BUREAU INTERNATIONAL DES POIDS ET MESURES

COMITÉ CONSULTATIF POUR LES ÉTALONS DE MESURE DES RAYONNEMENTS IONISANTS

Rapport de la 14e session
Report of the 14th Meeting

1996

Organisation intergouvernementale de la Convention du Mètre

COMITÉ CONSULTATIF POUR LES ÉTALONS DE MESURE DES RAYONNEMENTS IONISANTS

SESSION DE 1996

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LISTE DES SIGLES UTILISÉS DANS LE PRÉSENT VOLUME
LIST OF ACRONYMS USED IN THE PRESENT VOLUME

1. Sigles des laboratoires, commissions et conférences
Acronyms for laboratories, committees and conferences

AIEA/IAEA	Agence internationale de l'énergie atomique/International Atomic Energy Agency
ANSTO	Australian Nuclear Science and Technology Organisation, Menai (Australie)
APMP	Asia/Pacific Metrology Programme
ARCS	*voir* ÖFS
ARL	Australian Radiation Laboratory, Yallambie (Australie)
*BCMN/CBNM	Bureau central de mesures nucléaires/Central Bureau for Nuclear Measurements, IMMR-CCE, Geel (Belgique)
BEV	Bundesamt für Eich- und Vermessungswesen, Vienne (Autriche)
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)
*CBNM	*voir* IMMR/IRMM
CCEMRI	Comité consultatif pour les étalons de mesure des rayonnements ionisants
CCU	Comité consultatif des unités
CEA	Commissariat à l'énergie atomique, Bruyères-le Châtel (France)
CIAE	Chinese Institute of Atomic Energy, Beijing (Rép. pop. de Chine)
CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, Madrid (Espagne)
CIPM	Comité international des poids et mesures
EC-JRC	European Communities, Joint Research Centre
ENEA/LMRI	Ente per le Nuove Tecnologie, l'Energia e l'Ambiente, Laboratorio di Metrologia delle Radiazioni Ionizzanti, Rome (Italie)
ETL	Electrotechnical Laboratory, Tsukuba (Japon)

* Les laboratoires ou organisations marqués d'un astérisque soit n'existent plus soit figurent sous un autre sigle.

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

EURADOS	European Radiation Dosimetry Group
EUROMET	European Collaboration in Measurement Standards
GUM	(ex PKNM) Glówny Urzad Miar/Central Office of Measures, Varsovie (Pologne)
IAEA	*voir* AIEA
ICRM	International Committee for Radionuclide Metrology
ICRU	International Commission on Radiation Units and Measurements
IIR	(ex UVVVR) Inspectorate for Ionizing Radiation, Prague (Rép. tchèque)
IMMR/IRMM	(ex BCMN/CBNM) Institute for Reference Materials and Measurements, Geel (Belgique)
IRA-OFMET	Institut de Radiophysique Appliquée, Lausanne (Suisse)
IRD	*voir* LNMRI
IRK	Institut für Radiumforschung und Kernphysik, Vienne (Autriche)
IRMM	*voir* IMMR
ISO	Organisation internationale de normalisation/International Organization for Standardization
*ITRI-TNO	Institute of Applied Radiobiology and Immunology, Rijswijk (Pays-Bas), *voir* TNO-MBL
KRISS	(ex KSRI) Korea Research Institute of Standards and Science, Taejon (Rép. de Corée)
*KSRI	Korea Standards Research Institute, Taejon (Rép. de Corée), *voir* KRISS
LMRI	*voir* ENEA
LNMRI/IRD	Laboratório Nacional de Metrologia das Radiaçoes Ionizantes, Instituto de Radioproteçao e Dosimetria, Rio de Janeiro (Brésil)
LPRI	Laboratoire primaire des rayonnements ionisants, Saclay (France), *voir* BNM
NAC	National Accelerator Centre, Faure (Afrique du Sud)
*NBS	National Bureau of Standards, Gaithersburg (É.-U. d'Amérique), *voir* NIST
NIM	Institut national de métrologie/National Institute of Metrology, Beijing (Rép. pop. de Chine)
*NIRP/SSI	National Institute of Radiation Protection, Stockholm (Suède), *voir* SRPI
NIST	(ex NBS) National Institute of Standards and Technology, Gaithersburg (É.-U. d'Amérique)
NMi	(ex VSL) Nederlands Meetinstituut, Delft (Pays-Bas)
NPL	National Physical Laboratory, Teddington (Royaume-Uni)
NRC	Conseil national de recherches du Canada/National Research Council of Canada, Ottawa (Canada)
OFMET	Office fédéral de métrologie, Wabern (Suisse)
ÖFS/ARCS	Österreichisches Forschungszentrum Seibersdorf, GmbH/Austrian Research Centre, Seibersdorf (Autriche)
OMH	Országos Mérésügyi Hivatal, Budapest (Hongrie)

OMS/WHO	Organisation internationale de la santé/World Health Organization
*PKNM	Polski Komitet Normalizacji, Miar i Jakości, Varsovie (Pologne)
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig (Allemagne)
RC	Radioisotope Centre, Otwock (Pologne)
SRPI	(ex NIRP/SSI) Swedish Radiation Protection Institute, Stockholm (Suède)
SSDL	Secondary Standards Dosimetry Laboratories
TNO-MBL	TNO Medical Biological Laboratory, Rijswijk (Pays-Bas)
*UVVVR	Ústav pro výzkum, výrobu a vyuziti radioisotopu, Prague (ex Tchécoslovaquie), *voir* IIR
VNIIM	Institut de métrologie D. I. Mendéléev/D. I. Mendeleyev Institute for Metrology, Saint-Pétersbourg (Féd. de Russie)
*VSL	Van Swinden Laboratorium, Delft (Pays-Bas)
WHO	*voir* OMS

2. Sigles des termes scientifiques
Acronyms for scientific terms

EGS4	Electron Gamma Showers Version 4
HVL	Couche de demi-atténuation/Half-value layer
LSC	Système de comptage à scintillation liquide/Liquid Scintillation Counting
MCNP	Code de transport de Los Alamos selon la méthode de Monte Carlo pour les neutrons et les photons/Los Alamos Monte-Carlo neutron and photon transport code
SI	Système international d'unités/International System of Units
SIR	Système international de référence pour les mesures d'activité d'émetteurs de rayons gamma/International Reference System for gamma-ray emitting radionuclides
TDCR	Rapport des coincidences triples aux coincidences doubles/Triple-to-double coincidence ratio
TLD	Dosimètre thermoluminescent/Thermoluminescent dosimeter

COMITÉ CONSULTATIF POUR LES ÉTALONS DE MESURE DES RAYONNEMENTS IONISANTS

MEETING IN 1996

Note on the use of the English text

To make its reports and those of its various Comités Consultatifs more widely accessible the Comité International des Poids et Mesures has decided to publish an English version of these 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.

Note sur l'utilisation du texte anglais

Afin de faciliter l'accès à ses rapports et à ceux des divers Comités consultatifs, le Comité international des poids et mesures a décidé de publier une version en anglais de ces rapports. Le lecteur doit cependant noter que le rapport officiel est toujours celui qui est rédigé en français. C'est le texte français qui fait autorité si une référence est nécessaire ou s'il y a doute sur l'interprétation.

THE BIPM

AND THE CONVENTION DU MÈTRE

The Bureau International des Poids et Mesures (BIPM) was set up by the Convention du Mètre 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 Convention du Mètre*.

The task of the BIPM is to ensure world-wide unification of physical measurements; its function is to:

— establish the fundamental standards and scales for measurement of the principal physical quantities and maintaining the international prototypes;
— carry out comparisons of national and international standards;
— ensure the co-ordination of corresponding measuring 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).

Delegates from all the Member States of the Convention du Mètre attend the Conférence Générale which, at present, meets every four years. At each meeting the Conférence Générale receives the Report of the Comité International on the work accomplished, its function being to:

— discuss and instigate 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;
— adopt the important decisions concerning the organization and development of the BIPM.

The Comité International 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 Convention du Mètre. The principal task of the CIPM is to ensure world-wide 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 for 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, in 1984 for the laser work and 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

* As of 31 December 1996, forty-eight States were members of this Convention: Argentina (Rep. of), Australia, Austria, Belgium, Brazil, Bulgaria, Cameroon, Canada, Chile, China (People's Rep. of), Czech Republic, Denmark, Dominican Republic, Egypt, Finland, France, Germany, Hungary, India, Indonesia, Iran, Ireland, Israel, Italy, Japan, Korea (Dem. People's Rep. of), Korea (Rep. of), Mexico, Netherlands, New Zealand, Norway, Pakistan, Poland, Portugal, Romania, Russian Federation, Singapore, Slovak Republic, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, United Kingdom, U.S.A., Uruguay, Venezuela.

and calibrations of standards. An annual report, published in the *Procès-Verbaux des séances du Comité International des Poids et Mesures*, gives the 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 Comités Consultatifs, whose function is to provide it with information on matters that it refers to them for study and advice. These Comités Consultatifs, 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 Comités Consultatifs have common regulations (*BIPM Proc.-Verb. Com. Int. Poids et Mesures*, 1963, **31**, 97). They meet at irregular intervals. The chairman of each Comité Consultatif is designated by the CIPM and is normally a member of the CIPM. The members of the Comités Consultatifs are metrology laboratories and specialized institutes, agreed by the CIPM, which send delegates of their choice. In addition, individual members are appointed by the CIPM, and there is also a representative of the BIPM. At present, there are nine such committees:

1. The Comité Consultatif d'Électricité (CCE), set up in 1927;
2. The Comité Consultatif de Photométrie et Radiométrie (CCPR), new name given in 1971 to the Comité Consultatif de Photométrie (CCP) set up in 1933 (between 1930 and 1933 the preceding committee (CCE) dealt with matters concerning photometry);
3. The Comité Consultatif de Thermométrie (CCT), set up in 1937;
4. The Comité Consultatif pour la Définition du Mètre (CCDM), set up in 1952;
5. The Comité Consultatif pour la Définition de la Seconde (CCDS), set up in 1956;
6. The Comité Consultatif pour les Étalons de Mesure des Rayonnements Ionisants (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 Comité Consultatif des Unités (CCU), set up in 1964 (this committee replaced the "Commission for the System of Units" set up by the CIPM in 1954);
8. The Comité Consultatif pour la Masse et les grandeurs apparentées (CCM), set up in 1980;
9. The Comité Consultatif pour la Quantité de Matière (CCQM), set up in 1993.

The proceedings of the Conférence Générale, the Comité International and the Comités Consultatifs 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;*
— *Sessions des Comités Consultatifs.*

The Bureau International also publishes monographs on special metrological subjects and, under the title *Le Système International d'Unités (SI)*, a booklet, periodically up-dated, 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; a list of these publications is published 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 Convention du Mètre.

Comité International des Poids et Mesures

Secretary	*President*
J. KOVALEVSKY	D. KIND

MEMBERS
OF THE
COMITÉ CONSULTATIF POUR LES ÉTALONS DE MESURE
DES RAYONNEMENTS IONISANTS

President

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

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, Laboratoire Primaire des Rayonnements Ionisants, Saclay.

Members

AUSTRALIAN RADIATION LABORATORY [ARL], Yallambie.

BUREAU NATIONAL DE MÉTROLOGIE, Paris: Laboratoire Primaire des Rayonnements Ionisants [BNM-LPRI], Saclay.

D. I. MENDELEYEV INSTITUTE FOR METROLOGY [VNIIM], Saint-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 METEINSTITUUT [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

K. DEBERTIN, Physikalisch-Technische Bundesanstalt, Braunschweig.*

* K. Debertin replaced D. Smith, National Physical Laboratory, Teddington, as Chairman of Section II in 1994.

Members

AUSTRALIAN NUCLEAR SCIENCE AND TECHNOLOGY ORGANISATION [ANSTO], Menai.

BUREAU NATIONAL DE MÉTROLOGIE, Paris: Laboratoire Primaire des Rayonnements Ionisants [BNM-LPRI], Saclay.

D. I. MENDELEYEV INSTITUTE FOR METROLOGY [VNIIM], Saint-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, Paris: Laboratoire Primaire des Rayonnements Ionisants [BNM-LPRI], Saclay.

D. I. MENDELEYEV INSTITUTE FOR METROLOGY [VNIIM], Saint-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, Institute of Applied Radiobiology and Immunology [ITRI-TNO], Rijswijk.

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

AGENDA

for the 14th Meeting

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1. Opening of the meeting; designation of a rapporteur.
2. Reports of the three sections of the CCEMRI and related BIPM work:
   - 2.1 Section I — X and γ rays, electrons;
   - 2.2 Section II — Measurement of radionuclides;
   - 2.3 Section III — Neutron measurements.
3. Programme for future work.
4. Traceability and equivalence in national standards.
5. Other business.
6. Membership and meetings of the sections of the CCEMRI.
7. Date of the next meeting.

REPORT

OF THE

COMITÉ CONSULTATIF POUR LES ÉTALONS DE MESURE

DES RAYONNEMENTS IONISANTS

(14th Meeting — 1996)

TO THE

COMITÉ INTERNATIONAL DES POIDS ET MESURES

by V. E. LEWIS, Rapporteur

Abstract. The Comité Consultatif pour les Étalons de Mesure des Rayonnements Ionisants held its fourteenth meeting in June 1996. All three sections presented reports. Section I (X and γ rays, electrons) reported on comparisons of air kerma standards and absorbed dose to water standards, and discussed the work on standards for radiation protection and radiotherapy. Section II (Measurement of radionuclides) described comparisons of radionuclide standards and the development of the Système International de Référence and the activities of its working groups. Section III (Neutron measurements) reviewed progress on comparisons of fast and thermal neutron measurements. BIPM staff members reported on some of their recent work and future work of the BIPM was discussed. The issue of equivalence was discussed. The membership of the Committee and its Sections was reviewed and dates were agreed for future meetings.

Introduction

The Comité Consultatif pour les Étalons de Mesure des Rayonnements Ionisants (CCEMRI)* held its fourteenth meeting at the Pavillon de Breteuil, in Sèvres, on 27 and 28 June 1996.

* See the list of acronyms on page V.

