguchi, 1 p.

97-6 ETL (Japon), NIM (Chine). — Methods to calculate diffusion loss of ions in cavity ionization chambers, N. Takata, N. Takeda, Zaizhe Yin, 5 p.

97-7 NPL (Royaume-Uni). — Progress report on radiation dosimetry at NPL, P. Sharpe, 6 p.

97-8 INMRI-ENEA (Italie). — Report to the CCEMRI Section I on the activities at INMRI-ENEA, R.F. Laitano, 3 p.

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97-9 INMRI-ENEA (Italie), NIST (États-Unis). — Definitive results of the ENEA-NIST air-kerma comparison, R.F. Laitano, P.J. Lamperti, M.P. Tomi, 3 p.

97-10 INMRI-ENEA (Italie). — Mean energy calculations for proton beams in a tissue-substitute and in water: preliminary results, R.F. Laitano, M. Rosetti, 4 p.

97-11 ARL (Australie). — Status report on radiation dosimetry standards at ARL, J.F. Boas, R.B. Huntley, L.H. Kotler, D.V. Webb, K.N. Wise, 4 p.

97-12 BNM-LPRI (France). — Progress report (dosimetry of photons and charged particles), B. Chauvenet, 3 p.

97-13 VNIIM (Féd. de Russie). — Report on the research work of the laboratory for metrology of ionizing radiation in the field of x-, gamma- and beta-ray dosimetry, N. Villevalde, A. Oborin, E. Yurjatin, V. Fominykh, S. Fedina, I. Urjaev, E. Rumjantseva, 3 p.

97-14 VNIIM (Féd. de Russie). — Some results of the laboratory activity of the D.I. Mendeleyev All-Russian Institute for Metrology in the field of neutron measurements in 1995-1997 years, N.N. Moiseev, M.A. Rasko, I.A. Kharitonov, non diffusé.

97-15 INMRI-ENEA (Italie). — Preliminary results of heat flow calculations in a sealed water calorimeter for horizontal beams, E. Gargioni, R.F. Laitano, 5 p.

97-16 PTB (Allemagne). — Progress report on radiation dosimetry at PTB, K. Hohlfeld, 15 p.

97-17 IAEA. — IAEA dosimetry programme. Report on activities in 1995-96, P. Andreo *et al.*, 12 p.

97-18 CIEMAT (Espagne). — Report of the status of CIEMAT to CCEMRI, Section I, A. Brosed, 4 p.

97-19 NIST (États-Unis). — Report to the CCEMRI Section I, S.M. Seltzer, 8 p.

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97-20 NIST (États-Unis). — NIST activities in brachytherapy dosimetry, C.G. Soares, 3 p.

97-21 NIST (États-Unis). — Status of NISTmammography calibration range, C.M. O'Brien, 2 p.

97-22 NIST (États-Unis). — Development of a secondary standard system to measure absorbed dose to water, J. Shobe, 2 p.

97-23 NMi (Pays-Bas). — Summary of dosimetry comparisons conducted in the framework of EUROMET, A.H.L. Aalbers, 3 p.

97-24 ARL (Australie). — Exposure and absorbed dose measurement standards for ^{60}Co and MV x-rays, J.F. Boas, R.B. Huntley, D.V. Webb, K.N. Wise, 4 p.

97-25 ARL (Australie). — High energy absorbed dose standards, J.F. Boas, R.B. Huntley, D.V. Webb, K.N. Wise, 4 p.

97-26 SSI (Suède). — Progress report, J.-E. Grinborg, L. Lindborg, 4 p.

97-27 NPL (Royaume-Uni). — Absorbed dose calibrations and CCEMRI (I) meeting, Letter of J.E. Burns, 2 p.

97-28 NMi (Pays-Bas). — Progress report on radiation dosimetry standards, facilities and related topics at NMi, 1995-1997, A.H.L.Aalbers, 3 p.

97-29 NRC (Canada). — NRC activities and publications 1995-1997, D.W.O. Rogers, A.F. Bielajew, N.V. Klassen, C.K. Ross, J.P. Seuntjens, K.R. Shortt, L. van der Zwan, 23 p.

97-30 GUM (Pologne). — Progress report 1995-1997 to CCEMRI(I), Z. Referowski, 2 p.

97-31 NMi (Pays-Bas), BIPM. — Photon fluence spectra of the BIPM reference qualities for low energy x-rays, T.W.M. Grimbergen, E. van Dijk, M. Boutillon, 3 p.

97-32 NMi (Pays-Bas). — Combination of correction factors calculated with the Monte-Carlo method with measured x-ray spectra for the NMi free-air ionization chamber for medium energy x-rays, T.W.M. Grimbergen, E. van Dijk, W. de Vries, 3 p.

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97-33 NMi (Pays-Bas). — Progress report on EUROMET comparison project 364, W. de Vries, 1 p.

97-34 NIM (Chine). — Progress report 1997, Xu Mian, 2 p.

97-35 BIPM. — CCEMRI Section I response to the issues concerning the Consultative Committees's responsibilities in the "Draft report on the agreement for metrological equivalence of standards" distributed by the director of the BIPM, 3 p.

CONSULTATIVE COMMITTEE FOR STANDARDS OF IONIZING RADIATION

SECTION II: MEASUREMENT OF RADIONUCLIDES REPORT OF THE 14th MEETING

(23-25 April 1997)

Agenda

1 Opening of the meeting; designation of a rapporteur.

2 Report on the CCEMRI and CIPM meetings.

3 International comparisons of activity measurements.

4 International Reference System for activity measurements.

5 Reports of the working groups.

6 New working groups.

7 Future international comparisons.

8 BIPM activities.

9 Reports from member laboratories.

10 Other business.

Abstract

Section II (Measurement of radionuclides) of the Consultative Committee for Standards of Ionizing Radiation held its fourteenth meeting at the Pavillon de Breteuil, Sèvres, on the 23, 24 and 25 April 1997. Additional results on the ^{204}Tl trial comparison were presented and a report was given on the status of the full-scale comparison. Results from the ^{192}Ir trial comparison were discussed and a working group was established to examine measurement difficulties. The radionuclide ^{152}Eu was chosen for the next comparison. Technical difficulties related to liquid-scintillation counting were raised with regard to the extension of the SIR, and preliminary results from the ^{90}Sr comparison were presented. Metrological equivalence was a key topic of discussion. Agreement was reached on how it should be realized in practical terms and selection criteria were agreed for the determination of A_e values. The proposal to develop a reproducible realization of the becquerel was well received and a working group was set up. Details were given on the establishment of a γ-ray spectrometry system at the BIPM for the measurement of radionuclidic impurities.

1 OPENING OF THE MEETING; DESIGNATION OF A RAPPORTEUR

Section II (Measurement of radionuclides)* of the Consultative Committee for Standards of Ionizing Radiation (CCEMRI)** held its fourteenth meeting at the Pavillon de Breteuil, Sèvres, on 23, 24 and 25 April 1997.

