

Bureau International des Poids et Mesures

**Consultative Committee
for Photometry and
Radiometry (CCPR)**

15th Meeting (March 1999)

Note on the use of the English text

To make its work more widely accessible the Comité International des Poids et Mesures publishes an English version of its reports.

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

TABLE OF CONTENTS

Photograph of participants attending the 15th meeting of the Consultative Committee for Photometry and Radiometry **2**

Member States of the Metre Convention **51**

The BIPM and the Metre Convention **53**

List of members of the Consultative Committee for Photometry and Radiometry **57**

Report to the Comité International des Poids et Mesures, by J.L. Gardner **59**

Agenda **60**

1 Opening of the meeting; appointment of a rapporteur **61**

2 Progress in the laboratories **61**

2.1 Progress on the Mutual Recognition Arrangement (MRA) **62**

2.2 Review of progress made by national laboratories since the 13th meeting **62**

3 Discussion of the results of key comparisons **66**

3.1 Report from the key comparison working group **66**

3.2 Luminous responsivity **67**

3.3 Luminous intensity and luminous flux **67**

3.4 Discussion **68**

3.5 Previous comparisons possibly to be included in the BIPM key comparison database **71**

4 Discussion of the results of the comparison of cryogenic radiometers **72**

5 Report on progress of the remaining comparisons **73**

5.1 Spectral irradiance CCPR-K1 **73**

5.2 Spectral responsivity CCPR-K2 **74**

5.3 Spectral diffuse reflectance CCPR-K5 **75**

5.4 Regular transmittance CCPR-K6 **75**

5.5 Spectral radiance **76**

5.6 Aperture area **76**

5.7 Future working programme of the CCPR **76**

6 Report from the working group on air-UV spectral radiometry **76**

7 Report from the Joint CCT/CCPR working group **78**

8 International comparisons and links to regional metrology organizations **78**

- 9 Liaison with other groups **79**
- 10 Discussion of the results of the meeting of the CCU concerning the Ω_0 question **80**
- 11 Report to the CIPM and recommendations **81**
- 12 Other business **81**
 - 12.1 NEWRAD meeting **81**
 - 12.2 Optoelectronics **81**
 - 12.3 Links with ionizing radiation **82**
- 13 Next meeting **82**

Appendix P 1. Working documents submitted to the CCPR at its 15th meeting **83**

List of acronyms used in the present volume 85

**MEMBER STATES
OF THE METRE CONVENTION**

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

THE BIPM AND THE METRE CONVENTION

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

The BIPM has its headquarters near Paris, in the grounds (43 520 m²) of the Pavillon de Breteuil (Parc de Saint-Cloud) placed at its disposal by the French Government; its upkeep is financed jointly by the Member States of the Metre Convention.

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

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

The BIPM operates under the exclusive supervision of the Comité International des Poids et Mesures (CIPM) which itself comes under the authority of the Conférence Générale des Poids et Mesures (CGPM) and reports to it on the work accomplished by the BIPM.

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

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

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

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

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

Some forty-five physicists and technicians work in the BIPM laboratories. They mainly conduct metrological research, international comparisons of realizations of units and calibrations of standards. An annual report, published in the *Procès-Verbaux des Séances du Comité International des Poids et Mesures*, gives details of the work in progress.

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

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

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

2. The Consultative Committee for Photometry and Radiometry (CCPR), new name given in 1971 to the Consultative Committee for Photometry (CCP) set up in 1933 (between 1930 and 1933 the CCE dealt with matters concerning photometry);
3. The Consultative Committee for Thermometry (CCT), set up in 1937;
4. The Consultative Committee for Length (CCL), new name given in 1997 to the Consultative Committee for the Definition of the Metre (CCDM), set up in 1952;
5. The Consultative Committee for Time and Frequency (CCTF), new name given in 1997 to the Consultative Committee for the Definition of the Second (CCDS) set up in 1956;
6. The Consultative Committee for Ionizing Radiation (CCRI), new name given in 1997 to the Consultative Committee for Standards of Ionizing Radiation (CCEMRI) set up in 1958 (in 1969 this committee established four sections: Section I (X- and γ -rays, electrons), Section II (Measurement of radionuclides), Section III (Neutron measurements), Section IV (α -energy standards); in 1975 this last section was dissolved and Section II was made responsible for its field of activity);
7. The Consultative Committee for Units (CCU), set up in 1964 (this committee replaced the “Commission for the System of Units” set up by the CIPM in 1954);
8. The Consultative Committee for Mass and Related Quantities (CCM), set up in 1980;
9. The Consultative Committee for Amount of Substance (CCQM), set up in 1993;
10. The Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV), set up in 1999.