Present:

G. MOSCATI, Member of the CIPM, President of the CCEMRI.

A. ALLISY, International Commission on Radiation Units and Measurements [ICRU].

G. DIETZE, Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

A. DUTREIX, University Hospital St-Rafael, Lewen.

G. F. KNOLL, University of Michigan, Ann Arbor.

J.-P. SIMOËN, Chairman of Section I, Laboratoire Primaire des Rayonnements Ionisants [BNM-LPRI], Saclay.

K. DEBERTIN, Chairman of Section II, Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

V. E. LEWIS, Chairman of Section III, National Physical Laboratory [NPL], Teddington.

The Director of the Bureau International des Poids et Mesures [BIPM] (T. J. QUINN).

Also attending the meeting:

P. GIACOMO (Director Emeritus of the BIPM), P. ALLISY-ROBERTS, M. BOUTILLON, D. BURNS, C. MICHOTTE, J. W. MÜLLER and G. RATEL (BIPM).

Regrets were received from Prof. A. M. KELLERER who was unable to attend.

1. Opening of the meeting; designation of a rapporteur

The President, Prof. Moscati, opened the meeting by welcoming the committee members and the BIPM staff.

Dr Lewis was appointed rapporteur.

Two items were added to the draft agenda which had been circulated prior to the meeting. These were: item 4, Traceability and equivalence in national standards and item 6, Membership of the sections of the CCEMRI. With these additions, the meeting agreed to the agenda.

2. Reports of the three sections of the CCEMRI and related BIPM work

Each Chairman summarized his section's activities and the BIPM staff presented selected topics from the work performed in the ionizing radiation laboratories.

2.1 Section I — X and γ rays, electrons (Chairman: J.-P. Simoën)

Dr Simoën presented the report on the activities of Section I, which held its twelfth meeting in April 1995.

He noted that seven comparisons of air kerma standards had been reported, of which one was for low-energy x rays, one for medium-energy x rays, two for ^{137}Cs γ rays and three for ^{60}Co γ rays. An additional six comparisons measured ^{60}Co radiation, three in terms of absorbed dose to water and three in terms of absorbed dose to graphite. These thirteen comparisons involved seven national laboratories.

A total of thirty-three secondary standards from nine countries and the IAEA had been calibrated. Of these, four were for low-energy x rays, seven for medium-energy x rays, three for ^{137}Cs γ rays and nineteen for ^{60}Co γ rays. Most calibrations are in terms of the quantities air kerma and absorbed dose to water. In addition, nine sets of thermoluminescent dosimeters were irradiated with ^{60}Co for the IAEA.

A "double-blind", high-dose comparison of absorbed dose to water, organized by the IAEA using an alanine dosimetry system, yielded relative standard deviations of 2,1 % and 2,4 % for 15 kGy and 45 kGy respectively. It was suggested that a similar comparison of measurements in the range from 10 kGy to 50 kGy, involving all laboratories active in high-dose measurements, should be organized under the auspices of the BIPM.

Section I expressed its concern that the BIPM should develop a role in comparisons and calibrations in the field of high-energy photons and electrons, even though the BIPM does not possess a linear accelerator. A recommendation was adopted in favour of a system based on a set of ionization chambers to be maintained by the BIPM. Three national laboratories (NPL, NRC and PTB) agreed to participate in this scheme, and a working party was formed to study reference irradiation conditions for high-energy radiation beams.

Dr Simoën continued his report noting that members had been asked to reconsider the uncertainties associated with the different physical quantities used to establish the air kerma standards they quote in reports. A working party had been formed to collect, summarize and review all BIPM comparisons, and all comparisons of primary standards carried out under the auspices of organizations such as EUROMET. The findings will be presented at the next Section I meeting in a form suitable for publication in *Metrologia*. This will make information on the coherence of national standards more readily available. The working party will also make proposals for future comparisons.

Dr Allisy-Roberts then reported on the development of the ^{137}Cs air kerma standard at the BIPM which is realized using a parallel-plate ionization chamber with graphite walls, noting that the long-term stability had been better than 0,2 % over two years. She noted that a comparison

of ^{137}Cs air kerma standards was in progress at the BIPM and that, so far, four primary laboratories had taken part.

Mme Boutillon described the development of standards at the BIPM for low-energy x rays and the influence of the uncertainties due to beam quality, beam diameter and half-value layer accuracy in the energy bands 10 kV to 55 kV. Dr Burns reported on the project which uses the EGS4 Monte Carlo code to calculate correction factors to be applied to the BIPM free-air chambers.

Four ISO qualities had been chosen to add to the x-ray reference qualities available at the BIPM; three of these were considered to be unsuitable for use at the BIPM due to the very low air kerma rate.

2.2 Section II — Measurement of radionuclides (Chairman: K. Debertin)

Dr Debertin reviewed the work of Section II, which held its thirteenth meeting in May 1995. Comparisons of standards and the development of the Système International de Référence (SIR) continue to be major activities.

The trial comparison of standards of the pure β emitter ^{204}Tl was completed in 1995 and involved six participants. After taking supplementary measurements, good consistency was obtained. Dr Debertin noted that a full-scale exercise was planned for the end of 1996. The distribution of an aliquot of a suitable scintillator in addition to the radioactive solution was recommended.

The nuclide ^{192}Ir, which is widely used in industry and medicine, was chosen for a trial comparison because of discrepancies in the SIR. Dr Ratel of the BIPM reported that the results appear to fall into two groups. A report of the trial, which involved nine laboratories, was in preparation.

A comparison based on ^{90}Sr is planned. For this, participants will submit, all at the same time, a standardized solution to the BIPM for measurement by the SIR. The intention is to test the capabilities of the SIR for the measurement of pure β emitters following its extension to include a liquid scintillation system.

Dr Ratel noted that the BIPM has provided a focus for the SIR, which was now some twenty years old. The current produced by the BIPM standard radium source in the SIR ionization chamber has been stable to 0,2 % over this time. Since 1976, 491 results for 55 radionuclides have been obtained from 26 laboratories. Over 665 ampoules have been processed. All these results originate from absolute measurements made by national laboratories.

The working group on the extension of the SIR continues to support its development and has initiated a study of new scintillation cocktails. Another working group is carrying out a systematic analysis of SIR results in order to judge the present-day performance of standards laboratories

in the standardization of solutions of radionuclides. Some 25 % of the radionuclides submitted are considered to have presented problems, some of which were systematic.

The working group planning further comparisons has reported that ^{152}Eu is favoured as the next candidate because its decay scheme is complex and it has practical applications. However, as there was disagreement over this choice at the Section II meeting, members will be asked to re-consider the criteria for choosing radionuclides.

A working group has been established to examine the implications of equivalence and traceability for radioactivity standards, and to draw up guidelines for the establishment of equivalence between standardizing laboratories. This working group was scheduled to meet during the week following the CCEMRI meeting.

Problems were experienced in arranging joint procurement of radionuclide supplies probably because suppliers operate within short time frames. A database of suppliers is being prepared by the working group concerned. The working group on source preparation has been dissolved and its work taken over by the working group on the extended SIR.

The second draft of the BIPM Monograph on *Activity Measurements with Ionization Chambers* has been edited by Dr Blackburn (editor of *Metrologia*) in collaboration with Dr Müller. Final corrections were made at the PTB and a final version, suitable for duplication at the BIPM, was expected soon*. Work on the review *High Efficiency Detectors for Activity Measurements* by Dr Winkler (IRK) has ceased for the time being.

It was considered that the working group on the principles of the coincidence method is likely to disband following the retirement of Dr Müller from the BIPM. This method appears to be well established; the recently published *ICRU Report* 52 (*Particle Counting in Radioactivity Measurements*), prepared essentially by past and present members, represents a fitting conclusion to the activities of this group.

In his presentation of work performed at the BIPM, Dr Ratel reported on progress with the SIR and described the results of comparisons involving ^{204}Tl and ^{192}Ir. Dr Michotte described the calibration of a Ge(Li) detector over the range from 50 keV to 3 MeV. This detector will be used initially to identify impurities in radioactive samples. It may be used later to measure emission probabilities. Prof. Knoll suggested that a Ge detector would be better, but Dr Debertin thought that the size and resolution of the BIPM detector would be adequate. Dr Müller gave a presentation on the theory of the parity method for the measurement of coincidences and expressed his hope that it will be possible to carry out a trial of the technique at the BIPM.

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* SCHRADER H., Activity Measurements With Ionization Chambers, *Monographie BIPM*-4, 1997.

2.3 Section III — Neutron measurements (Chairman: V. E. Lewis)

Dr Lewis reported on the activities of Section III, which held its eleventh meeting in April 1995.

A comparison of measurements of 2,5 MeV and 14,7 MeV neutron fluence, employing a set of Bonner spheres, was concluded successfully after good agreement was obtained between experimental and computational evaluations of the corrections for target interaction effects.

The comparison of measurements of 24,5 keV neutron fluence, employing the same Bonner sphere set, is due for completion in 1997. In this project, the BIPM was responsible for the transportation arrangements for the instrumentation and for stability checks between participants' measurements. Neutron fields in this energy region can be produced using reactor beams with iron filters, antimony-beryllium (γ,n) sources or charged particle accelerators employing the $^{45}Sc(p,n)^{45}Ti$ reaction. Spectral response functions for the Bonner spheres, calculated using a neutron-photon transport code, will be used to correct measured values to the equivalent values for 24,5 keV neutrons. The evaluation of the results will be carried out by Dr Lewis.

A comparison of thermal neutron fluence measurements is planned. This will involve the circulation of a set of ionization chambers with boron-coated plates. The NIST will provide the plates and the electronics, and will organize the exercise. The start of the comparison has been delayed by a problem in the manufacture of the ionization chambers caused by an apparent loss of boron from the plates. The NIST is looking at the possibility of using ^{235}U deposits as an alternative to ^{10}B. Adding ^{235}U chambers to the transfer instrument set would, in any case, provide useful information as their spectral response is different. Six laboratories are interested in participating in the exercise.

At an earlier meeting, the NPL and the PTB expressed interest in a comparison of neutron spectral fluence measurements. There is now no need for Section III to organize such a comparison, as this has already been done by a EURADOS working group which has organized several comparisons of measurements at different European laboratories.

Measurement comparisons have been carried out under the auspices of Section III over the past thirty years. The fluence measurement comparisons cover the energy range from 25 keV to 14,8 MeV, plus thermal neutrons. This includes all ISO-recommended energies except for 19 MeV. Radionuclide source emission rate measurements have also been compared and there have been two comparisons of absorbed dose measurements. There is no immediate need to repeat comparisons or to extend them to higher or lower energies. The situation will be reviewed following an examination of the consistency of present standards.

Recognizing the need for quality assurance of measurement standards, Section III now considers it necessary to review standards for neutron

metrology and re-assess their uncertainty budgets. Such a review would demonstrate traceability to primary standards and clarify whether further comparisons are necessary for the validation of national standards. The NPL and the PTB plan to initiate the compilation of a catalogue or handbook covering manganese bath and fluence standards, addressing such matters as principles and techniques, requirements for other standards, ancillary data, uncertainty budgets and validation.

The BIPM has been active in most of the comparison exercises, although the BIPM accelerator facility was limited to only two neutron energies. Cessation of neutron metrology at the BIPM has posed some problems for Section III, but it now considers that world-wide consistency in neutron measurements can be maintained by comparisons among the laboratories represented in Section III, and the dissemination of standards to other nations. The instrumentation, at the BIPM and elsewhere, that has been used and characterized by Section III and the BIPM over many years is now either maintained at the BIPM or is in the care of member laboratories which make it generally available to other laboratories.

3. Programme for future work

Much of the programme for future work was addressed by section Chairmen in their individual reports. Particular aspects were taken up again during discussion of the general programme.

Dr Allisy-Roberts reviewed actions arising from the Section I meeting and noted that a schedule for comparisons is being prepared. This includes a comparison of low-energy x ray measurements (10 kV to 50 kV) planned for 1996. For high-energy x rays, the PTB will supply the BIPM with a parallel-plate ionization chamber, which will be assessed for use as a transfer standard for absorbed dose by the BIPM. Its calibration and stability will be determined for ^{60}Co and high-energy x rays. The BIPM will investigate a robust transfer system for the measurement of absorbed dose in high-energy radiation beams.

Prof. Allisy emphasized the importance of the high-energy comparison programme and proposed that the BIPM should assemble a pool of ionization chambers to be taken around laboratories by BIPM staff, the “best” being held as a reference standard at the BIPM. The participants agreed with this approach, which is essentially the Section I proposal with the additional provision that the BIPM staff will work at other laboratories. It was considered that it would be a useful experience for all concerned if BIPM staff were to visit other establishments, and it would reduce costs. The proposal would require the support of the national laboratories, but this was expected to be forthcoming.

The outcome of this programme would be comparisons of the standards held by the laboratories. While a later stage might involve the circulation

of a graphite calorimeter, it was agreed that the current priority is to establish a pool of ionization chambers.

The need for the BIPM to compare its low-energy standards with those of national laboratories was discussed. The many calibrations made for other laboratories by the BIPM depend on these standards. Mme Boutillon suggested that a frequency of ten years was adequate but the meeting thought that the matter should be given further consideration and no formal recommendation was made.

Standards for brachytherapy sources were discussed and it was agreed that these should be specified in terms of kerma rate at a reference distance. This, in turn, suggested that the BIPM should calibrate ^{192}Ir and ^{137}Cs sources in terms of air kerma rate at 1 metre. Such a standard would require the use of high-activity sources. Problems of dissemination, such as the transportation of intense sources or the use of a transfer standard ionization chamber, were discussed. For such a project, the BIPM would need to make contact with the national laboratories, some of which are already involved in this field. No recommendations were made.

4. Traceability and equivalence in national standards

Dr Quinn noted the increasing pressure on national measurement institutes to demonstrate quality assurance of standards, a pressure which arises from the drive for accreditation and the demands of international trade. He noted that it is not appropriate for assessors from accreditation or registration bodies to accredit national standards. To establish equivalence between national measurement institutes peer evaluation is essential, and this must take into account the results of comparisons of standards between member laboratories and between regional groups of laboratories. This is an issue that must be addressed by all consultative committees for it would be better if they were to evaluate the results of comparisons, as opposed to merely publishing them and leaving the interpretation to others. It is essential to consider the next step, i.e. the demonstration of equivalence, in an objective and systematic manner.