The following were present: S.M. Buckman (ANSTO), N. Coursol (BNM-LPRI), K. Debertin (Chairman of Section II, PTB), J.-J. Gostely (IRA-OFMET), J.M.R. Hutchinson (NIST), H. Janssen (PTB), I. Kharitonov (VNIIM), Li Fen (NIM), T.J. Quinn (Director of the BIPM), B.R.S. Simpson (NAC), Á. Szörényi (OMH), G. Winkler (IRK), M.J. Woods (NPL).

Observers: R. Broda (RC), P. de Felice (ENEA), W. de Vries (NMi-VSL), A. Grau Malonda (CIEMAT), Y. Hino (ETL), N.I. Karmalitsyn (VNIIM), D.F.G. Reher (IRMM), Tae Soon Park (KRISS).

Also attending the meeting: P. Giacomo (Director Emeritus of the BIPM); A. Allisy (member of the CCEMRI); P.J. Allisy-Roberts, M. Boutillon, D.T. Burns, C. Michotte, J.W. Müller and G. Ratel (BIPM).

Apologies were received from NRC.

The Director of the BIPM, T.J. Quinn, opened the meeting by welcoming the participants. A special welcome was extended to W. de Vries, H. Janssen (who succeeds K. Debertin as the representative of the PTB) and I. Kharitonov, all attending a Section II meeting for the first time.

In his introduction, the Chairman, K. Debertin, emphasized the important role being played by Section II and pointed out that this role is increasing as a

* For the list of members, see on page 132.

** For the list of acronyms mentioned in this report, see on page 225.

consequence of the increasing awareness of quality assurance worldwide. This is demonstrated by a shift in emphasis from purely scientific and technical concerns to the more practical aspects of metrology. National communities expect support from Section II in demonstrating the mutual equivalence of their measurements, and these expectations must be met.

The Chairman also reminded members and observers of their responsibilities as participants in Section II, and reminded them that it is important to complete assigned tasks in a timely manner. With this in mind, the Chairman briefly reviewed an appendix listing actions agreed at the last meeting and reported on the current status of each action.

The agenda was approved and S.M. Buckman was appointed rapporteur.

2 REPORT ON THE CCEMRI AND CIPM MEETINGS

The Chairman reported briefly on the fourteenth meeting of the CCEMRI in June 1996. As usual, the three section Chairmen reported to the CCEMRI on the activities undertaken by their sections, in particular on the advances achieved in the individual working groups. Key topics of discussion were the need to develop standards for brachytherapy sources, the demonstration of equivalence between standards of national metrology institutes, the publication of the results of comparisons, and membership of the sections.

T.J. Quinn reported on the eighty-fifth meeting of the Comité International des Poids et Mesures (CIPM) in September 1996, with particular reference to membership of Consultative Committees. He noted that the CIPM has adopted new criteria for the acceptance of members, and pointed out that, in addition to member laboratories, individuals can be members, as can international organizations. For those who do not meet these criteria, the term "guest" is now replaced by "observer". Membership is scheduled for review in September 1997; this meeting will also address recent requests for membership.

3 INTERNATIONAL COMPARISONS OF ACTIVITY MEASUREMENTS

3.1 Additional information on the results of the ^{204}Tl trial comparison

G. Ratel reported on work undertaken to identify the reason for the CIEMAT result being approximately 2.5 % below the unweighted mean of $\overline{A}$ = 55.30 Bq/mg (u_c = 0.18 Bq/mg) obtained from the other results. In September 1995, ampoule No. 8 was sent to CIEMAT where nine samples were prepared and standardized in the same manner as previously. A new activity concentration of A = 55.56 Bg/mg (u_c = 0.29 Bq/mg) was obtained which is in good agreement with the other results. The revised results of the comparison, obtained by accepting this new result and rejecting the previous CIEMAT result, cover a range of 0.88 Bq/mg (1.6 %) (see Fig. 1 of document 97-9*).

As an additional check, the remainder of the original solution (ampoule No.2) was returned to the BIPM where it was divided into two samples. One sample was standardized at the BIPM using the NIST/CIEMAT method whilst the other was standardized at the BNM-LPRI using the TDCR method. The results obtained are in good agreement with the original CIEMAT result. The reason for the discrepancy was discussed with adsorption again being proposed.

G. Ratel confirmed that the trial comparison was complete and that the results distributed to the attendees as document 97-9 were scheduled for publication as a *Rapport BIPM*. Members were requested to send their comments to G. Ratel in the four weeks following the meeting. The planned measurement at IRMM using a 4π CsI detector was cancelled, as the laboratory was in

* Documents submitted by the participants are listed in Annexe R(II) 1, and are referred to in the text in the form 97-1, 97-2, etc.

course of refurbishment. Measurements will still be performed, but will not be included in the BIPM report.

3.2 Results of the ^{192}Ir trial comparison

As agreed at the previous Section II meeting, the proposed EUROMET activity comparison for ^{192}Ir was terminated and a trial comparison was conducted under the auspices of the BIPM. Ten laboratories (BIPM, BNM-LPRI, ETL, IRA, IRMM, KRISS, NIST, NPL, OMH, VNIIM) participated in the comparison with five independent methods being used. D.F.G. Reher and his staff were thanked for preparing and distributing the samples.

G. Ratel introduced the results of the comparison. He noted the two groups of results, which appear in the SIR tables, and reviewed the considerations associated with the ^{192}Ir decay scheme. The comparison results were shown to exhibit a total spread of 2.5 %, the mean value being consistent with the lower grouping of data from the SIR tables.

Participants discussed the various techniques that had been used to obtain their results. Of particular interest were the extrapolation curves shown by Y. Hino which compare results obtained using a HPGe system with those obtained using a NaI(Tl) system. This work clearly demonstrates the potential problems arising in the electron capture branch.

Discussion among the participants highlighted a number of important factors such as the carrier concentration and γ-gate setting. The use of different decay data had no significant effect. Good reasons were identified for preferring the $4\pi\gamma$ method over coincidence techniques in the case of ^{192}Ir.

Several participants worked with G. Ratel to produce a conclusion for the summary paper that will be presented at the ICRM symposium. The paper was scheduled for completion by the end of April 1997. The Chairman commented that, in reports on international comparisons, the backing of the CCEMRI(II) should be emphasized and the conclusions should be based on a consensus of opinion.

The trial comparison highlighted unresolved problems with the measurement of ^{192}Ir. Rather than proceeding immediately with a full-scale comparison, a working group was established to investigate remaining difficulties. The members of this working group are Y. Hino, G. Ratel, D.F.G. Reher, T.S. Park and M.J. Woods. No co-ordinator was chosen for the working group, but the first meeting will be organized by D.F.G. Reher.

3.3 Status of the large-scale ^{204}Tl comparison

Having addressed the discrepancy noted in the ^{204}Tl trial comparison, the BIPM continued with the planned full-scale comparison. G. Ratel reported that 30 ampoules had been distributed to 24 participating laboratories with 7 results already received by the BIPM. The deadline for submission of results to the BIPM had been extended to the 30 April 1997. G. Ratel presented various efficiency curves relating to liquid-scintillation counting and presented some early results.

A preliminary report will be prepared and distributed to participants and members. To ease the workload on BIPM staff, it was agreed that several additional people would assist in the assessment of results. G. Ratel agreed to prepare and distribute a graph of the final results by the end of May 1997; at this stage members and observers will be asked if they are prepared to assist in the evaluation. One or more individuals will then be invited by G. Ratel to join an evaluation committee.

A schedule was agreed: a graph showing the results will be completed by the end of May 1997, the evaluation committee will be nominated in July 1997 and a preliminary report from the committee will be circulated in January 1998.

3.4 Status of publications on the ^{75}Se large-scale comparison

G. Ratel announced that a draft report on the ^{75}Se comparison was close to completion and that it should be distributed to members and participants in mid-May 1997. Comments were invited but must be received at the BIPM before the end of June 1997. A final draft of the report will be submitted for publication in *Nuclear Instruments and Methods A* by the end of August 1997. The Chairman referred to a letter from D.C. Santry (NRC) which includes suggestions regarding the ^{75}Se comparison. G. Ratel agreed to reply in writing to D.C. Santry.

4 INTERNATIONAL REFERENCE SYSTEM FOR ACTIVITY MEASUREMENTS

4.1 Status report on the ionization chamber system

C. Michotte reported on recent BIPM measurements which demonstrate the excellent long-term stability of the International Reference System (SIR). Small but distinct periodic fluctuations in the results were pointed out. Several delegates reported on seasonal variations observed in their own laboratories.

In 1996, fourteen new results for eleven radionuclides, including for the first time ^{140}Ba, were received from twelve laboratories with two results being withdrawn. Details were presented on the procedure used for calculating the equivalent activity A_e in related cases such as ^{140}Ba/^{140}La, where there is an unstable daughter nucleus.

Based on the responses to the SIR questionnaire, the BIPM expected to receive twenty-one ampoules of fourteen radionuclides from eight laboratories in 1998. G. Ratel described measurements made using the SIR in connection with the EUROMET ^{133}Xe comparison (project No. 304).

Several changes will be made to the forms associated with the SIR. In particular, a distinction will be made between contributions to the SIR for the purpose of establishing equivalence and those which will be used in the determination of A_e values (Sections 5.6 and 5.7).

4.2 Status report on the liquid scintillation system

G. Ratel mentioned that comparisons of ^{63}Ni and ^{55}Fe had been conducted as EUROMET projects. Preliminary results from these comparisons reveal excellent agreement for ^{63}Ni and some discrepancies for ^{55}Fe. Discussion of this topic continued in connection with the ^{204}Tl comparison (further discussion was deferred until the report of the working group, see Section 5.4).

4.3 Comparison of activity of ^{90}Sr solutions

The radionuclide ^{90}Sr had been chosen for comparison as a means of testing the operation of the extended SIR. Samples were received from the following laboratories: BARC, BNM-LPRI, CIEMAT, CMI, ETL, IRA, IRMM, NIST, NPL, OMH, PTB and RC. Sample activity concentrations ranged from 4 kBq/g to 790 kBq/g. Results were presented by G. Ratel and will be regraphed to show the data in order of activity. For future measurements a range of activities will be specified: only material falling within this range will be accepted.

The spread in the results (a range of 4 %) is larger than expected and is a cause for concern. Possible factors were discussed, among them the stability of the samples and the acidity concentration. The BIPM had prepared five samples from each contribution, and good reproducibility was obtained in all but one case.

G. Ratel agreed to re-measure some of the older samples and D.F.G. Reher to perform measurements using the 4π CsI system at the IRMM. The working group for the extended SIR was asked to evaluate the results of the comparison and to examine any problems that become apparent. G. Ratel agreed to distribute a brief summary of the results by the end of June 1997.

The results of the ^{90}Sr comparison will be the subject of an oral presentation at the ICRM symposium in May 1997 but will not appear in the proceedings. Members are requested to send their comments to A. Grau Malonda before September 1997. The report from the working group should be completed by January 1998.

Note: Soon after the Section II meeting concluded, G. Ratel checked the ^{90}Sr results and found an error in the calculation of the decay corrections. Removing the error reduced the scatter in the results to approximately 1 %.

4.4 Realization of the becquerel

In introducing this topic, D.F.G. Reher described how the becquerel (Bq) is currently realized through the calibration of reference ionization chambers, the best calibrated system being the International Reference System for gamma-emitting nuclides (SIR). He pointed out that, if this system were to fail it could mean the loss of many decades of international effort. To avoid such a catastrophe, D.F.G. Reher and M.J. Woods proposed, in document 97-24, the establishment of a reproducible artefact which they referred to as the "Becquerel Reference System" (BRS).

In concept, the system would be similar to the SIR except that the design would be optimized to provide a long-term reference that could be reproduced accurately at any time. The construction of the system would be well defined with tolerances close enough to take account of future improvements in the accuracy of radionuclide standardizations. Such a system could allow the realization of the becquerel to be transferred, provide equivalence and solve the problem of measuring short-lived nuclides using the SIR.

The proposal received the support of those attending and a working group was established. The working group will initially comprise just D.F.G. Reher and M.J. Woods, with further members being nominated as required.

The first part of the project will be a feasibility study including consideration of the cost, the possibility of using existing chambers (such as the NPL's Vinten chamber) and the tolerances required based on computer simulations. Once the design is complete a prototype, or possibly several prototypes, will be built. The final stage of the project will be the implementation of the BRS. The complete project will be carried out under the auspices of Section II and in close co-operation with the BIPM. The first results from the working group will be presented in the next nine-monthly report.

5 REPORTS OF THE WORKING GROUPS

5.1 **Ionization chamber monograph** (Co-ordinator: H. Schrader)

The Chairman reported, on behalf of H. Schrader (PTB), that BIPM monograph No. 4 had been reviewed by Dr Blackburn and that work was now complete. Copies were distributed to those present.

5.2 **High-efficiency detection systems** (Co-ordinator: G. Winkler)

G. Winkler reported that work on the preparation of the review paper on high-efficiency detection systems had been delayed. It was decided that the review paper should be published in a refereed journal rather than as a BIPM monograph. It was anticipated that the paper would be submitted to *Applied Radiation and Isotopes* by the end of 1997.

5.3 **Joint procurement of radionuclides** (Co-ordinator: D.F.G. Reher)

There was nothing new to report on joint procurement of radionuclides since the last meeting and there had been no new interest expressed. In the absence of interest in this work, the working group was discontinued.