The ensuing discussion touched upon the issue of terminology and the need for definitions of traceability and equivalence. It was recognized that such fundamental matters will be addressed by more broadly-based working groups, which will take into account ideas and suggestions from individual committees and their associated working groups. Although some members thought in terms of starting from concepts, the general view was that no decision could be taken until the matter had been considered by the individual sections. Dr Quinn argued in favour of a pragmatic approach with contributions from all fields, including, for example, that from the Section II working group.

The practical demonstration of equivalence was discussed. It was suggested that consultative committees should fix bands of equivalence

(at three standard deviations, for example); laboratories with standards inside these bands would be regarded as equivalent. This would, however, put pressure on laboratories obtaining outlying results to obtain other data placing them within the bands. As the financial implications could be important, the motivation to obtain consensus values could become economic rather than scientific. These decisions also have legal and political aspects; for example, use could be made of the information obtained during a comparison to close down laboratories perceived to be inferior. It was suggested that different criteria for fixing the band limits might be needed even for the fields covered by individual sections of the CCEMRI.

In conclusion, it was agreed that discussions would continue within the sections. Dr Quinn asked sections to examine the results of their comparisons and then look at relevant terms and concepts.

5. Other business

The importance, for the establishment of equivalence, of reviewing and publicizing all comparisons held under the auspices of CCEMRI was recognized. It was agreed that *Metrologia* should be used for the publication of the results and conclusions reached in the course of comparisons, although the technical details could be published elsewhere. Section II, which has always used *Nuclear Instruments and Methods* for wider circulation and publicity, will adopt this latter approach. Section III has always used *Metrologia*, and more recently published a summary in *Radiation Protection Dosimetry* to address a wider audience. It was noted that short summaries of EUROMET comparison results could also be published in *Metrologia*, as could those of comparisons held by similar organizations.

6. Membership and meetings of the sections of the CCEMRI

The membership of the three sections was discussed. Members and observers who do not actively contribute to the work of the sections should no longer be invited and non-member laboratories which contribute actively should be proposed to the CIPM as members.

Dr Debertin, after chairing only one meeting of Section II, announced that he would retire from the PTB. At the request of Dr Quinn he agreed to stay on as Chairman of Section II for the next meeting.

The dates of the next meetings of the three sections were discussed and it was agreed that meetings would not overlap and no joint sessions would be held, although the meetings for Sections I and III could be held in the same week. The date of the Section II meeting had already been chosen, 23, 24, 25 April 1997, to fit with the meeting of the International

Committee on Radionuclide Metrology. Meetings of Sections I and III were scheduled for April 1997; precise dates would be decided following consultation with members.

7. Date of the next meeting

It was agreed that the existing system in which CCEMRI meetings and section meetings are held in alternate years is no longer appropriate, and that CCEMRI should now meet in the months following section meetings. The next CCEMRI meeting will be held on 7 and 8 July 1997.

In closing the meeting, the President thanked the members and the staff of the BIPM for their participation and for their contributions. The Committee expressed its gratitude to the BIPM for its hospitality.

6 September 1996

Section I — X and γ rays, electrons

12th Meeting (April 1995)

AGENDA

for the 12th Meeting

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1. Opening of the meeting; designation of a rapporteur.
2. Calibrations and comparisons of measurement standards (x and γ rays):
   - 2.1 BIPM;
   - 2.2 National laboratories.
3. Present and future work at the BIPM:
   - 3.1 Behaviour of a transfer instrument for low-energy x rays;
   - 3.2 Development of the standard of air kerma in the ^{137}Cs beam and results of first comparisons;
   - 3.3 Presentation and discussion regarding high-energy x-ray calibrations;
   - 3.4 Future comparisons and dissemination of results of comparisons.
4. Development and improvement of national standards for photon dosimetry:
   - 4.1 Standards for air kerma and exposure;
   - 4.2 Standards for absorbed dose to water.
5. Brachytherapy standards.
6. Standards for radiation protection.
7. Standards for radiation processing.
8. Development and improvement of national standards for charged particle dosimetry:
   - 8.1 Beta-ray field;
   - 8.1 Proton beams.
9. Reports from member laboratories.
10. Report from the IAEA:
    - 10.1 Comparison (^{60}Co) of absorbed dose at the kGy level using alanine dosimetry;
    - 10.2 Comparison (^{60}Co) of absorbed dose at therapy level using thermoluminescent dosimeters.
11. Publication of results.
12. Other business.

COMITÉ CONSULTATIF POUR LES ÉTALONS DE MESURE
DES RAYONNEMENTS IONISANTS

SECTION I. — **X and γ rays, electrons**
12th Meeting (April 1995)

REPORT
by N. J. HARGRAVE, Rapporteur

Abstract. Section I (X and γ rays, electrons) of the Comité Consultatif pour les Étalons de Mesure des Rayonnements Ionisants (CCEMRI) held its twelfth meeting in April 1995. The recent work at the BIPM was reviewed and recommendations for the BIPM involvement in future work were made. The results of comparisons of standards both at the BIPM and between national standards laboratories were discussed. The need to ensure that the results of comparisons were adequately disseminated was emphasized. A programme to facilitate this was established. Steps were taken to ensure that the BIPM has a continuing role in the comparison and maintenance of standards for radiations generated by linear accelerators.

Introduction

Section I (X and γ rays, electrons)* of the Comité Consultatif pour les Étalons de Mesure des Rayonnements Ionisants (CCEMRI)** held its twelfth meeting at the Pavillon de Breteuil, in Sèvres, on 24, 25 and 26 April 1995.

Present:

J.-P. SIMOËN, Chairman of Section I, Laboratoire Primaire des Rayonnements Ionisants [BNM-LPRI], Saclay.

Delegates of the member laboratories and organizations:

Australian Radiation Laboratory [ARL], Yallambie (N. J. HARGRAVE).

Bureau National de Métrologie, Paris: Laboratoire Primaire des Rayonnements Ionisants (J.-P. SIMOËN).

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* For the list of the members, *see* page R 72.

** Laboratories and organizations mentioned in this report are listed on page V.

Electrotechnical Laboratory [ETL], Tsukuba (N. TAKATA).

Glówny Urzad Miar [GUM], Varsaw (Z. REFEROWSKI).

International Commission on Radiation Units and Measurements [ICRU] (W. A. JENNINGS).

National Institute of Standards and Technology [NIST], Gaithersburg (S. SELTZER).

National Physical Laboratory [NPL], Teddington (D. BURNS).

National Research Council of Canada [NRC], Ottawa (D. W. O. ROGERS).

Nederlands Meetinstituut [NMi-VSL], Bilthoven (A. H. L. AALBERS).

Országos Mérésügyi Hivatal [OMH], Budapest (J. CSETE).

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig (K. HOHLFELD).

Swedish Radiation Protection Institute [SRPI], Stockholm (L. LINDBORG).

The Director of the Bureau International des Poids et Mesures [BIPM] (T. J. QUINN).

Member *ad personam*:

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

Guests:

Ente per le Nuove Tecnologie, l'Energia e l'Ambiente [ENEA], Rome (R. F. LAITANO).

International Atomic Energy Agency [IAEA], Vienna (K. ZSDÁNSZKY).

Österreichisches Forschungszentrum Seibersdorf GmbH [ÖFS], Seibersdorf (K. DUFTSCHMID).

Attended all or part of the meeting: G. MOSCATI (member of the CIPM); P. GIACOMO (Director Emeritus of the BIPM); A. ALLISY (member of the CCEMRI); P. ALLISY-ROBERTS, M. BOUTILLON, J. W. MÜLLER and G. RATEL (BIPM); A.-M. PERROCHE (guest worker at the BIPM).

Apologies were received from:

National Institute of Metrology [NIM], Beijing.

Absent:

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

1. Opening of the meeting; designation of a rapporteur

J.-P. Simoën, Chairman of Section I, declared the meeting open and invited the Director of the BIPM to begin the meeting.

The Director of the BIPM welcomed those present and gave a brief introduction on the Convention du Mètre and the activities of the various organs of the Convention, namely the Conférence Générale des Poids et Mesures, the Comité International des Poids et Mesures, the consultative committees and the BIPM. He drew attention to the recent creation of a consultative committee in the field of metrology in chemistry. He emphasized the importance of the activities of the consultative committees in the context of increasing demands for international traceability in measurement standards. One of the tasks he gave to the meeting was to discuss and, if possible, identify those key international comparisons whose results can be used to demonstrate such traceability. The Director then passed the meeting back to the Chairman.

The Chairman thanked the Director for his words of welcome and introduced those who were present for the first time or present in a new capacity. In particular, he welcomed Professor G. Moscati of Brazil who was present as a new CIPM member, S. Seltzer representing the NIST, K. Zsdánszky representing the IAEA, J. Csete representing the OMH and D. Burns representing the NPL. A. Jennings, former Chairman of Section I, now representing the ICRU, and Professor A. Allisy, of the CCEMRI, were also welcomed to the meeting. A new worker at the BIPM, P. Allisy-Roberts, was introduced.

N. J. Hargrave agreed to act as rapporteur for the meeting.

A new item, item 3.4 on future comparisons, was added to the provisional agenda, circulated prior to the meeting. The meeting approved the agenda with this addition.

2. Calibrations and comparisons of measurement standards (x and γ rays)

2.1 BIPM

Two documents on the topic of calibrations and comparisons of measurement standards (95-2 and 3)* had been circulated prior to the meeting. Mme Perroche indicated that since the last meeting of Section I, one national standards laboratory had compared its own standards with those of the BIPM for x rays of low energy (between 10 kV and 50 kV) and medium energy (between 100 kV and 250 kV). Four and seven calibrations, respectively, were performed in these energy ranges. For the γ rays from ^{60}Co, three laboratories had made comparisons in terms of air kerma,

* Documents submitted by the participants are listed in Annexe R(I) 1, and are referred to in the text in the form 95-1, 95-2, etc.

three in terms of absorbed dose to water, one in terms of absorbed dose to graphite. In addition, each year, three sets of thermoluminescent dosimeters were calibrated for the IAEA in terms of absorbed dose to water. The results of many past comparisons were summarized and are presented in Figures 1-3 (95-2).

Work with the new ^{137}Cs source was reported for the first time. It had been used for one calibration in terms of ambient dose equivalent and two in terms of air kerma. Two laboratories had compared their air kerma standards at this energy (*see* section 3.2).

In discussion of the working documents presented, it was noted that in comparisons with the BIPM the results reported for medium-energy x rays have a tendency to fall with increasing energy. It was suggested that this may be related to the correction factor for electron loss which varies with the physical dimensions of the standard chambers.

2.2 National laboratories

Four working documents related to the topic of national laboratories. Preliminary results of a comparison between the ENEA and the NIST, referenced to the BIPM, were reported (95-14 and 29). It was stated that, while the values for ^{60}Co had not been finalized, the deviation is likely to be about 0,3 %. Corrections to the ENEA chamber for axial non-uniformity and chamber wall were still being evaluated. In the x-ray region, agreement is within approximately 0,8 %.

Measurements in a ^{137}Cs beam similar to that at the BIPM had been made at the BEV (95-7) using two 5 cm^3 chambers at 1 m and 2 m: similar measurements were carried out at the NIST (95-14). Using these chambers, the agreement of the air kerma standards determined using the two chambers was respectively 0,4 % and 0,5 % at 1 m and 2 m.

A comparison of measurements of absorbed dose to graphite was reported between the NMi and the NPL. In this, the two laboratories used fields of the same dimensions. When appropriate allowance was made for the density of graphite used, the previously reported agreement changed from 0,9995 to 0,9959. Part of this change resulted from use of the same thermistor for measurement and calibration in the NMi calorimeter (95-22 and 23).

3. Present and future work at the BIPM

3.1 Behaviour of a transfer instrument for low-energy x rays

Attention was drawn to the use of calibration factors provided by the BIPM, particularly in the x-ray region below 50 kV. Measurements

on some chambers indicate significant changes in the factors for beams having the same half-value layer (HVL), but with different x-ray spectra. The quoted BIPM uncertainties for these calibrations apply only to radiation beams identical with those used at the BIPM for the calibration. The actual beam diameter used also seems to be of importance. If other beams were used the uncertainties should be increased: for beams of HVL less than 0,1 mm aluminum from 0,2 % to 0,5 %; for those of HVL between 0,1 mm and 1,0 mm aluminum from 0,2 % to 0,3 %; and for those having HVLs from 1,0 mm to 2,25 mm aluminum from 0,2 % to 0,3 %.

3.2 Development of the standard of air kerma in the ^{137}Cs beam and results of first comparisons

Detailed information on the new ^{137}Cs facility was presented. This outlined the construction of the source housing and the determination of the factors used with the standard cavity chamber at this energy. The relationship between these factors and those applicable to the standard used for ^{60}Co was discussed. The long-term stability of the standard since early 1994 was considered to be excellent ($\sigma = 2 \times 10^{-4}$). Data from the first two comparisons performed with standards laboratories are outlined in Table 1 and show a combined standard uncertainty, u_c, of 0,3 %.

TABLE 1

Result of the comparisons of air kerma standards ^{137}Cs γ rays

Indirect comparison NIST-BIPM	Direct comparison OMH-BIPM
$\frac{K_{\mathrm{NIST}}}{K_{\mathrm{BIPM}}} = 0,995_1 \; u_c = 0,003$	$\frac{K_{\mathrm{OMH}}}{K_{\mathrm{BIPM}}} = 0,995_4 \; u_c = 0,003$

Representatives from several of the member laboratories indicated a keen desire to make comparisons using the newly available beam quality. Following a comment regarding the extrapolation performed at the BIPM to estimate the wall correction for the new ^{137}Cs standard cavity chamber it was noted that the BIPM was interested in the Monte-Carlo calculation of these factors. The NRC representative offered to perform them.

For the comparisons using the new ^{137}Cs source, the OHM used its own standard while the NIST used two Shonka transfer chambers (type A4, 30 cm^3 volume). All results lie within the experimental uncertainties and agree to within 0,5 %.