5.4 **Extension of the SIR to β-emitters with the liquid scintillation system** (Co-ordinator: A. Grau Malonda)

In his report on the extension of the SIR, A. Grau Malonda detailed concerns regarding sample preparation and the different computer codes used in liquid-scintillation counting. While the use of the different codes does not present a problem when measuring β-emitters, it can produce serious errors in the case of electron-capture nuclides (particularly those with low Z, i.e. the number of atoms). Further study is required on the determination of the quantity referred to as the Q value (ionization quenching correction factor), especially for electron-capture nuclides, and the optimization of the Q value for each code.

In discussing the very important issue of source preparation for liquid-scintillation counting, he referred to the extensive study made by B. Coursey (NIST). Whilst the recipes in the study are no longer valid, the systematic procedures given are still very appropriate. A. Grau Malonda suggested that the recipes developed by individual laboratories be assembled so that a consensus can be reached on the best procedure for a given type of specimen.

A. Grau Malonda suggested that a BIPM monograph on liquid-scintillation counting be produced with an emphasis on the problems identified during the extension of the SIR. This suggestion was accepted and A. Grau Malonda was appointed as the co-ordinator of a writing committee. Completion of the monograph is expected within the medium term; however, no specific timetable was assigned. A page listing the contents will be distributed for comment before engaging further work.

The Chairman stated that any action proposed by this working group should focus on the resolution of problems concerned with the extension of the SIR, particularly those associated with laboratories preparing their own samples.

5.5 **Future comparisons** (Co-ordinator: Á. Szörényi)

Á. Szörényi reported on the results of a questionnaire on future comparisons that had been distributed to working group members and to the laboratories that participated in the last comparison. The nuclides ^{192}Ir and ^{152}Eu were the most popular proposals for a future activity comparison. Even although ^{152}Eu remains a popular choice, its appropriateness for international comparison was questioned given that SIR results appear consistent and its use for the calibration of γ-spectrometers can result in coincidence summing problems.

It was agreed that the next questionnaire will include selection criteria such as: are there discrepant data in SIR tables?; is the radionuclide of practical interest?; are there problems with the measurement of a particular nuclide?; and has another comparison of the radionuclide proposed been performed recently?

Another questionnaire will be circulated by Á. Szörényi at the end of 1998.

5.6 **Systematic analysis of the SIR** (Co-ordinator: D.F.G. Reher)

D.F.G. Reher reported that the first evaluation of SIR results had been circulated. In the worst case the discrepancy in the SIR results was 6 %, but it was more commonly about 1 %.

For the determination of A_e he proposed stricter criteria for the selection of data, the aim being to deduce a best A_e value, and an associated uncertainty, for each radionuclide. A set of best A_e values should then serve to assess international equivalence, a measure of quality assurance in individual laboratories and to export the SIR to other ionization chambers.

His proposal (97-16) stimulated much lively debate regarding selection criteria and the evaluation of A_e. The agreements reached are listed below and follow those contained in document 97-26 bis.

The working group for the systematic analysis of SIR results will undertake the following tasks:

- establish for each radionuclide in the SIR a reference equivalent activity value (A_{eref}) and an associated uncertainty $u(A_{eref})$ on the basis of the best available data;
- publish these A_{eref} values at regular intervals.

In the selection of data for the determination of A_{eref} values:

- only data from direct measurements (primary standardization) will be considered;
- if more than one ampoule is submitted by the same laboratory at the same time, the unweighted mean of the values and the unweighted mean of the uncertainties will be used;
- correlation of data must be carefully considered and the number of data from any one laboratory should be restricted.

Data from the BIPM or other comparisons (EUROMET, etc.) among primary laboratories should be included, provided:

- the BIPM received an ampoule from the comparison;
- the comparison was carried out in “BIPM-fashion”;
- in the case of a non-BIPM comparison, the CCEMRI(II) agreed to its inclusion;
- only one result is declared per laboratory;
- the individual A_e values are calculated by the BIPM.

The value and uncertainty declared for A_{eref} will be the median and its uncertainty, as specified in the *Rapport BIPM*-95/2 by J.W. Müller. In addition, the efficiency curve will be re-established on the basis of the A_{eref} values.

The members of the working group continue to be N. Coursol, G. Ratel, H. Janssen (supported by H. Schrader), D.F.G. Reher (co-ordinator) and M.J. Woods.

5.7 **Standards equivalence** (Co-ordinator: M.J. Woods)

T.J. Quinn introduced the topic of metrological equivalence by discussing the evolution in thinking since the last Section II meeting. He reminded members that the underlying purpose of the Metre Convention is that, for the purposes of trade and science, Member States agree on measurement standards. A balance must be maintained between these two tasks, and in recent years this balance has been changing.

He explained that a more structured system was required as more structured systems are being used within individual countries. With this aim, the CIPM has been working with the national metrology institutes to obtain international agreements on mutual equivalence. He noted that, to a large extent, international equivalence already exists among the national metrology institutes of industrialized nations, as documented in the results of comparisons. Equivalence must now be extended to include the calibration certificates of national metrology institutes in order to link national standards with the national calibration and testing services.

International equivalence will be based on the results of "key comparisons" which are chosen to compare the principal methods within a field. The structure for evaluating the results of these comparisons will depend on the quantity involved but must be robust, viable in the long term and not require an unreasonable amount of work by participants. Evaluation of results is best carried out by the organizers and participants in the comparison.

It is not acceptable for a national metrology laboratory to "not be equivalent to" other laboratories. Furthermore, it is not the role of the BIPM to accredit individual organizations, to set limits on what qualifies for equivalence or to define the frequency with which equivalence must be re-established. Rather its role, with the assistance of Consultative Committees, is to put in place a structure by which the extent of metrological equivalence existing between individual laboratories may be established.

M.J. Woods began his report on the activities of the working group by summarizing the progress made on the drafting of guidelines for the practical realization of equivalence, and referred to the meeting of the working group held at the BIPM in July 1996. An amended draft statement had been

circulated and no objections had been received (97-26). The document includes a recommendation that metrological equivalence be established primarily via comparisons carried out by the BIPM and notably through the SIR.

After extended discussion of the proposals made by the working group and the implications of the CIPM decisions, a series of decisions were agreed. These decisions follow those circulated as document 97-26 bis.

The tasks of the working group on equivalence are to:

- establish the metrological equivalence of the activity values (A_{lab}) of individual laboratories, for individual radionuclides, against reference activity values (A_{ref}) and their associated uncertainties;
- publish the results of these exercises at regular intervals.

Realization of metrological equivalence and additional criteria:

- metrological equivalence is to be taken to be the difference between A_{lab} and A_{ref} and its associated uncertainty;
- metrological equivalence will be established primarily by submission of samples to the SIR;
- data from other comparisons, particularly full BIPM comparisons, may be included in the evaluation of A_{lab} and A_{ref} provided satisfactory supporting data are supplied by the comparison organizers.

The members of the working group on equivalence are: S. Buckman, J.M.R. Hutchinson, G. Ratel, D.F.G. Reher and M.J. Woods (co-ordinator). The working groups on the SIR and standards equivalence will work in close co-operation, and a report on their activities will be given in the next nine-monthly report of CCEMRI(II).

6 NEW WORKING GROUPS

New working groups were established to consider the practical realization of the becquerel and to examine the discrepancies in the ^{192}Ir trial comparison (see Sections 3.2 and 4.4 respectively). The working group for the joint procurement of radionuclides was discontinued (Section 5.3) and the high-efficiency detection systems group will end when the review paper has been completed (Section 5.2).

7 FUTURE INTERNATIONAL COMPARISONS

After consideration of the working group report (Section 5.5), ^{152}Eu was chosen as the radionuclide for the next comparison. The conflict between the need to carry out a larger number of comparisons on a regular basis and the importance of conducting new trial comparisons was solved through a compromise arrangement in which a single stock solution will be prepared. The PTB offered to prepare and distribute the ^{152}Eu solution. A trial comparison will be conducted and after resolution of any problems which may arise, the full-scale comparison will proceed. The NRC will be invited to join the ETL, OMH and PTB as participants in the trial comparison. Samples will be sent to participants in the trial comparison during November 1997 with a deadline for the submission of results at the end of February 1998. The decision on whether to proceed with a full-scale comparison will be made in April 1998.

Other nuclides proposed for future comparisons were ^{55}Fe, ^{85}Sr, ^{90}Sr, ^{153}Gd and ^{192}Ir.

8 BIPM ACTIVITIES

C. Michotte reported (97-20) on the calibration of a γ-spectrometry system for the non-destructive measurement of radionuclidic impurities in samples submitted to the SIR. The design of the system ensures that the dead-time and pile-up corrections are independent of the analog-to-digital converter and of the multichannel analyser. The results of extensive testing were reported. These include corrections for dead-time and pile-up, the uncertainties due to the ampoule characteristics and positioning, and the use of a linear gate.

All standardizations were performed at two distances from the detector (19.5 cm and 50 cm). Two lucite holders prevent the detection of β-particles which would distort the γ-ray spectrum. In April 1997 the efficiency calibration of the system was still in process.

9 REPORTS FROM MEMBER LABORATORIES

Written progress reports from each member laboratory were circulated and representatives were given the opportunity to present a brief oral report. This session continues to be a valuable forum for outlining the nature and scope of radionuclide metrology activities occurring within member organizations.

10 OTHER BUSINESS

10.1 Visit to the BIPM laboratories

Most attendees took advantage of an invitation to visit the laboratories concerned with the maintenance of length and radioactivity standards.

10.2 Other business

T.J. Quinn explained that K. Debertin had agreed to remain Chairman up to this meeting despite having already retired from the PTB. He thanked K. Debertin for his active work as Chairman and congratulated him on the excellent manner in which he had chaired this meeting. B.R.S. Simpson was welcomed as the new Chairman. T.J. Quinn invited both B.R.S. Simpson and K. Debertin to attend the CCEMRI meeting at the BIPM on 7 and 8 July 1997.

K. Debertin thanked those present for the active contribution that they had made over the years to Section II, and to the field in general. He expressed his best wishes to all.

S.M. Buckman, Rapporteur
September 1997
revised June 1998

APPENDIX R(II) 1.

Working documents submitted to Section II of the CCEMRI at its 14th meeting

(see the list of documents on page 93)

ANNEXE R(II) 1.

Documents de travail présentés à la 14e réunion de la Section II du CCEMRI

Ces documents de travail peuvent être obtenus sur demande adressée au BIPM.

Document
CCEMRI (II)/

97-1 NIST (États-Unis). — NIST radioactivity group report - 1995-1996, 6 p.

97-2 IRK (Autriche). — Summary of the research programme related to radionuclide metrology for the years 1996 and 1997 at the "Institut für Radiumforschung und Kernphysik" (IRK) of the University of Vienna, Austria, G. Winkler, 3 p.

97-3 NAC (Afrique du Sud). — Review of the activities at the NAC standardization laboratory (June 1995 to March 1997), 2 p.

97-4 CIEMAT (Espagne). — Radionuclide metrology at MRI-CIEMAT - Progress report (1995-1997), A. Grau Malonda, 5 p.

97-5 NPL (Royaume-Uni). — Review of activities in radionuclide metrology (June 1995 to April 1997), 4 p.

97-6 VNIIM (Féd. de Russie). — Communication for CCEMRI (Section II) on the work carried out at the D.I. Mendeleyev Institute for Metrology in the field of radionuclide metrology for the period of 1995-1996, I.A. Kharitonov, N.I. Karmalitsyn, 3 p.

97-7 KRISS (Rép. de Corée). — Progress report on radionuclide metrology (1995-1997), 2 p.

Document
CCEMRI (II)/

97-8 BNM-LPRI (France). — Progress report 1995-1996 on radionuclide metrology at BNM-LPRI, N. Coursol, 5 p.

97-9 BIPM. — Trial comparison of activity measurements of a solution of ^{204}Tl, G. Ratel, 32 p.

97-10 NIM (Chine). — Progress report concerning radioactivity measurements at NIM (March 1995-1996), Li Fen, 2 p.

97-11 ANSTO (Australie). — Radionuclide metrology at ANSTO 96/97. Progress report, S. Buckman, 1 p.

97-12 ETL (Japon). — Review of activities at the ETL in 1995-96, Y. Hino, 3 p.

97-13 CIEMAT (Espagne). — Extension of the SIR, 4 p.

97-14 IMMR (Commission européenne). — Programme progress report 1996 of the radionuclide metrology group. Extract for CCEMRI(II), D.F.G. Reher, 13 p.

97-15 IMMR (Commission européenne), NPL(Royaume-Uni).— Proposal for realizing the becquerel at the basic level, D.F.G. Reher, M.J. Woods, 1 p.

97-16 IMMR (Commission européenne). — Critical evaluation of SIR, D.F.G. Reher, 2 p.

97-17 IRA (Suisse), OFMET (Suisse). — Progress report 1995-1997 on radionuclide metrology, 2 p.

97-18 ENEA (Italie). — Summary of the most recent activities (1995-1997) at ENEAin the field of interest of the CCEMRI Section II, P. De Felice, 4 p.

97-19 OMH (Hongrie). — Progress report on radionuclide metrology (1995-97), Á. Szörényi, 3 p.

97-20 BIPM. — Progress report on the detection of radioactive impurities at the BIPM, C. Michotte, 6 p.

97-21 VNIIM (Féd. de Russie). — Communication for CCEMRI (Section II) on the work carried out at the D.I. Mendeleyev Institute for Metrology in the field of radionuclide metrology for the period of 1995-1996, I.A. Kharitonov, N.I. Karmalitsyn, 2 p.

Document
CCEMRI (II)/

97-22 RC (Pologne). — Review of the activities at the RC radionuclide metrology (May 1995 to April 1997), 2 p.

97-23 NRC (Canada). — Progress report on radionuclide metrology 1995-1997, D. Santry, 2 p.

97-24 IMMR (Commission européenne). — Proposal for realising the becquerel at the basic level, D.F.G. Reher, M.J. Woods (NPL), 1 p.
Realising the Bq at the basic level. What has to be done, D.F.G. Reher, 1 p.