3.3 Presentation and discussion regarding high-energy x-ray calibrations

Participants expressed the view that the BIPM should have a role in high-energy calibrations and comparisons even although it does not possess a linear accelerator of appropriate energy (95-1). Several ways of doing this are outlined in a discussion document (95-16) and were discussed at length. These included the use of a thin-walled chamber and associated electronics, solid-state methods involving thermoluminescent dosimeters and electron spin resonance, and the use of Fricke and diamond detectors. The discussion mainly revolved around the repeatability of the systems. The actual dose levels were not seen to be a problem. Participants were in favour of an ionization-chamber-based system as the most suitable for circulation between laboratories.

In concluding the discussion, Section I, considering that calibrations in terms of absorbed dose to water for high-energy photons and electrons are of increasing importance, accepted the proposal contained in 95-40. The PTB representative offered to supply a suitable ionization chamber complying with the proposal. The representatives of the NPL, the NRC and the PTB each agreed that their laboratory would consider participation in the scheme. These three laboratories, together with the ARL, the BIPM and the NIST, agreed to form a working group to specify reference conditions for these chambers. As there is no consensus on how to specify beam quality, it was agreed that results should be measured and reported by as many methods of beam quality specifications as possible.

The PTB chambers will ultimately be placed at the disposal of primary laboratories for comparison of absorbed dose standards at the highest level of precision. Meanwhile, the BIPM will continue to investigate a robust transfer standard.

3.4 Future comparisons and dissemination of results of comparisons

The Director of the BIPM raised the question of how best to publish the results of comparisons. He suggested that summaries of the results of comparisons be published in *Metrologia*. Other consultative committees already do this. It was considered that this form of publication makes information on the coherence of national standards more readily available. A working party comprising the representatives of the BNM-LPRI, the NMi-VSL, the PTB and the BIPM was formed to discuss this further and to report to Section I on matters relating to past comparisons, the comparison programme and the publication of results in *Metrologia*. After some deliberation, Section I agreed to the working party’s proposals: it will collect, summarize and review all past comparisons at the BIPM (from 1966 to 1994) and representative comparisons amongst primary and national standards laboratories, including regional comparisons such

as those of EUROMET (NMi to provide details), of the Asia/Pacific Metrology Programme (ARL to provide details) and from Eastern Europe (GUM to provide details). A draft paper summarizing the information will be distributed to Section I members for agreement before submission to *Metrologia*. Among its conclusions, the paper will indicate the likely programme of future comparisons.

The working party is also to identify a programme of future comparisons to cover: air kerma for low- and medium-energy x rays and γ radiation from ^{137}Cs and ^{60}Co, absorbed dose to graphite and absorbed dose to water for ^{60}Co and high-energy photons and electrons. A schedule for the comparisons will be presented to the next meeting of Section I.

At subsequent Section I meetings the working party will present an update of all comparisons which have been finalized since the last publication, in a form ready for submission to *Metrologia*, following approval by the committee.

4. Development and improvement of national standards for photon dosimetry

4.1 Standards for air kerma and exposure

Five working documents concern standards for air kerma and exposure (95-18, 22, 29, 36 and 37). One from the NIST informed members of a new standard being developed for use with spectra typical of those used in mammography. Other laboratories, the NMi, the NPL and the PTB reported that they are engaged in similar developments. Tubes having Mo and Rh targets are increasingly common, and standards laboratories need to develop beam qualities typical of these tubes as the response of some commercial ionization chambers varies significantly with energy. The committee did not consider, however, that there is a need for the BIPM to develop such qualities for comparison purposes as the standards used in this work have a flat response with respect to beam quality. The BIPM is, however, following the CCEMRI Section I working party proposal to choose appropriate x-ray spectra to develop as references for future comparisons.

Two documents from the NMi (95-20 and 21) deal with the determination of x-ray spectra and the calculation of corrections for their medium-energy free-air chamber. Both involve the use of Monte-Carlo methods. It was suggested that the uncertainties in the correction for electron loss, photon scattering and radiation transmission through the front of the free-air chamber may be higher than was thought in the past.

The working party established at the previous meeting of Section I to consider the uncertainties associated with various physical quantities was not in a position to make a firm recommendation. One document (95-18)

from the BNM-LPRI indicates that measurements made when applying a new method of deriving K_{air} from D_c confirm a deviation of 0,5 % from the value obtained using the primary standard chamber. This deviation could be caused by a change in the value used for $\bar{s}_{c,a}$. The BNM-LPRI document also suggests that their measurements confirm a change in the I values for water and graphite. A preliminary document (95-34) by the convener of the working party, on a re-evaluation of W/e and $(W/e) \cdot \bar{s}_{c,a}$, supports the change in $\bar{s}_{c,a}$. It should be noted, however, that this change is hardly significant in view of the uncertainties, in particular of the stopping power ratio carbon to air and the influence on this ratio of recommended changes in the value of I for carbon. Consequently Section I did not agree to recommend new values. In view of the uncertainties, it was concluded that laboratories should consider individually the uncertainties associated with these quantities and the values quoted in their reports. It was thought that an uncertainty approaching 0,6 % (1 σ) may well be appropriate for the value of $\bar{s}_{c,a}$ for ^{60}Co. It was reported that the NPL is measuring stopping power ratios, $\bar{s}_{w,c}$, for electrons between 4 MeV and 16 MeV (95-35).

4.2 Standards for absorbed dose to water

The topic of standards for absorbed dose to water is addressed by four documents submitted from member laboratories (95-22, 29, 36 and 37). Two deal with recalculation of the results of a comparison between the NMi and the BIPM and recent improvements to the ENEA standard. These comparisons involved graphite calorimetry and the use of the photon fluence scaling theorem. The other documents, from the NRC, present a status report on water calorimetry at that laboratory and a study of the behaviour and heat defect of ice considering it as a possible candidate for an absorbed dose calorimeter, as recently suggested by Rosser. The NMi report (95-22) indicates an intention to test the validity of the scaling theorem by measurement and Monte-Carlo calculation. The ENEA work also used the scaling theorem, but scaled all dimensions of the water phantom. The ratios of N_W/N_K obtained by experiment and calculation agree to within 0,5 %. A thick-walled ionization chamber, relatively insensitive to the low-energy part of the electron spectrum, was used.

The NRC representative spoke on the two reports from that laboratory. The first (95-36) outlines the effects of various contaminants on the behaviour of a water calorimeter. The presence of small amounts of O_2 in the H_2 bubbled system caused a significant effect. Earlier results based on Fricke had shown NRC results to be 0,7 % lower than those from the BIPM for ^{60}Co γ rays; modification of these results, based on recent knowledge of glass wall effects and heat defect, however, brought the results within a few tenths of a percent of one another. The second report (95-37) represents a thorough study of the behaviour of ice and its

heat defect between – 23 °C and – 0,8 °C. It shows that ice near 0 °C is suitable for ice calorimetry since it has a steady state and a zero heat defect. In discussion, however, it was shown that the probability of developing a primary standard using an ice calorimeter is not large.

5. Brachytherapy standards

A document from the NIST (95-12) presents the status of the wide-angle free-air chamber which was under development as a standard for ^{125}I brachytherapy sources. A problem caused by poor alignment had been resolved and the clinically unimportant Ti x rays produced in the source cladding had been removed. Following further measurements it was planned to establish the instrument as a national standard for ^{125}I brachytherapy sources. The instrument response has been compared with that of the free-air ionization chamber usually used as the standard for photons between 25 kV and 40 kV and the two instruments were found to agree to better than 1 %.

A second document from the NIST (95-13) also relates to the characterization and calibration of brachytherapy sources. This suggests a general approach similar to that based on the programme already in place for ^{90}Sr + ^{90}Y ophthalmic applicators. The primary calibration method is ionometric using 2π, 4π or large-angle geometry, depending on the source to be calibrated.

In discussion of the two documents, the IAEA representative stated that his Agency has begun a brachytherapy programme in its SSDLs which will be based on an air kerma calibration and the use of thermoluminescent dosimeters. At the NMi, the calibration of ^{192}Ir sources is based on an air kerma calibration protocol published in 1994. The NRC plans to develop a new carbon-cavity chamber and to predict its response to x rays generated at 200 kV and to ^{192}Ir gamma rays. Providing that the measurements confirm the reliability of the calculations at 200 kV, the NRC intends to rely on the calculated response at ^{192}Ir and use the chamber for calibration purposes. At present all member laboratories assume that their ionization chambers have a flat energy response around ^{192}Ir and use interpolation methods. The question of whether the BIPM should develop qualities using ^{192}Ir in addition to its ^{137}Cs and ^{60}Co qualities was raised, but it was agreed that this was currently unnecessary.

6. Standards for radiation protection

The matter of the apparent anomaly between the results of the assessment of personal and environmental dosimeters based on standards using ^{137}Cs or ^{60}Co irradiation, which had been raised from time to time in the literature, was raised in one document (95-28). Section I discussed the

problem and agreed it was unlikely that the problem, if real, was related to primary standards. It was noted that the BIPM caesium beam may prove useful in resolving the apparent discrepancies.

7. Standards for radiation processing

The NIST (95-9) supplied information of a preliminary nature on standards for radiation processing. Alanine electron spin resonance dosimetry methods were used to transfer its standard from its normal dose range to the high dose rates applicable to food irradiation and medical sterilization.

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

8.1 Beta-ray field

No working documents addressed the topic of β-ray fields. In discussion it was noted that some work relating to the dosimetry of ^{14}C sources embedded in plastic had been performed at the NRC. Good agreement had been obtained between calculated and measured spectra for these sources. Some of the corrections necessary when using the usual approach with an extrapolation chamber are quite large. The NRC noted that it has plans to publish the results of these studies.

8.2 Proton beams

The ENEA (95-32) is developing reference dosimetry systems for proton beams and two documents address this topic. Nuclear interactions cannot be ignored at proton energies above a few tens of MeV. The primary proton fluence is attenuated and the proton energy spectrum along the proton pathlength in the medium is modified. The effect increases with increasing proton energy and must be considered when determining the relevant energy used in the calculation of stopping powers in ionization chambers and absorbed dose determinations from fluence measurements. Experimental and calculated correction factors appropriate to some common ionization chambers were presented for 6 MV and 15 MV proton beams.

Representatives of other member laboratories indicated a developing interest in proton dosimetry. The topic was being explored in France, Japan, the Netherlands and the U.S.A. In France, a Shonka plastic calorimeter had been used for the dosimetry of protons at 17 MeV and 200 MeV.

9. Reports from member laboratories

Many of the documents submitted describe progress in standards, facilities, services and research since the eleventh meeting of Section I in 1993. These were presented, discussed and are now available in bound form.

The NPL representative outlined the principle of a new method being used to determine electron stopping power ratios for water and graphite. The method combines an experimental determination of a ratio of electron ranges with a Monte-Carlo calculation of electron ranges and spectra at depth. The overall uncertainty in the stopping power ratio may be as low as 0,5 % at the $2\,\sigma$ level.

Several laboratories reported that they were in a position to offer calibrations in terms of the narrow spectrum series of radiations (ISO standard No. 4037).

10. Report from the IAEA

10.1 Comparison (^{60}Co) of absorbed dose at the kGy level using alanine dosimetry

A “double blind” comparison at high dose levels involving nine laboratories (from Canada, the People’s Rep. of China, Denmark, France, Italy, Japan, the Russian Fed., United Kingdom and the U.S.A.) and the IAEA was reported (95-15). The BIPM assisted in the development of the protocol and undertook the analysis of the results. The absorbed dose levels were in the range 10 kGy to 50 kGy. The results show a standard deviation of 2,1 % at 15 kGy and 2,4 % at 45 kGy. The mean IAEA value was within 1 % of the mean value of the participants. It was suggested that the BIPM should consider organizing and coordinating a similar high dose comparison for all national laboratories active in the high-dose field.

10.2 Comparison (^{60}Co) of absorbed dose at therapy level using thermoluminescent dosimeters

In a general report on the activities of the IAEA Dosimetry Section (95-27), details were given of the ongoing work and membership (currently 73 laboratories) of the IAEA/WHO SSDL network. The extension of the annual ^{60}Co comparisons to medical accelerator beams was reported. Four SSDLs initially had a larger deviation than the accepted limit of 3,5 %, but, on a repeat comparison, three of these laboratories had solved their deviation.

Information on the other activities of the IAEA was reported, including the use of the thermoluminescent dosimeter service to check the calibration

performance of 300 radiotherapy centres in developing countries and to test electron beams from medical accelerators in Europe and the U.S.A. In the tests of radiotherapy dose delivery in the developing countries, one third of those tested were outside acceptable limits. The service had therefore demonstrated its usefulness.

In addition, the Agency now has its own alanine electron spin resonance service which is traceable indirectly to the BIPM.

11. Publication of results

Members of Section I were encouraged by the Chairman to publish all comparison results in refereed journals. It was noted that summaries of all comparisons will appear in *Metrologia* as discussed under item 3.4. The details of these comparisons are available in the BIPM and other laboratory reports.

12. Other business

The Director of the BIPM informed participants that two new staff members were being recruited for the Ionizing radiation section.

The importance of publishing was agreed by Section I and the proliferation of memoranda of understanding between primary standards laboratories was mentioned.

Following discussion about the organization of future meetings, it was agreed that participants could facilitate discussion by more regular use of viewgraphs and, particularly, by the provision and circulation of working documents well in advance of the meeting.

The Chairman noted that both Mme A.-M. Perroche, a long-term guest worker at the BIPM, and J. W. Müller, head of the Ionizing radiation section at the BIPM, would be retiring soon. He thanked them both for their significant contribution to the work of the BIPM, thanks which Section I supported with acclamation.

It was agreed that the next meeting of Section I of the CCEMRI should be held in two years time.

September 1995,
revised November 1995

APPENDIX R(I) 1

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

(*see* the list of documents on page R 26)

ANNEXE R(I) 1

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

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

Document CCEMRI (I)/

95-1 BIPM. — Proposals for the involvement of the BIPM in high-energy calibrations, 2 pages.

95-2 BIPM. — Comparisons and calibrations at the BIPM (1993-1995), by A.-M. Perroche and M. Boutillon, 6 pages.

95-3 BIPM. — Determination of air kerma for ^{137}Cs gamma rays, by A.-M. Perroche and M. Boutillon, 5 pages.