97-25 IMMR (Commission européenne). — Some comments to the remarks of J.M.R. Hutchinson (1997-04-08) about the proposal of the equivalence working group on international traceability and equivalence, D.F.G. Reher, 1 p.

97-26 NPL (Royaume-Uni). — Equivalence of national and international measurement standards in the field of radioactivity for the purposes of international traceability, M.J. Woods, 3 p.

26 bis CCEMRI(II) decisions on metrological equivalence and critical evaluation of SIR, M.J. Woods, D.F.G. Reher, 2 p.

97-27 NMi-VSL (Pays-Bas). — Developments on the NMi standards for radioactivity measurements, W. de Vries, 2 p.

97-28 OMH (Hongrie). — Summary of the proposals of laboratories for a future activity comparison, Á. Szörényi, 5 p.

97-29 PTB (Allemagne). — Review of recent work and projects (April 1995 to March 1997), 5 p.

APPENDIX R(II) 2.
Actions arising from the 14th CCEMRI (II) meeting

Responsible	Date	Task
All	5/97	Comments on ^{204}Tl trial comparison to G. Ratel
G. Ratel	4/97	Completion of draft paper on ^{204}Tl trial comparison
G. Ratel	5/97	Distribute plot of results from the full-scale comparison of ^{204}Tl
D.F.G. Reher		Measure ^{204}Tl sample from trial comparison using 4π CsI
G. Ratel	6/97	Nominate ^{204}Tl evaluation committee
G. Ratel	1/98	Circulate preliminary report from ^{204}Tl evaluation committee
G. Ratel	5/97	Circulation of report on ^{75}Se comparison
All	6/97	Send comments on ^{75}Se report to G. Ratel
G. Ratel	8/97	Submission of ^{75}Se report to *Nuclear Instruments and Methods*
G. Ratel		Reply in writing to D.C. Santry regarding ^{75}Se comparison
G. Ratel		Re-plot results of ^{90}Sr comparison in order of activity level
G. Ratel		Measure again the older ^{90}Sr samples
D.F.G. Reher		Measure ^{90}Sr samples using 4π CsI system
G. Ratel	6/97	Distribute brief summary of ^{90}Sr results

All	8/97	Send remarks on ^{90}Sr results to A. Grau Malonda
Ext-SIR WG		Evaluate the results of ^{90}Sr comparison
Ext-SIR WG	1/98	Complete WG report on ^{90}Sr comparison
BRS WG		Presentation of results in next 9-monthly report
G. Winkler	12/97	Complete and submit review paper on high-efficiency counting to *Applied Radiation and Isotopes*
A. Grau Malonda		Distribute contents page for BIPM monograph on liquid scintillation counting
Á. Szörényi	12/98	Distribute questionnaire and criteria to members for selection of radionuclides for comparison
G. Ratel		Invite NRC to participate in ^{152}Eu trial comparison
PTB	11/97	Prepare and distribute ^{152}Eu solution
BIPM	97	Organize ^{152}Eu trial comparison
Participants	2/98	Send ^{152}Eu results to BIPM
BIPM	4/98	Decision on whether to proceed with full-scale ^{152}Eu comparison

CONSULTATIVE COMMITTEE FOR STANDARDS OF IONIZING RADIATION

SECTION III: NEUTRON MEASUREMENTS REPORT OF THE 12th MEETING

(21-22 April 1997)

Agenda

1 Opening of the meeting; designation of a rapporteur.

2 Comparison of measurements of 24.5 keV fluence.

3 Thermal neutron fluence measurement comparison.

4 Metrological equivalence.

5 Future measurement comparisons.

6 The BIPM standard neutron sources.

7 Other business; date of next meeting.

Abstract

Section III (Neutron measurements) of the Consultative Committee for Standards of Ionizing Radiation held its twelfth meeting at the Pavillon de Breteuil, Sèvres, in April 1997. Progress in the comparison of 24.5 keV fluence measurements was reviewed. Five members of the Section had reported results, and measurements remained to be made by one more member. Delays in the preparations for a comparison of measurements of thermal neutron fluence were described. The concept of equivalence of national measurement standards and the need for a more structured system of international recognition of equivalence were discussed. In this context, the programme of comparisons was reviewed and the priorities for future comparisons were considered. These include measurements of fast neutron fluences at several energies and radionuclide neutron source emission rates. The NIST delegate reported on measurements of the emission rates of the former BIPM neutron sources that had been received by the NIST. Finally there was an exchange of information on work in progress at the members' laboratories.

1 OPENING OF THE MEETING; DESIGNATION OF A RAPPORTEUR

Section III (Neutron measurements)* of the Consultative Committee for Standards of Ionizing Radiation (CCEMRI)** held its twelfth meeting at the Pavillon de Breteuil, Sèvres, on 21 and 22 April 1997. This was the first meeting since the termination of the neutron laboratory programme at the BIPM.

The following were present: N. Coursol (BNM-LPRI), D.M. Gilliam (NIST), N. Karmalitsyn (VNIIM), I.A. Kharitonov (VNIIM), H. Klein (PTB), K. Kudo (ETL), V.E. Lewis (Chairman of Section III, NPL), Li Fen (NIM), T.J. Quinn (Director of the BIPM).

Observer: A. Plompen (IRMM).

Attended all or part of the meeting: A. Allisy (member of the CCEMRI); P. Giacomo (Director Emeritus of the BIPM); P.J. Allisy-Roberts, M. Boutillon, D.T. Burns, C. Michotte and G. Ratel (BIPM).

Sent regrets: J.J. Broerse (TNO-MBL).

The Director of the BIPM welcomed the participants and expressed his interest in seeing how worldwide consistency in neutron measurements was being maintained in the absence of the experimental programme in neutron metrology at the BIPM.

The Chairman of Section III welcomed members and observers.

D.M. Gilliam accepted the task of rapporteur.

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* For a list of the members, see on page 133.

** For the list of acronyms mentioned in this report, see on page 225.

2 COMPARISON OF MEASUREMENTS OF 24.5 keV FLUENCE

The Chairman reported on the results that he had received from five laboratories participating in the comparison of fluence measurements at 24.5 keV, each of which had made measurements with the three Bonner spheres. In all, four different types of neutron field were employed by the participants, listed in chronological order below. The comparison will be completed when results become available from the ETL in mid-1997.

Laboratory	Neutron field
CIAE	Sb/Be Filtered reactor beam
NIST	Filtered reactor beam
NPL	^{45}Sc(p,n)
PTB	Filtered reactor beam ^{7}Li(p,n) ^{45}Sc(p,n)
VNIIM	Sb/Be

G. Ratel reported on the checks of the instrumentation carried out at the BIPM and reviewed the normalization steps which were carried out to overcome the failure of one of the ^{3}He proportional counters employed in the comparisons. H. Klein described the highly detailed model of the polyethylene spheres and ^{3}He counter which were employed for the Monte Carlo transport calculations (MCNP code, B. Wiegel, PTB), to correct the response of these transfer instruments for the small differences in the energies of the various neutron sources employed by the laboratories and for spurious neutrons of higher and lower energies than the main component.

The experimental results, regarded as interim until inclusion of the ETL results, were normalized with arbitrary factors to preserve the blind nature of the comparison. They are consistent within the estimated uncertainties, which vary between 4 % and 22 % at the 95 % confidence level, and show no obvious trends. At the request of the Section, the analysis will be completed by the Chairman, who was not involved in the measurements at the NPL. It was originally hoped to finish this work by 1996, but problems caused by major component failure at the NPL and extensive refurbishment at the ETL delayed its completion.

3 THERMAL NEUTRON FLUENCE MEASUREMENT COMPARISON

At the 1995 meeting of Section III, D.M. Gilliam had reported that there appeared to be a problem with loss of boron from the active deposits of the intended ionization chamber transfer instruments. To assess this problem and evaluate possible solutions, a special set of very thin boron deposits had since been provided to the NISTby the IRMM for testing with various combinations of flow gases and humidity. Some of the deposits also have thin graphite coatings with a view to reducing any loss of boron. The IRMM has also agreed to provide a set of ^{235}U deposits as a supplement to, and possibly a substitute for, the boron deposits.

It was hoped that, with the 24.5 keV neutron fluence comparison almost complete, it would be possible to proceed promptly with the thermal neutron comparison. However, further tests of the stability of the deposits was considered likely to delay the start until 1998. D.M. Gilliam mentioned his intention to prepare a protocol when adequate experience of using the instrumentation had been gained. The BNM-LPRI had asked to be included in the review of the protocol for this comparison.

4 METROLOGICAL EQUIVALENCE

Dr Quinn, Director of the BIPM, spoke briefly on the equivalence of the measurement standards at the national metrology institutes represented in Section III and of the connections between national measurement systems. He asked Section III to identify key comparisons which should be carried out and to decide how frequently these should be repeated to maintain or improve the degree of equivalence of the measurements at member institutes.

Dr Quinn expressed the opinion that, to a very large extent, the equivalence of neutron measurements at national metrology institutes has already been established. He noted that increases in international commerce are creating pressures for a more structured system for recognition of the equivalence of national quality assurance systems.

5 FUTURE MEASUREMENT COMPARISONS

The Chairman reviewed the achievements of the programme of comparisons of neutron measurements carried out by Section III over the past thirty years. For fluence measurements these studies cover the energy range from 25 keV to 15 MeV, and include thermal neutrons. Other topics studied also include radionuclide neutron source emission rate and neutron absorbed dose measurement comparisons. Most of the exercises involved the circulation of transfer instrumentation and, individually, had lasted up to five years. He noted that the most recent results for several energies and fields were now over ten years old.

H. Klein considered key comparisons for Section III to be measurements of monoenergetic neutron fluence in the energy range from below 0.1 MeV to 15 MeV and thermal neutrons (≈ 0.025 eV). He suggested that these comparisons should be repeated every five to eight years and that the specific neutron energies recommended by the International Organization for Standardization (ISO) should be adopted by Section III as the key comparison energies. The principal energy points are 27 keV, 144 keV, 250 keV, 565 keV, 1.2 MeV, 2.5 MeV, 5.0 MeV, 14.8 MeV and 19.0 MeV. These should have equal priority, but for the next comparisons the best known fields should be selected. H. Klein suggested that the time required to carry out most of these comparisons could be greatly reduced if participants from Section III were to bring their measuring instruments to one laboratory, eg. the PTB, where most of these energies can be realized conveniently. This would eliminate the need to circulate a transfer instrument, avoid the uncertainty component introduced by the use of a transfer instrument in different fields, and allow consistent application of spectral fluence corrections, both calculated and measured.

The meeting discussed these proposals and agreed that the above energies should be adopted and given equal priority. With the completion of the

24.5 keV comparison, this meant that the energies higher than 27 keV should be considered for the next comparisons. It was also thought that the programme would be accelerated if the measurements were carried out in common neutron fields at one (or more) laboratory. The main disadvantage would be that of transportation. It was generally thought that H. Klein's proposals had considerable merit and required further consideration and consultation. H. Klein agreed to circulate a more detailed proposal for members to consider.

K. Kudo of the ETL stated that neutron source emission rate comparisons should be included among the key comparisons. This was agreed by the meeting and the question of what type of source would be most appropriate was discussed. I.A. Kharitonov of the VNIIM expressed the opinion that a repetition interval of ten years would be sufficient for the key comparisons. He suggested that a ^{244}Cm source from the VNIIM would be better than a ^{252}Cf source for circulation to the participating laboratories, because of its longer half-life. The Chairman asked I.A. Kharitonov if the VNIIM would consider allowing the use of such a valuable source for the exercise. I.A. Kharitonov said that he would make enquiries. The VNIIM would then inform the Chairman who would write to all potential participants asking their views.

The Chairman expressed the view that the above comparisons could be planned and carried out independently (i.e. it should not be necessary to wait for one exercise to finish before starting the next) and that a repetition interval of about ten years was realistic for repeating comparisons.

6 THE BIPM STANDARD NEUTRON SOURCES

The BIPM standard neutron sources were transferred to the NIST for maintenance following the termination of the neutron measurements programme at the BIPM. D.M. Gilliam reported that the emission rates of these sources measured at the NIST agree to within 0.6 % with the values obtained at the BIPM, as shown in the table below. This is well within the estimated uncertainties. He noted that these sources are available for use by other laboratories to allow bilateral comparisons with the NIST(and indirectly with the BIPM).

Measured emission rates

	NIST	BIPM
Am-Be(α, n)	2.278×10^6 s^{-1}	2.285×10^6 s^{-1}
Ra-Be(α, n)	3.381×10^6 s^{-1}	3.360×10^6 s^{-1}
Ra-Be(γ, n)	6.401×10^5 s^{-1}	6.404×10^5 s^{-1}

7 OTHER BUSINESS; DATE OF NEXT MEETING

7.1 ENDF/B-VI re-evaluation

H. Klein initiated a discussion of the ENDF/B-VI re-evaluation of the H(n,n)H angular distribution. Both H. Klein and V.E. Lewis expressed scepticism about the new evaluation, which does not appear to take into account measurements made at 14 MeV during a comparison held under the auspices of the CCEMRI. These measurements did not indicate a need for the change that was made between ENDF/B, versions V and VI. H. Klein asked that the NIST help him obtain a copy of the report by Dodder and Hale which documents the re-evaluation. It was suggested that A. Carlson of the NIST will contact H. Klein to provide references and discuss the ENDF/B-VI evaluation. The relevant cross section is one of the most fundamental standards employed in fluence comparisons.