95-4 ARL (Australie). — Status report for CCEMRI(I) on absorbed dose standards at the Australian Radiation Laboratory, by R. B. Huntley, K. N. Wise, D. V. Webb and J. F. Boas, 6 pages.

95-5 ETL (Japon). — Ion loss characteristics of parallel plate ionization chambers, by N. Takata, 8 pages.

95-6 ETL (Japon). — Report of the Status of ETL to the CCEMRI Section I, by N. Takata, K. Sakihara and Y. Koyama, 2 pages.

95-7 SSDL (Autriche). — Intercomparison Measurements with 30 ccm Ion. Chambers in ^{137}Cs-Fields Kalibration for the NIST-Chambers at SSDL-Seibersdorf, 4 pages.

95-8 ARL (Australie). — Report on work-in-progress at Australian Radiation Laboratory. Monte Carlo Models Applied to Absorbed Dose Standards, by K. N. Wise, L. H. Kotler and D. V. Webb, 2 pages.

95-9 NIST (É.-U. d'Amérique). — High-Dose Radiation Dosimetry Services and Measurement Assurance Program, by J. C. Humphreys, M. F. Desrosiers, D. L. Bensen, J. M. Puhl, S. M. Seltzer, W. L. McLaughlin, M. L. Walker, 9 pages.

Document CCEMRI (I)/

95-10 NIST (É.-U. d'Amérique). — Development of National Standards for Mammographic X-ray Beams: Summary and Update, by C. M. Johnson and P. J. Lamperti, 1 page.

95-11 NIST (É.-U. d'Amérique). — Report to the CCEMRI Section I, by S. M. Seltzer, 8 pages.

95-12 NIST (É.-U. d'Amérique). — The Wide-Angle Free-Air Chamber: A Proposed I-125 Brachytherapy Standard, by R. Loevinger, 2 pages.

95-13 NIST (É.-U. d'Amérique). — A Generalized Approach for the Calibration and Characterization of Brachytherapy Sources, by C. G. Soares, 4 pages.

95-14 NIST (É.-U. d'Amérique). — International Comparison of X-Ray and Gamma-Ray Standards, by P. J. Lamperti, 3 pages.

95-15 AIEA. — Report of the IAEA to the CCEMRI section I – High-dose intercomparison in the ^{60}Co field, 2 pages.

95-16 BIPM. — Preliminary investigation of high-energy dosimetry transfer systems, by P. J. Allisy-Roberts, 9 pages.
+ Supplement: Discussion of transfer system options for comparison of absorbed dose to water at high energies, 2 pages.

95-17 BNM-LPRI (France). — Progress Report (Dosimetry), by B. Chauvenet, 2 pages.

95-18 BNM-LPRI (France). — Remarks of LPRI concerning stopping power ratios (Re.: fax of D. W. O. Rogers to CCEMRI), 2 pages.

95-19 NMi (Pays-Bas). — Progress report on radiation dosimetry standards, facilities and related topics at NMi, 1993-1995, by A. H. L. Aalbers, 3 pages.

95-20 NMi (Pays-Bas). — Correction factors for the NMi free-air ionisation chamber for 50-320 kV x-rays, by E. Van Dijk, 3 pages.

95-21 NMi (Pays-Bas). — Determination of X-ray spectra, by W. de Vries, 1 page.

95-22 NMi (Pays-Bas). — Ratios of calibration factors for absorbed dose to water and absorbed dose to graphite for the NE2561 chamber, by T. W. M. Grimbergen, 2 pages.

95-23 NMi (Pays-Bas). — Review of comparisons of absorbed dose to graphite standards of the Netherlands, the United Kingdom and the BIPM, by T. W. M. Grimbergen, 3 pages.

Document CCEMRI (I)/

95-24 GUM (Pologne). — Progress report 1993-1995 to CCEMRI, by Z. Referowski, 2 pages.

95-25 CIEMAT (Espagne). — Application of glow curve analysis methods to radiotherapy mailed dosimetry with LiF TDL-100, by J. L. Muñiz, A. Delgado, J. M. Gómez Ros and A. Brosed, *Phys. Med. Biol.*, 1995, **40**, 253-268.

95-26 SRPI (Suède). — The Swedish National Dosimetry Laboratory Progress Report 1995:
– Absorbed dose to water calibrations for cobalt-60 gamma rays, by U. Nilsson, O. Gullberg and J.-E. Grindborg, 5 pages,
– Absorbed dose measurements in x-ray beams at different gas pressures, by J.-E. Grindborg, J. E. Kyllönen and L. Lindborg, 3 pages.

95-27 AIEA. — Report on the activities of the IAEA dosimetry section in 1994, 5 pages.

95-28 ARL (Australie). — Is the apparent anomaly between cobalt and caesium calibrated exposures in environmental TLD dosimetry related to standards?, by J.G. Young, J. F. Boas and N. J. Hargrave, 2 pages.

95-29 ENEA (Italie). — Recent improvements on the ENEA absorbed-dose-to-water standard based on graphite calorimeter, by A. S. Guerra, R. F. Laitano and M. Pimpinella, 15 pages.

95-30 ENEA (Italie), NIST (É.-U. d'Amérique). — Preliminary report on the comparison between the NIST and the ENEA exposure standards, by R. F. Laitano, P. Lamperti and M. P. Toni, 9 pages.

95-31 ENEA (Italie). — Experimental determination of the beam quality dependence factors k_Q, for ionisation chambers used in photon and electron dosimetry (Synopsis), by A. S. Guerra, R. F. Laitano and M. Pimpinella, 7 pages.

95-32 ENEA (Italie). — Nuclear interaction effects on the energy spectra of proton beams for radiotherapy. Preliminary results, by R. F. Laitano, M. Frisoni and M. Rosetti, 10 pages.

95-33 NPL (Royaume-Uni). — Progress Report on Radiation Dosimetry at NPL, by D. T. Burns, 6 pages.

95-34 NRC (Canada). — Re-evaluation of (W/e) and $(W/e)s_{gr,air}$, Status Report to CCEMRI(I) Meeting April 24-26 1995, by D. W. O. Rogers, 4 pages.

Document CCEMRI (I)/

95-35 NRC (Canada). — NRC Activities and Publications 1993-1995, Status Report to CCEMRI(I) Meeting, BIPM, April 24-26 1995, by D. W. O. Rogers, 12 pages.

95-36 NRC (Canada). — Absorbed Dose to Water via Water Calorimetry: A Status Report, by C. K. Ross, N. V. Klassen and K. R. Shortt, 8 pages.

95-37 NRC (Canada). — The radiolysis of ice near 0 °C and the heat defect, by N. V. Klassen, 15 pages.

95-38 OMH (Hongrie). — Progress Report on the dosimetry (1993-1995), by I. Csete, 2 pages.

95-39 CCEMRI (I) Working group on comparisons, 1 page.

95-40 CCEMRI (I) Proposal for high-energy calibrations, 1 page.

APPENDIX R(I) 2

Actions arising from the 12th meeting of Section I of the CCEMRI

Responsible	Action
Interested laboratories	To compare ^{137}Cs air kerma standards at the BIPM.
BNM-LPRI, NMi-VSL, PTB and BIPM (Comparisons working party)	To identify a programme of future comparisons to cover air kerma for low- and medium-energy x rays, ^{137}Cs and ^{60}Co; absorbed dose to graphite and absorbed dose to water for ^{60}Co and high-energy photons and electrons. To produce a schedule of comparisons for the next Section I meeting.
All laboratories	To reconsider uncertainties associated with physical quantities which they quote in their reports.
NMi, SRPI and BIPM (ISO working party)	To choose the ISO qualities to be added to the x-ray reference qualities at the BIPM.
NPL, NRC, PTB and BIPM (High-energy working party)	To recommend reference irradiation conditions for high-energy radiation beams.
PTB	To supply the BIPM with an ionization chamber to be used as a transfer standard for absorbed dose in high-energy radiation beams.
BIPM	To calibrate the above chamber in ^{60}Co and determine its stability.
BIPM	To investigate a robust transfer system for absorbed dose measurement in high-energy radiation beams.
BNM-LPRI, NMi-VSL, PTB and BIPM (Comparisons working party)	To collect, summarize and review all past comparisons at the BIPM (1966 to 1994), representative comparisons amongst primary and national standards laboratories and regional comparisons. To produce a draft paper for publication.

Comparisons working party	To present, at each subsequent meeting, an update of all comparisons which have been finalized since the last publication, in a form suitable for publication in *Metrologia*.
All laboratories	To publish comparison results in refereed journals.
BIPM	To organize and co-ordinate a high-dose comparison involving all national laboratories active in the high-dose field.
All members	To circulate documents at least one month in advance of the next meeting; to use viewgraphs whenever possible when presenting information at CCEMRI Section I meetings.

Section II — Measurement of radionuclides

13th Meeting (May 1995)

AGENDA

for the 13th Meeting

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1. Opening of the meeting; designation of a rapporteur.
2. Results of recent comparisons of activity measurements:
   - 2.1 Results of the ^{204}Tl trial comparison;
   - 2.2 Status of publication of recent comparisons.
3. International reference system for activity measurements:
   - 3.1 Status report on the ionization chamber system;
   - 3.2 Systematic analysis of SIR results;
   - 3.3 International traceability;
   - 3.4 Liquid scintillation system as extension to the SIR.
4. Reports of the working groups:
   - 4.1 Principles of the coincidence method;
   - 4.2 Source preparation;
   - 4.3 Extension to β emitters with the liquid-scintillation system;
   - 4.4 Ionization chamber monograph;
   - 4.5 High-efficiency detection systems;
   - 4.6 Future comparisons of activity measurement;
   - 4.7 Joint procurement of radionuclides.
5. Future comparisons.
6. BIPM activities:
   - 6.1 Robust evaluation of data from international comparisons;
   - 6.2 Parity method;
   - 6.3 Dwell times of multichannel analysers;
   - 6.4 Uncertainty of dead times measured by the two-oscillator method.
7. Reports from member laboratories.
8. Visit to the BIPM laboratories.
9. Other business.
10. Date of the next meeting.

COMITÉ CONSULTATIF POUR LES ÉTALONS DE MESURE
DES RAYONNEMENTS IONISANTS

SECTION II. — **Measurement of radionuclides**
13th Meeting (May 1995)

REPORT
by S. M. BUCKMAN, Rapporteur

Abstract. Section II (Measurement of radionuclides) of the Comité Consultatif pour les Étalons de Mesure des Rayonnements Ionisants held its thirteenth meeting in May 1995. The draft report on the 1994 trial comparison of ^{204}Tl was presented. The results from the six participating laboratories are in good agreement except for one outlier. Additional experiments will be conducted to investigate the discrepancy. A paper summarizing the results of the ^{109}Cd full-scale comparison has been published in the open literature and a condensed report on the ^{125}I international comparison has been submitted for journal publication. A preliminary analysis of all the results obtained using the Système International de Référence (SIR) has been completed and a working group has been established to make a full systematic analysis. The committee developed a recommendation on the equivalence of national and international measurement standards, and established a working group which will prepare guidelines for establishing the equivalence of measurement standards. The implementation of the extended SIR will be completed, and routine operation started, with a ^{90}Sr comparison. A trial comparison of ^{192}Ir scheduled for 1995 will be followed, in 1996, by a full-scale comparison of ^{204}Tl. Other recent BIPM activities, including the robust analysis of results from international comparisons, were discussed and the working groups presented detailed reports on their activities.

Introduction

Section II (Measurement of radionuclides)* of the Comité Consultatif pour les Étalons de Mesure des Rayonnements Ionisants (CCEMRI)**

* For the list of members, *see* page R 72.
** For the list of abbreviations used in the report, *see* page V.

held its thirteenth meeting at the Pavillon de Breteuil, at Sèvres, on 9, 10 and 11 May 1995.

Present:

K. DEBERTIN, Chairman of Section II, Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

Delegates from the member laboratories and organizations:

Australian Nuclear Science and Technology Organisation [ANSTO], Menai (S. M. BUCKMAN).

Bureau National de Métrologie, Paris: Laboratoire Primaire des Rayonnements Ionisants [BNM-LPRI], Saclay (N. COURSOL).

National Accelerator Centre [NAC], Faure (B. R. S. SIMPSON).

National Institute of Metrology [NIM], Beijing (LI FEN).

National Institute of Standards and Technology [NIST], Gaithersburg (J. M. R. HUTCHINSON).

National Physical Laboratory [NPL], Teddington (M. J. WOODS).

Országos Mérésügyi Hivatal [OMH], Budapest (Á. SZÖRÉNYI).

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig (K. DEBERTIN).

The Director of the Bureau International des Poids et Mesures [BIPM] (T. J. QUINN).

Members *ad personam*:

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

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

Guests:

P. DE FELICE, Ente per le Nuove Tecnologie, l'Energia e l'Ambiente [ENEA], Rome.

A. GRAU MALONDA, Centro de Investigaciones Energeticas, Medio-ambientales y Tecnológicas [CIEMAT], Madrid.

Y. HINO, Electrotechnical Laboratory [ETL], Ibaraki.

D. F. G. REHER, Institute for Reference Materials and Measurements [IRMM], Geel.

TAE SOON PARK, Korea Research Institute of Standards and Science [KRISS], Taejon.

R. BRODA, Metrological Laboratory of Radioactive Materials, Radioisotope Centre [RC], Otwock.

Also attending the meeting: G. MOSCATI (member of the CIPM); A. ALLISY (member of the CCEMRI); P. ALLISY-ROBERTS, M. BOUTILLON, V.-D. HUYNH, J. W. MÜLLER and G. RATEL (BIPM).

Apologies were received from:

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

International Atomic Energy Agency [IAEA], Vienna.

National Research Council of Canada [NRC], Ottawa.

1. Opening of the meeting; designation of a rapporteur

The Director of the BIPM opened the meeting and welcomed members of Section II of the CCEMRI. He reminded members of the purpose of the meeting and highlighted the importance of international comparisons as a means for demonstrating "equivalence of measurements" between national metrology institutes.

The Chairman of Section II welcomed the new delegates and guests. S. M. Buckman was appointed as rapporteur and the draft agenda was accepted.

2. Results of recent comparisons of activity measurements

2.1 Results of the ^{204}Tl trial comparison

G. Ratel summarized the draft report (95-6)* on the results of the trial comparison of activity measurements for a solution of ^{204}Tl. The solution was purchased from the BNM-LPRI and prepared by the BIPM. Glass ampoules, which contained a solution with an activity concentration of approximately 70 kBq/g, were dispatched to the participating laboratories at the end of August 1994.

Six laboratories participated in the trial comparison (BIPM, BNM-LPRI, CIEMAT, NAC, NIST and PTB) and four different methods were used: CIEMAT-NIST/LSC (five laboratories), TDCR/LSC (two laboratories), $4\pi(x,e)$-x_K coincidence counting (one laboratory) and $4\pi\beta$ counting (one laboratory). The $4\pi\beta$ measurement was the only result not based on a scintillation technique.

The weighted mean of the activity concentration was 55,48 Bq/mg, combined standard uncertainty u_c = 0,16 Bq/mg. The values show a total

* Documents submitted by the participants are listed in Annexe R(II) 1, and are referred to in the text in the form 95-1, 95-2, etc.

spread of 3,4 % and the standard deviation of the mean is 0,3 %. Evaluation by robust analysis (*see* Section 6.1) yielded a median of 55,40 Bq/mg with an uncertainty of 0,20 Bq/mg. A single outlier was 2,5 % below the unweighted mean of the other results. While source preparation and adsorption by the walls of the ampoules were proposed as possible reasons for the discrepant result, no convincing explanation has yet been found. Measurements conducted at the BIPM have confirmed that solution stability depends on the type of scintillator used, with Ultima-Gold being significantly more stable than Readysafe. Past experience in several member laboratories confirms that adsorption of thallium can be a problem. There was insufficient evidence to confirm whether adsorption had been the cause of the outlier in this comparison.

The results of the trial comparison (*see* Fig. 1) suggest that particular care needs to be taken in the preparation of samples for liquid scintillation counting. Problems arising from the scintillator could be avoided in future measurements by sending an aliquot of a well-known scintillator, together with the active solution, to all participants who plan to use a liquid-scintillation method.

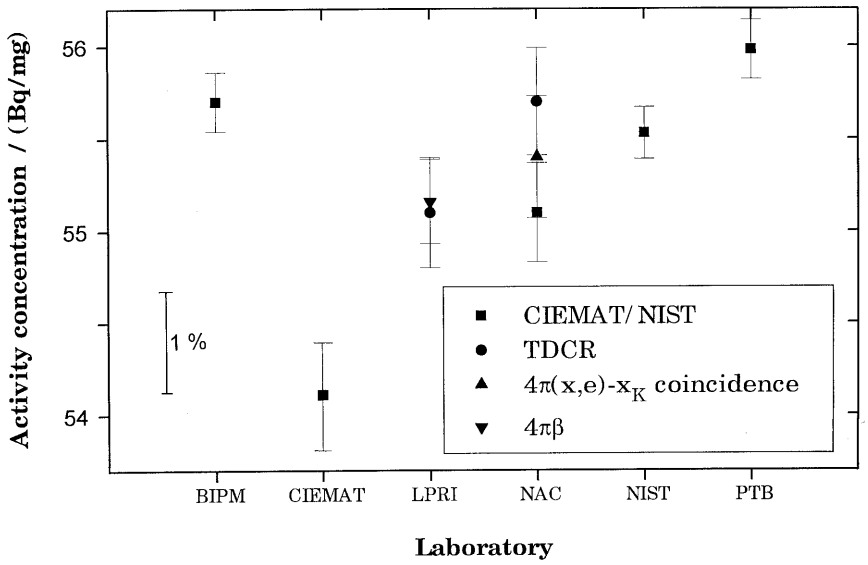

Figure 1. — Results of the ^{204}Tl trial comparison

2.2 Publication of the results of recent comparisons

A condensed version of the report on the ^{109}Cd activity comparison has been published in *Nucl. Instrum. Meth.*, 1994, **A345**, 289-295. The

condensed version of the report on the ^{125}I comparison has been submitted for publication in *Nuclear Instruments and Methods**. A first draft of the shortened report on the ^{75}Se comparison was scheduled for completion by the end of June 1995. The 21 participating laboratories produced a total of 24 independent results using 5 different methods.

Completion of these reports will bring the documentation on international comparisons up-to-date. The Chairman re-affirmed the importance of publishing the results of international comparisons as soon as possible after results are obtained.

3. International Reference System for activity measurements

3.1 Status report on the ionization chamber system

G. Ratel reported on recent measurements made at the BIPM which confirm the excellent long-term stability of the International Reference System for activity measurements (Système International de Référence, SIR). The increase in the number of contributions to the SIR observed in recent years has continued. Since the last meeting, 57 ampoules had been received from 14 laboratories with 2 of these laboratories participating for the first time. No new nuclides were submitted during this period. Samples of ^{133}Xe were submitted to the SIR as part of EUROMET Project No. 304. Gas ampoules have been purchased by the BIPM and can be supplied on request.

Since the commencement of the SIR, a total of 645 ampoules of 54 different radionuclides have been received, and 474 independent results have been obtained. The tabulation of SIR results has recently been improved: graphs of the results are now prepared for each nuclide.

3.2 Systematic analysis of SIR results

The SIR provides national and international metrology laboratories with a convenient means of comparing their measurement standards of activity for a wide range of radionuclides. The large number of results contributing to the SIR has made it the world's most accurately calibrated system of ionization chambers for activity measurements.

D. F. G. Reher reported on his preliminary analysis of the SIR results. From data provided by the BIPM, the equivalent activity, A_e, results for each nuclide were plotted in both chronological and numerically ascending

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* RATEL G., Activity concentration of a solution of ^{125}I: results of an international comparison, *Nucl. Instrum. Meth.,* 1995, **A366**, 183-191.

order. In addition, means and standard deviations of the data were computed with obvious outliers being removed on the basis of personal judgement.

The analysis highlights 14 nuclides for which measurement difficulties may still exist. These include 6 nuclides which appear to have discrepant groups of results (among them ^{51}Cr and ^{85}Sr).

D. F. G. Reher also showed that for the SIR, the equivalent activity, A_e, for any given radionuclide is proportional to the inverse of the calibration figure for other ionization chambers. This feature allows the SIR results to be transferred. For a chamber identical with those used in the SIR, the calibration figures are given exactly by $1/A_e$. For an ionization chamber system that differs slightly from that of the SIR, it is expected that the calibration figures for that ionization chamber would be nearly proportional to $1/A_e$. This hypothesis was tested using the Ar-filled chambers at the IRMM. When the "best values" of A_e were plotted against the calibration figures for the IRMM chamber, a plot was obtained which was very close to linear (for a linear fit, the standard deviation of the slope was 1,4 %).

This "portability" of A_e data may provide a way of using SIR results to calibrate other ionization chambers. This would be particularly helpful in the establishment of secondary standard instruments in developing countries.

A new working group was established to pursue further the "systematic analysis of SIR results". The group will develop criteria for the selection of best A_e values and evaluate possible applications of these results. In addition, the working group will examine whether SIR results can be maintained on a database in such a way that results can be updated when new values of decay-scheme data, such as the half life, are adopted. The members chosen for this working group were: R. Broda, N. Coursol, G. Ratel, D. F. G. Reher (coordinator), H. Schrader (PTB) and M. J. Woods. Members of Section II were requested to send a list of their ionization chamber calibration figures, along with details of the ionization chamber, to D. F. G. Reher at the IRMM.

It was agreed that independent comparisons, performed with the cooperation of the CCEMRI Section II and the BIPM, may be linked to the SIR through the contribution of an ampoule from the comparison.

3.3 International traceability

Accreditation and certification bodies are, in general, bringing increased pressure on national metrology institutes to demonstrate the equivalence of their measurements. Given the diverse nature of physical measurements, it is important that the meaning of "equivalence" be defined explicitly for a given physical quantity.

For activity measurements, traceability to a national standards laboratory is reasonably well defined. However, generally accepted definitions for the

"international traceability" and the associated concept of "equivalence" have yet to be established.

After considerable discussion, the CCEMRI Section II approved the following declaration on the "Equivalence of national and international measurement standards in the field of radioactivity for the purpose of international traceability":

> International and national measurement systems and the establishment of international traceability are critically dependent on the equivalence of measurement standards among the national and international metrology laboratories. In the context of radioactivity measurements, Section II of the Comité Consultatif pour les Étalons de Mesure des Rayonnements Ionisants recommends that such equivalence shall be established via international comparisons carried out by the Bureau International des Poids et Mesures, and notably through its Système International de Référence, on the basis of guidelines drawn up by Section II.

In addition, a working group on standards equivalence was established. The terms of reference for this working group are to define guidelines for national and international metrology laboratories allowing them to establish the equivalence of their measurement standards for radioactivity. Among the factors to be considered are: the possible advantages of sub-dividing radionuclides into groups, the recommendations relating to traceability of the International Committee for Radionuclide Metrology (ICRM), the frequency with which samples should be submitted to the SIR, statements of uncertainty and the format in which comparison results will be published in *Metrologia*. The members of the working group are: S. M. Buckman, J. M. R. Hutchinson, G. Ratel, D. F. G. Reher and M. J. Woods (coordinator).

A schedule was agreed which calls for: 1) a letter of information to be sent to Section II members by the end June 1995, 2) production of a first draft of the guidelines for distribution to all who contributed to the preliminary draft, and 3) completion of a report for the CCEMRI meeting in April 1996.

3.4 Liquid scintillation system as extension to the SIR

The results from the ^{14}C and ^{99}Tc comparisons were considered by J. M. R. Hutchinson to demonstrate the validity of the extended SIR. In response to an inquiry from the Chairman, G. Ratel confirmed that the extended SIR was now ready to enter a routine phase.

As a final step in the implementation of the extended SIR, it was agreed that the BIPM will organize a comparison of activity measurements of ^{90}Sr. To ensure the consistency of results, samples will be of similar chemical composition and will be sent to the BIPM within a relatively narrow time-frame some time in 1995. The BIPM will circulate a letter

inviting laboratories to participate in this comparison. Included will be a questionnaire in which the participating laboratories are to specify their preference for the chemical composition and activity of the solution.

4. Reports of the working groups

4.1 Principles of the coincidence method (Coordinator: J. W. Müller)

J. W. Müller referred to the list of recent reports, the majority of which are concerned with mathematical problems associated with particle counting (95-10). He reported that the third version of the dead-time bibliography was being written. The response received to an appeal for comments on the second version was disappointing.

There was some discussion as to the future of this particular working group, given that the principles of the coincidence method appear to be well established and the function of the group fulfilled. It was decided that the future of the group would be reassessed at the next meeting.

It was suggested that the recently published *ICRU Report* 52 should be regarded as a suitable conclusion to the activities of this working group. It was noted that both past and present members from the working group had contributed to this report.

4.2 Source preparation (Coordinator: D. C. Santry)

As there was nothing new to report on source preparation, on the recommendation of D. C. Santry the working group was dissolved.

4.3 Extension to β emitters with the liquid-scintillation system (Coordinator: A. Grau Malonda)

The title of the working group “Extension of SIR” was changed to “Extension of SIR to β emitters with the liquid-scintillation system”. It was reaffirmed that the members of this working group are: R. Broda, P. Cassette, J.-J. Gostely, A. Grau Malonda (Coordinator), G. Ratel and B. R. S. Simpson. The Chairman will extend an invitation to B. Coursey (NIST) to join the working group. The role of the group is to examine liquid-scintillation source preparation procedures and the extension to the SIR.

4.4 Ionization chamber monograph (Coordinator: H. Schrader)

H. Schrader reported that the production of the monograph on ionization chambers was nearing completion. In August 1993 a draft of this report was distributed to 14 referees. After consideration of the comments received,

a second draft was produced and was forwarded to J. W. Müller. It was agreed that the Editor of *Metrologia*, D. A. Blackburn, will review this draft and note any necessary linguistic changes. Figures within the document which include German text will be translated by H. Schrader, any further changes being made by the BIPM. This report will be produced as a BIPM monograph* which will be freely available. Copies will be distributed to members and guests of the CCEMRI Section II.

The Chairman thanked H. Schrader and the BIPM for their valuable contribution to this sizeable document which contains over 110 pages of text, 100 figures and 500 references. J. W. Müller indicated that the BIPM would welcome the production of further such monographs, though not necessarily of the same size.

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

G. Winkler reported that material for the production of a review paper had been collected and a report was in preparation, the suggested title being "4π NaI and CsI detectors for high-efficiency counting." He anticipated that the report would be complete by the end of 1995, when a draft would be forwarded to J. W. Müller and K. Debertin, the decision on whether it should be published as a journal paper and/or a BIPM monograph being left to them. It was noted that the working group will be discontinued on submission of the final report.

The Chairman commented on the value of these high-efficiency systems and indicated that they should continue to be considered within the context of the CCEMRI Section II meetings.

4.6 Future comparisons of activity measurement (Coordinator: Á. Szörényi)

Á. Szörényi summarized the results from a questionnaire on future comparisons. The questionnaire was distributed to 27 laboratories of which 16 replied. Twenty-two nuclides were suggested for the next full-scale comparison, ^{152}Eu and ^{204}Tl being the most popular choices (suggested by 8 and 3 laboratories, respectively). It was noted that at the time when they completed the questionnaire, most people would have assumed that a full-scale ^{204}Tl comparison would be conducted.

The main reasons given for selecting ^{152}Eu were the complexity of the decay scheme and the practical application of ^{152}Eu to the calibration of γ-spectrometers. However, as ^{152}Eu is not generally recommended for the

* SCHRADER H., Activity Measurements With Ionization Chambers, *Monographie BIPM*-4, 1997.

calibration of γ-spectrometers and there is good agreement with the SIR results (i.e. 7 laboratories in agreement to within 0,6 %), ^{152}Eu was not seen as the best choice for the next international comparison.

This exercise has made it clear that, when selecting nuclides for full-scale comparisons, it is important to understand the reasons why laboratories have indicated a preference for a particular nuclide. To assist in the selection of radionuclides for international comparisons, it was decided that a set of criteria should be circulated to members and guests for consideration prior to the next CCEMRI Section II meeting.