7.2 Exchange of information on work in progress at participants' laboratories

A very interesting exchange of information took place. Brief summaries of work in progress at their laboratories were given by K. Kudo, H. Klein, N. Karmalitsyn, V.E. Lewis, A. Plompen, Li Fen and D.M. Gilliam.

7.3 Visit to the BIPM laboratories

An interesting visit was arranged to the BIPM quantum Hall effect laboratory.

7.4 Date of next meeting

The date for the thirteenth meeting of Section III was discussed. It was agreed that it would be desirable to meet in 1999 in order to expedite the business of the Section and to remain in phase with the meetings of CCEMRI.

Secretariat post-script: Following the CCEMRI meeting in July 1997, it was agreed that the dates would be 31 May 1999 and 1 June 1999.

D.M. Gilliam, Rapporteur
October 1997
revised June 1998

APPENDIX R(III) 1.

Working documents submitted to Section III of the CCEMRI at its 12th meeting

(see the list of documents on page 113)

ANNEXE R(III) 1.

Documents de travail présentés à la 12e réunion de la Section III du CCEMRI

Ces documents de travail peuvent être obtenus sur demande adressée au BIPM.

Document
CCEMRI (III)/

97-1 NIM (Chine). — Progress report on neutron measurements in recent years at NIM, 1 p.

97-2 ETL (Japon). — Recent activities on neutron standardization at the Electrotechnical Laboratory (1), K. Kudo, N. Takeda, T. Noguchi, H. Ohgaki, T. Yamazaki, 2 p.

Recent activities on neutron standardization at the Electrotechnical Laboratory (2), N. Takeda, K. Kudo, 1 p.

Nonlinearity of pulse height of recoil helium in ^{3}He proportional counters, 1 p.

97-3 VNIIM (Féd. de Russie). — Some results of the laboratory activity of the D.I. Mendeleyev All-Russian Institute for Metrology in the field of neutron measurements in 1995-1997 years, N.N. Moiseev, M.A. Rasko, I.A. Kharitonov, 3 p.

97-4 VNIIM (Féd. de Russie). — The use of a spontaneous fission source on the basis of ^{248}Cm in neutron measurements, N.N. Moiseev, M.A. Rasko, I.A. Kharitonov, 2 p.

97-5 NPL (Royaume-Uni). — Neutron measurements at the National Physical Laboratory, V.E. Lewis, 4 p.

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
ARCS	see ÖFS
ARL	Australian Radiation Laboratory, Yallambie (Australia)
BARC	Bhabha Atomic Research Centre, Trombay (India)
BEV	Bundesamt für Eich- und Vermessungswesen, Vienna (Austria)
BIPM	Bureau International des Poids et Mesures
BNM	Bureau National de Métrologie, Paris (France)
BNM-LPRI	Bureau National de Métrologie: Laboratoire Primaire des Rayonnements Ionisants, Saclay (France)
*CBMN	Central Bureau for Nuclear Measurements, IRMM-CCE, European Commission
CCEMRI	Consultative Committee for Standards of Ionizing Radiation
CIAE	Chinese Institute of Atomic Energy, Beijing (China)
CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, Madrid (Spain)
CIPM	Comité International des Poids et Mesures
CMI	Czech Metrological Institute, Inspectorate of Ionizing Radiation, Prague (Czech Rep.)
COMECON	Council for Mutual Economic Assistance
COOMET	Cooperation in Metrology among the Central European Countries

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

ENEA-INMRI	Ente per le Nuove Tecnologie, l'Energia e l'Ambiente, Instituto Nazionale di Metrologia delle Radiazioni Ionizzanti, Rome (Italy)
ETL	Electrotechnical Laboratory, Tsukuba (Japan)
EUROMET	European Collaboration in Measurement Standards
GUM	(ex PKNM) Glówny Urzad Miar/Central Office of Measures, Warsaw (Poland)
IAE	Institute of Atomic Energy, Beijing (China)
IAEA	International Atomic Energy Agency
ICRM	International Committee for Radionuclide Metrology
ICRU	International Commission on Radiation Units and Measurements
INMRI	see ENEA
IOMP	International Organization for Medical Physics
IRA	Institut de Radiophysique Appliquée, Lausanne (Switzerland)
IRD	see LNMRI
IRK	Institut für Radiumforschung und Kernphysik, Vienna (Austria)
IRMM	(formerly the BCMN) Institute for Reference Materials and Measurements, European Commission
IRPA	International Radioprotection Association
ISO	International Organization for Standardization
*ITRI-TNO	Institute of Applied Radiobiology and Immunology, Rijswijk (Netherlands), see TNO-MBL
KRISS	(ex KSRI) Korea Research Institute of Standards and Science, Taejon (Rep. of Korea)
*KSRI	Korea Standards Research Institute, Taejon (Rep. of Korea), see KRISS
LNMRI/IRD	Laboratório Nacional de Metrologia das Radiaçoes Ionizantes, Instituto de Radioproteçao e Dosimetria, Rio de Janeiro (Brazil)
LPRI	Laboratoire Primaire des Rayonnements Ionisants, Saclay (France), see BNM
NAC	National Accelerator Centre, Faure (South Africa)
*NBS	National Bureau of Standards, Gaithersburg (United States), see NIST
NIM	National Institute of Metrology, Beijing (China)
*NIRP-SSI	National Institute of Radiation Protection, Stockholm (Sweden), see SRPI

NIST	(formerly the NBS) National Institute of Standards and Technology, Gaithersburg (United States)
NMI	National institute of metrology
NMi-VSL	Nederlands Meetinstituut: Van Swinden Laboratorium, Delft (Netherlands)
NPL	National Physical Laboratory, Teddington (United Kingdom)
NRC	National Research Council of Canada, Ottawa (Canada)
OFMET	Office Fédéral de Métrologie, Wabern (Switzerland)
ÖFS/ARCS	Österreichisches Forschungszentrum Seibersdorf, GmbH/ Austrian Research Centre, Seibersdorf (Austria)
OMH	Országos Mérésügyi Hivatal, Budapest (Hungary)
*PKNM	Polski Komitet Normalizacji, Miar i Jakości, Warsaw (Poland)
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig (Germany)
RC	Radioisotope Centre, Otwock (Poland)
SRPI	(formerly the NIRP/SSI) Swedish Radiation Protection Institute, Stockholm (Sweden)
SSDL	Secondary Standards Dosimetry Laboratories
SSI	see SRPI
TNO-MBL	TNO Medical Biological Laboratory, Rijswijk (Netherlands)
VNIIM	D.I. Mendeleyev Institute for Metrology, St Petersburg (Russian Fed.)

2 Acronyms for scientific terms

BRS	Becquerel Reference System
EGS4	Electron Gamma Showers Version 4
ENDF	Evaluated Nuclear Data File
LSC	Liquid Scintillation Counting
MCNP	Monte Carlo Code for Neutron and Photon Transport
SIR	International Reference System for gamma-ray emitting nuclides
TDCR	Triple-to-Double Coincidence Ratio
WAFAC	Wide Angle Free Air Ionization Chamber

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