4.7 Joint procurement of radionuclides (Coordinator: D. F. G. Reher)

To assist with the purchase of those nuclides which are difficult to obtain, a database of suppliers has been produced. Updates of this database were distributed prior to the meeting (95-5) and will continue to be distributed once or twice per year.

Several laboratories indicated that they had successfully used this information to purchase radionuclides. No joint procurements had occurred to date, but this would have been difficult given the short time-frame for making the necessary arrangements. The Internet was proposed as a practical device for the rapid organization of joint arrangements. Information from another database, developed by S. Jerome at the NPL, will be incorporated into the existing database. This information will include inactive nuclides which might be useful for the production of radionuclides. An invitation requesting that S. Jerome join the working group was accepted by M. J. Woods on his behalf.

Participants were reminded that it was in their mutual interest to support this working group by providing supplier information.

5. Future comparisons

The Chairman re-emphasized the importance of international comparisons and the need to conduct them regularly (i.e. at least one full-scale comparison every two years). It was proposed that general criteria be formulated to assist with the selection of nuclides for these comparisons. In particular, it was noted that the nuclide should be of general interest and show problematic results in the SIR.

It was generally agreed that ^{192}Ir fulfils both of these criteria as it is widely used in brachytherapy and difficulties are still apparent in measurements of its activity. In particular, the SIR results for ^{192}Ir appear to form two distinct groups. Due to the current interest in this nuclide, EUROMET has proposed four ^{192}Ir projects. One of these is concerned

with measurement of the activity of a solution of ^{192}Ir. As the coordinator of this EUROMET project, D. F. G. Reher explained that the project would be discontinued if the BIPM were to organize an international comparison for ^{192}Ir in the near future.

Considerable debate ensued regarding future international comparisons. Much of it focused on whether ^{204}Tl should be the radionuclide chosen for the next full-scale comparison. Agreement was reached soon after it was realized that both a full-scale comparison of ^{204}Tl and a trial comparison of ^{192}Ir could be carried out in the period before the next meeting.

It was agreed that a full-scale comparison of ^{204}Tl be conducted after steps are taken to address the unexplained discrepancy noted in the trial comparison. The CIEMAT will look again at the adsorption of thallium and a measurement of comparative activity of ^{204}Tl will be made at the IRMM using a 4π CsI detector.

It was decided that a ^{192}Ir trial comparison will be conducted under the auspices of Section II of the CCEMRI and of the BIPM. This will replace the proposed EUROMET action. The source preparation for this trial comparison will be made either by the IRMM or by the NPL. The planned schedule is that the ampoules will be dispatched in the autumn of 1995 with a first evaluation in the spring of 1996. The following ten laboratories will participate in the trial comparison: BIPM, BNM-LPRI, ETL, IIR, IRA, IRMM, KRISS, NPL, OMH and VNIIM. If the results of this comparison are favourable a full-scale comparison, using a solution of ^{192}Ir, will follow soon afterwards.

6. BIPM activities

6.1 Robust evaluation of data from international comparisons (J. W. Müller)

The BIPM is responsible for the analysis of the results of international comparisons. This may lead to considerable difficulties when there are “outliers”. Mean values, which have traditionally been used in the analysis of international comparisons, show poor stability against the effect of such outliers. While the occurrence of outliers is a well-known fact, they pose problems for which there appears to be no satisfactory solution. In principle, they may be dealt with in three ways: 1) leave them as they are, 2) correct them or 3) delete them. However, each of these approaches has serious weaknesses. Fortunately, the development of “robust statistics” may offer a simple solution. Use of the median (or central) value, instead of the mean value, seems to solve the problem. Results expressed in terms of the median can be completed by a statement of uncertainty which is also based on the use of medians.

This simple method has the benefit of improved stability with regard to the presence of outliers. Application of the median has been demonstrated in treating the results from several international comparisons. The BIPM has analysed a number of comparisons using robust statistics in parallel with the conventional method and will continue to do so in order to make a thorough assessment of the method under a variety of situations.

6.2 Parity method (J. W. Müller)

In the parity method, the true coincidence rate needed for evaluation of the activity is determined indirectly by measurement of the parity (i.e. the frequency of finding an odd number of events) of the two input pulse trains. The exact dead-time correction, however, remains to be evaluated. This has led to a number of mathematical problems, some of which have been solved.

6.3 Dwell times of multichannel analysers (J. W. Müller)

Recent claims in the literature suggest that there exist systematic errors of up to 0,2 % in the effective channel widths of multichannel analysers. An experimental study has shown that, at least for the equipment used at the BIPM, such an effect, if it exists, must be smaller than 0,01 %. It is therefore rarely a limiting factor for the accuracy of measurements.

6.4 Uncertainty of dead times measured by the two-oscillator method (J. W. Müller)

The numerical determination of a dead time by means of two uncoupled oscillator frequencies at the input is generally considered to be the simplest and most accurate approach; however no exact expression is known for its experimental uncertainty. A study has been performed concerning the expected behaviour of the output pulses. This shows that for strongly coupled input events, such a phenomenon indeed becomes visible. This recalls the well-known Saros cycle observed for lunar and solar eclipses. For an accurate measurement of the dead time, however, it is preferable to let the phases between the two oscillators be random, i.e. to work with uncoupled pulse series, and this is the case usually studied.

7. Reports from member laboratories

Written reports from the laboratories represented at the meeting (95-1 to 4, 95-7 to 9, 95-12 to 18, 95-20 to 22) were distributed to those present. Summaries of these reports were presented by each attendee. This

session provided a valuable opportunity for attendees to detail the nature and scope of activities in radionuclide metrology occurring within their respective organizations.

8. Visit to the BIPM laboratories

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

9. Other business

At the conclusion of the meeting, T. J. Quinn referred to the approaching retirement of J. W. Müller, head of the Ionizing radiation section of the BIPM. As this was J. W. Müller's last CCEMRI Section II meeting in this role, T. J. Quinn took the opportunity to thank him for the many very valuable contributions which he has made to the field. This sentiment was affirmed by the Chairman and was followed by a round of applause from all of those present.

10. Date of the next meeting

It was agreed that the next meeting will take place in 1997, phased to fit in with the ICRM meeting. Specific details will be communicated to all representatives as they become available.

August 1995,
revised November 1995

APPENDIX R(II) 1

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

(*see* the list of documents on page R 49)

ANNEXE R(II) 1

Documents de travail présentés à la 13e réunion de la Section II du CCEMRI

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

Document CCEMRI (II)/

95-1 NIST (É.-U. d'Amérique). — NIST Radioactivity Group Report - 1993-1994, by J. M. R. Hutchinson, 4 pages.

95-2 NAC (Afrique du Sud). — Review of the activities at the NAC standardization laboratory (June 1993 to February 1995), 2 pages.

95-3 IMMR (Belgique). — Progress Report 1993-1995 on Radionuclide Metrology at the EC-JRC Institute for Reference Materials and Measurements, IRMM, by D. F. G. Reher, 7 pages.

95-4 PTB (Allemagne). — Review of recent work and projects (April 1993 to March 1995), 5 pages.

95-5 IMMR (Belgique). — Third list of difficult to obtain radionuclides, by D. F. G. Reher, 3 pages.

95-6 BIPM. — Trial comparison of activity measurements of a solution of ^{204}Tl, by G. Ratel, 29 pages.

95-7 Metrological Laboratory of Radioactive Materials, Radioisotope Centre (Pologne). — Review of the Activities in Radionuclide Metrology (June 1993 to April 1995), 2 pages.

95-8 NIM (Rép. pop. de Chine). — Progress report concerning radioactivity measurements at NIM (June 1993 - March 1995), by Li Fen, 3 pages.

95-9 ANSTO (Australie). — Progress report on the Radiation Standards Project Ansto-Physics (1993-1995), by S. M. Buckman and H. A. van der Gaast, 5 pages.

95-10 BIPM. — List of Reports distributed within the Working Party "Principles of the Coincidence Method", by J. W. Müller, 1 page.

Document CCEMRI (II)/

95-11 List of acronyms for laboratories participating in the International Reference System, 3 pages.

95-12 KRISS (Rép. de Corée). — Korea Research Institute of Standards and Science - Radiation Group, 2 pages.

95-13 ETL (Japon). — Status Report of ETL in 1993/94, by Y. Hino, 5 pages.

95-14 OMH (Hongrie). — Progress Report on Radionuclide Metrology (1993-95), by Á. Szörényi, 3 pages.

95-15 IRA-OFMET (Suisse). — Progress report 1993-1995 on radionuclide metrology, 2 pages.

95-16 BNM-LPRI (France). — Progress Report 1993-1994 on Radionuclide Metrology at LPRI, by N. Coursol, 7 pages.

95-17 ENEA (Italie). — Summary of the most recent activities (1993-1995) at ENEA in the field of interest of the CCEMRI Section II, 4 pages.

95-18 CIEMAT (Espagne). — Progress Report (May 94-95) on Radionuclide Metrology at the CIEMAT (Spain), 3 pages.

95-19 OHM (Hongrie). — Summary of the proposals of laboratories for a future activity intercomparison, by Á. Szörényi, 5 pages.

95-20 IRK of the University of Vienna (Autriche). — Summary of the research programme related to nuclide metrology for the years 1994 and 1995, by G. Winkler, 5 pages.

95-21 VNIIM (Féd. de Russie). — Communication for the CCEMRI (Section II) on the works Carried out at the D. I. Mendeleyev Institute for Metrology in the Field of Radionuclide Metrology for the Period of 1993-1994, by I.A. Kharitonov and N. I. Karmalitsyn, 2 pages.

95-22 NPL (Royaume-Uni). — Report of recent and current projects 1995-96, by M. J. Woods, 1 page.

95-23 PTB (Allemagne). — Contribution of Section II to the CCEMRI progress report to be presented at the 20th Conférence Générale des Poids et Mesures, by K. Debertin, 2 pages.

APPENDIX R(II) 2

Actions arising from the 13th meeting of Section II of the CCEMRI

Responsible	Date	Action
G. Ratel	June 1995	Complete first draft of report on ^{75}Se comparison.
WG on SIR		Develop criteria for the selection of best A_e values; create database of SIR results.
All		Supply D. F. G. Reher with ionization chamber calibration figures.
WG on standards equivalence		Define guidelines to establish equivalence of measurement standards for radioactivity.
M. J. Woods	June 1995	Send letter to all members listing the ideas of the WG on standards equivalence.
M. J. Woods	December 1995	Send first draft of the guidelines of the WG on standards equivalence to contributors.
BIPM	1995	Conduct ^{90}Sr comparison in the frame of extended SIR.
Chairman	June 1995	Send letter of invitation to B. M. Coursey to participate in the WG on the extension of the SIR.
H. Schrader	June 1995	Supply J. W. Müller with translations of German texts in figures of the ionization chamber Monograph.
BIPM		Issue ionization chamber Monograph.
G. Winkler	December 1995	Send draft of paper on high-efficiency counting to J. W. Müller and Chairman.

Á. Szörényi	February 1997	Circulate set of criteria to assist members in selecting radionuclides for comparisons.
D. F. G. Reher		Update database of suppliers of radionuclides.
All		Supply D. F. G. Reher with information on suppliers of radionuclides.
BIPM	1995	Organize ^{192}Ir trial comparison.
D. F. G. Reher	June 1995	Stop EUROMET Project on ^{192}Ir activity measurements.
CIEMAT	1995	Investigate adsorption of thallium in ampoules.
IRMM	1995	Do ^{204}Tl activity measurement with 4π CsI detector.
BIPM	1996	Organize full-scale ^{204}Tl comparison.

Section III — Neutron measurements

11th Meeting (April 1995)

AGENDA

for the 11th Meeting

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1. Opening of the meeting; designation of a rapporteur.
2. Report on neutron work at the BIPM:
   - 2.1 Emission rate measurements of neutron sources;
   - 2.2 Measurements and calculations of neutron response functions and detection efficiencies of the BIPM NE-213 liquid scintillation detector;
   - 2.3 Organization of the international comparison of neutron fluence measurements at 24,5 keV.
3. Fast neutron fluence comparisons:
   - 3.1 Comparison of measurements of 24,5 keV neutron fluences using Bonner spheres as transfer instruments;
   - 3.2 Comparison of measurements of 2,5 MeV and 14,7 MeV neutron fluences using Bonner spheres.
4. Thermal neutron fluence measurement comparison.
5. Future concerns of Section III:
   - 5.1 Future comparisons;
   - 5.2 Comparison of spectral fluence measurements;
   - 5.3 Future of equipment at the BIPM.
6. Visit to the BIPM laboratories.
7. Exchange of information on work in progress at participants' laboratories.
8. Other business.
9. Date of the next meeting.

COMITÉ CONSULTATIF POUR LES ÉTALONS DE MESURE
DES RAYONNEMENTS IONISANTS

SECTION III. — **Neutron measurements**
11th Meeting (April 1995)

REPORT
by D. M. GILLIAM, Rapporteur

Abstract. Section III (Neutron measurements) of the Comité Consultatif pour les Étalons de Mesure des Rayonnements Ionisants held its eleventh meeting in April 1995. Recent work carried out at the BIPM in the field of neutron measurements was reported. This included the organization of the comparison of 24,5 keV neutron fluence measurements in which half the groups involved had completed the measurements. Additional results for a fluence measurement comparison involving a Bonner sphere set were reported. Plans were discussed for a future comparison of thermal neutron fluence measurements. The possibilities for a comparison of neutron spectral fluence measurements were considered. The future concerns of Section III and the future of the equipment used for neutron measurements at the BIPM were discussed. Finally there was an exchange of information on work in progress at the participants' laboratories.

Introduction

Section III (Neutron measurements)* of the Comité Consultatif pour les Étalons de Mesure des Rayonnements Ionisants (CCEMRI)** held its eleventh meeting at the Pavillon de Breteuil, Sèvres, on 27-28 April 1995.

Present:

V. E. LEWIS, Chairman of Section III, National Physical Laboratory [NPL], Teddington.

Delegates of the member laboratories and organizations:

Electrotechnical Laboratory [ETL], Tsukuba (K. KUDO).

* For a list of the members, *see* page R 73.

** Laboratories and organizations mentioned in this report are listed on page V.

National Institute of Standards and Technology [NIST], Gaithersburg (D. M. GILLIAM).

National Physical Laboratory [NPL], Teddington (V. E. LEWIS).

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig (H. KLEIN).

The Director of the Bureau International des Poids et Mesures [BIPM] (T. J. QUINN).

Guest:

Institute for Reference Materials and Measurements [IRMM], Geel (E. WATTECAMPS).

Attended all or part of the meeting: G. MOSCATI (member of the CIPM); P. GIACOMO (Director Emeritus of the BIPM); A. ALLISY (member of the CCEMRI); P. ALLISY-ROBERTS, M. BOUTILLON, V.-D. HUYNH, J. W. MÜLLER, A.-M. PERROCHE and G. RATEL (BIPM).

Apologies were received from:

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

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

National Institute of Metrology [NIM], Beijing.

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

S. CRESPIN, Commissariat à l'Énergie Atomique [CEA], Bruyères-le-Châtel.

1. Opening of the meeting; designation of a rapporteur

The Director of the BIPM welcomed the participants of Section III. He posed this question for Section III "How shall we maintain the consistency of world-wide neutron measurements without the BIPM experimental programme?"

V. E. Lewis, the Chairman of Section III, welcomed its members and the guest from IRMM. He also welcomed Professor G. Moscati who was attending for the first time.

D. M. Gilliam accepted the task of Rapporteur.

2. Report on neutron work at the BIPM

The Chairman noted that the neutron work at the BIPM was scheduled to be terminated late in 1995 upon the retirements of V.-D. Huynh and L. Lafaye, so this progress report from the BIPM will be the

last. V.-D. Huynh summarized the main activities of the BIPM neutron measurement group since 1993.

2.1 Emission rate measurements of neutron sources

Six absolute calibrations of the BIPM Ra-Be(α,n) standard source gave emission rates that were consistent to within 0,2 % (extreme range of results) over a period of thirty years, when corrected for the decay of ^{226}Ra and the growth of daughter activities. Three relative comparisons of the BIPM standards Ra-Be(α,n)/Am-Be(α,n) over the last twenty years were also consistent to within 0,2 % when similarly corrected. Preliminary results of a comparison with the BNM-LPRI show BNM-LPRI measured values to be 1 % lower than those of the BIPM, but the final results from the BNM-LPRI were not available. Measurements were also made on a source from LNMRI.

2.2 Measurement and calculation of neutron response functions and detection efficiencies of the BIPM NE-213 liquid scintillation detector

Fluences determined using NE-213 spectrometry were found always to be higher than those derived from time-correlated associated particle counting. The discrepancy varied from 2,0 % to 2,6 % for 2,5 MeV neutrons, and from 1,8 % to 4,4 % for 14,65 MeV neutrons, depending on the NE-213 discriminator threshold setting. These discrepancies are within the combined estimated uncertainties.

The observed NE-213 pulse-height spectra agree well with the spectra calculated by the PTB Monte-Carlo code, especially after lowering the photomultiplier tube voltage to reduce a previously unrecognized saturation effect.

2.3 Organization of the international comparison of neutron fluence measurements at 24,5 keV

See Section 3.1 below.

3. Fast neutron fluence comparisons

3.1 Comparison of measurements of 24,5 keV neutron fluences using Bonner spheres as transfer instruments

Progress on measurements of neutron fluences with energies around 24,5 keV, produced at participating laboratories using filtered beams, antimony-beryllium sources and accelerators, was described. These

measurements employ the set of Bonner spheres previously used in the 2,5 MeV and 14,7 MeV comparisons (*see* item 3.2 below). Measurements have been completed at the CIAE, the NIST and the PTB, and some results have been reported to the coordinator, V.-D. Huynh. The comparison will also include measurements at the ETL, the NPL and the VNIIM, the task being completed by mid-1996. On the retirement of V.-D. Huynh, G. Ratel of the BIPM will take over the task of checking the stability of the ^{3}He counter between the measurements of the participants. It was agreed that the evaluation of the comparison will be carried out by V. E. Lewis, who will not be involved in the measurements at the NPL.

Some difficulties were encountered, both with the original ^{3}He proportional counter and with its replacement. The original counter began to malfunction during the CIAE measurements and was replaced. Furthermore, the replacement counter was found to have undergone a 2,5 % change in efficiency when returned to BIPM for the stability check at the end of the PTB measurements. It was noted that some supplementary measurements may be required to ensure that the measurements from all laboratories are accurately normalized by the transfer instruments.

H. Klein reported that he is making calculations of the spectral response of the Bonner spheres using MCNP (the Los Alamos Monte-Carlo neutron and photon transport code). These response functions will be provided to all participants to enable them to correct their measured values to the equivalent values for 24,5 keV neutrons. The MCNP-calculated relative responses for the different sizes of spheres at 24,5 keV will be included with the tabulation of relative experimental values in the final report of results. V. E. Lewis will provide detailed specifications of all air-filled voids in the Bonner spheres.

3.2 Comparison of measurements of 2,5 MeV and 14,7 MeV neutron fluences using Bonner spheres

At the previous meeting, general agreement was reported between the values measured by participants, but some apparent trends could have been due to differences in the treatment of target interaction effects. V. E. Lewis presented calculations made using the PTB code “TARGET” for the NPL targets. For three of the four configurations there was excellent agreement between the calculated and observed effects; for the fourth, the NPL measured value was obviously inaccurate. It was concluded that both techniques were generally consistent and that no further work was required.

4. Thermal neutron fluence measurement comparison

D. M. Gilliam reported that there appeared to be a problem with the use of a set of ^{10}B ionization chambers as the transfer instruments in

the proposed thermal neutron fluence measurement comparison. In three separate experiments at the NIST there was an apparent loss of ^{10}B from deposits of the same kind as those expected to be used in the transfer chambers. It was suspected that some of the elemental ^{10}B deposit may have been converted to boric acid by reaction with humid air or water vapour in the gas circulated through the ionization chamber. Boric acid can be lost by sublimation at room temperature. For this reason, the target preparation laboratory at the IRMM was preparing a special set of light ^{10}B deposits for the NIST to use in investigating this problem. The intention is that, if the loss of ^{10}B is confirmed in well-controlled exposures to different levels of humidity and different choices of the ionization chamber gas, the IRMM group will try alternative methods of sample preparation and coating with a view to reducing or eliminating the problem.

H. Klein suggested that ^{235}U deposits be considered as an alternative to ^{10}B, if the boron problem cannot be solved quickly. He also suggested adding ^{235}U chambers to the transfer instrument set even if the ^{10}B problem is solved, because the ^{235}U would have an interesting difference in spectral response. D. M. Gilliam considered this a very constructive suggestion and agreed that he would try to acquire appropriate ^{235}U deposits.

D. M. Gilliam also agreed to 1) circulate a draft protocol for the comparison even before the ^{10}B problem is solved, 2) provide preamplifier, bias supply, and amplifier electronics for the transfer instrument, and 3) perform integrity checks on the transfer instruments at the NIST before and after each participating laboratory performs its measurements. He also suggested that the target uncertainty for the comparison should be 0,5 % (one standard deviation) noting that attempting a more stringent target might slow the comparison excessively. No objection was raised to this suggestion.

Indications of interest in participation had been received from six laboratories (pending agreement on the protocol): CIAE, ETL, NIST, NPL, PTB and VNIIM.

5. Future concerns of Section III

5.1 Future comparisons

The need for future comparisons of neutron measurements (in addition to those already planned and in progress) was discussed. V. E. Lewis presented a summary of past comparisons which had been carried out under the auspices of the CCEMRI Section III. These may be found in the review article by R. S. Caswell and V. E. Lewis (*Rad. Prot. Dosimetry*, 1992, **44**, 105-110). It was agreed that there was no immediate need for further comparisons, either by repeating comparisons at energies used

before or by extending comparisons to higher or lower energies, but the situation would be reviewed following examination of the consistency of current standards (*see* item 8 below).

5.2 Comparison of spectral fluence measurements

H. Klein explained that the possibility of a Section III spectral fluence comparison had been made redundant by the pace of the EURADOS Working Group 7 activity on this topic. He noted that laboratories not participating in EURADOS programmes had the opportunity to benefit from the results of this work by attending the Neutron Dosimetry Symposium sponsored by the European Communities, the CEA and the PTB, in Paris in 1995. In addition a related Neutron Spectroscopy and Applications Workshop was scheduled for 1996.

5.3 Future of equipment at the BIPM

It was noted that several valuable instruments, standard sources, and pieces of equipment would be distributed among interested member laboratories on the termination of the neutron experimental programme at the BIPM. The receiving laboratory would generally pay for packing and shipping expenses.

G. Moscati had expressed interest in taking the SAMES accelerator to the LNMRI in Brazil. However, shipping requirements require inspection of the sealed, high pressure, hydrogen-filled vessel which contains the 150 kV electrostatic high voltage generator. Unfortunately this sealed unit cannot be opened without damaging it. Various solutions to this problem were under consideration by the LNMRI: the alternative was that the LNMRI would be unable to acquire the accelerator.

It was noted that the manganese bath system would be shipped to the LNMRI and the three standard sources, Ra-Be (γ,n), Ra-Be (α,n) and Am-Be (α,n), would be shipped to the NIST. Shipping containers had been made at the BIPM, and shipment was scheduled for July 1995.

The NE-213 liquid scintillation detector would go to the PTB. The set of Bonner spheres would be returned to the NPL (the Harwell fission chambers, which were owned by AEA Technology, had been purchased by the PTB).

6. Visit to the BIPM laboratories

Participants paid an interesting visit to the BIPM laboratory for the dosimetry of γ rays.

7. 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 D. M. Gilliam, H. Klein, K. Kudo, V. E. Lewis and E. Wattecamps. In addition, H. Klein reported on work in progress at the VNIIM.

8. Other business

T. J. Quinn and H. Klein stressed the necessity for quality assurance of measurement standards in view of the increasing expectation for the accreditation of calibrations provided by national standards laboratories and the BIPM. They noted the pressure from laboratories to register under the ISO 9000 standard. This, in their view, made it essential to review the basis of the standards for neutron metrology and to re-assess their uncertainty budgets. Such a review would demonstrate traceability to primary standards and clarify the need for further comparisons (*see* item 5.1 above) to validate national standards. H. Klein considered such an exercise necessary, in particular because some standards are based on the H(n,n)H scattering cross section, a quantity which appears to be less accurately known than had previously been thought.

It was agreed that Section III would examine these standards. H. Klein and V. E. Lewis will first compile a catalogue or handbook covering manganese bath and fluence standards, addressing aspects such as basis, technique, requirements for other standards, ancillary data, uncertainty budgets and validation. This will be submitted to the ETL, the IRMM and the NIST for comment and the addition of further information, e.g. on evaluated cross sections. A plan was agreed which called for completion of a comprehensive document within one year. This would then be updated and maintained by the CCEMRI Section III and be available for purposes of quality assessment.

The Chairman expressed his disappointment that fewer members and guests were present than at previous meetings. The reasons for this were discussed and the view was expressed that more participation from laboratories outside Western Europe should be encouraged in future Section III meetings. The importance of making the agenda relevant to the needs of such groups was stressed.

The Chairman agreed to produce and circulate a progress report in April 1996 on the comparison and other items discussed at this meeting. Participants were asked to submit contributions in February/March 1996.

The Chairman drew the attention of the Section to the proposal of the Comité Consultatif des Unités to transfer the barn, among other units such as the curie and rad, from Table 10 (*Units in use temporarily with the SI*) to Table 12 (*Other units generally deprecated*) of the SI brochure. He noted

that the CIPM will make a decision on the future of the barn in 1996. It was generally accepted that, in line with developments concerning other such units, the barn would gradually be replaced by a unit such as square femtometre, fm^2, i.e. 10^{-30} m^2.

The Chairman noted that V.-D. Huynh would be retiring in 1995 after almost thirty years at the BIPM and that this Section III meeting would be his last. On behalf of the Section, V. E. Lewis expressed his gratitude for the unique contribution V.-D. Huynh had made to neutron metrology and to the work of Section III. The accuracy and consistency of the work at the BIPM was much appreciated, as was the spirit in which it was carried out. All present joined the Chairman in wishing V.-D. Huynh a long and happy retirement.

Returning to the question that T. J. Quinn posed in his introductory remarks, the consensus was that, in the absence of an experimental programme in neutron metrology at the BIPM, world-wide consistency in neutron measurements will be maintained by comparisons among the national laboratories represented in Section III.

The Chairman thanked participants for their contributions to a very interesting and valuable meeting, and expressed his gratitude to the staff of the BIPM for their hospitality.

9. Date of the next meeting

The date for the twelfth meeting of Section III was discussed. For several reasons, it was generally considered desirable to meet in 1997, rather than in three years time.

August 1995,
revised September 1995

APPENDIX R(III) 1

Working documents submitted to Section III of the CCEMRI at its 11th meeting

(*see* the list of documents on page R 64)

ANNEXE R(III) 1

Documents de travail présentés à la 11e réunion de la Section III du CCEMRI

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

Document CCEMRI (III)/

95-1 ETL (Japon). — Recent Activities on Neutron Standardization at the Electrotechnical Laboratory (1) - Neutron Standards and Related Works, by K. Kudo, N. Takeda and A. Fukuda, 3 pages.

95-2 ETL (Japon). — Recent Activities on Neutron Standardization at the Electrotechnical Laboratory (2) - Characteristics of ^{3}He Proportional Counter, by N. Takeda and K. Kudo, 3 pages.

95-3 NPL (Royaume-Uni). — Neutron Measurements at the National Physical Laboratory, by V. E. Lewis, 2 pages.

95-4 IMMR (Belgique). — Summary of recent neutron cross-section measurements at IRMM and some details on neutron flux and/or reference cross-section data measurements, by E. Wattecamps, 6 pages.

95-5 NIST (É.-U. d'Amérique). — ^{3}He Neutron Spin Filter, 18 pages.

95-6 VNIIM (Féd. de Russie). — A brief description of the VNIIM's facilities for measuring of neutron flux and neutron fluence rate, by I. A. Kharitonov, 5 pages.

95-7 IMMR (Belgique). — Comparison of two independent background determinations for neutron fluence measurements by the Bonner sphere technique applied at 2.5 and 16.0 MeV, by C. Goddio, E. Wattecamps and I.-G. Birn, 22 pages.

English text of the report

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