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

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

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

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

The scientific work of the BIPM is published in the open scientific literature and an annual list of publications appears in the *Procès-Verbaux* of the CIPM.

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

LIST OF MEMBERS OF THE CONSULTATIVE COMMITTEE FOR PHOTOMETRY AND RADIOMETRY

as of 24 March 1999

President

A.J. Wallard, member of the Comité International des Poids et Mesures,
National Physical Laboratory, Teddington.

Executive secretary

R. Köhler, Bureau International des Poids et Mesures [BIPM], Sèvres.

Members

All-Russian Research Institute for Optophysical Measurements [VNIIOFI],
Moscow.

Bureau National de Métrologie: Institut National de Métrologie [BNM-INM],
Paris.

CSIR, National Metrology Laboratory [CSIR], Pretoria.

CSIRO, National Measurement Laboratory [CSIRO], Lindfield.

Departamento de Metrologia, Instituto de Fisica Aplicada [CSIC-IFA],
Madrid.

Electrotechnical Laboratory [ETL], Tsukuba.

Helsinki University of Technology [HUT], Espoo.

Istituto Elettrotecnico Nazionale Galileo Ferraris [IEN], Turin.

Korea Research Institute of Standards and Science [KRISS], Taejeon.

Measurement Standards Laboratory of New Zealand [MSL], Lower Hutt.

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.

Office Fédéral de Métrologie [OFMET], Wabern.

Országos Mérésügyi Hivatal [OMH], Budapest

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

Slovenský Metrologický Ústav [SMU], Bratislava.

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

Observers

Centro Nacional de Metrologia [CENAM], Queretaro.

National Metrology Institute [UME], Gebze-Kocaeli.

Nederlands Meetinstituut [NMI] Delft.

Singapore Productivity and Standards Board [PSB], Singapore.

**Consultative Committee
for Photometry and Radiometry**

Report of the 15th meeting

(24-25 March 1999)

to the Comité International des Poids et Mesures

Agenda

- 1 Opening of the meeting; appointment of a rapporteur.
- 2 Progress in the laboratories:
 - 2.1 Progress on the Mutual Recognition Arrangement (MRA);
 - 2.2 Review of progress made by national laboratories since the 13th meeting.
- 3 Discussion of the results of key comparisons:
 - 3.1 Report from the key comparison working group;
 - 3.2 Luminous responsivity;
 - 3.3 Luminous intensity and luminous flux;
 - 3.4 Discussion;
 - 3.5 Previous comparisons possibly to be included in the BIPM key comparison database.
- 4 Discussion of the results of the comparison of cryogenic radiometers.
- 5 Report on progress of the remaining comparisons:
 - 5.1 Spectral irradiance CCPR-K1;
 - 5.2 Spectral responsivity CCPR-K2;
 - 5.3 Spectral diffuse reflectance CCPR-K5;
 - 5.4 Regular transmittance CCPR-K6;
 - 5.5 Spectral radiance;
 - 5.6 Aperture area;
 - 5.7 Future working programme of the CCPR.
- 6 Report from the working group on air-UV spectral radiometry.
- 7 Report from the Joint CCT/CCPR working group.
- 8 International comparisons and links to regional metrology organizations.
- 9 Liaison with other groups.
- 10 Discussion of the results of the meeting of the CCU concerning the Ω_0 question.
- 11 Report to the CIPM and recommendations.
- 12 Other business:
 - 12.1 NEWRAD meeting;
 - 12.2 Optoelectronics;
 - 12.3 Links with ionizing radiation.
- 13 Next meeting.

1 **OPENING OF THE MEETING; APPOINTMENT OF A RAPPORTEUR**

The Consultative Committee for Photometry and Radiometry (CCPR) held its 15th meeting at the Bureau International des Poids et Mesures (BIPM), Sèvres, on Wednesday 24 and Thursday 25 March 1999. Four sessions were held.

The following were present: J. Bastie (BNM-INM), A. Bittar (MSL), P. Blaser (OFMET), L.P. Boivin (NRC), A. Corróns (IFA), B.F. Denner (CSIR), G. Dézsi (OMH), N.P. Fox (NPL), J.L. Gardner (CSIRO), E. Ikonen (HUT), In Won Lee (KRISS), Lin Yandong (NIM), J. Metzdorf (PTB), P. Nemeček (SMU), D. Nettleton (NPL), H. Onuki (ETL), A.C. Parr (NIST), T.J. Quinn (Director of the BIPM), M.-L. Rastello (IEN), V. Sapritsky (VNIIOFI), R. Saunders (NIST), T.R. Scott (NIST), P. Soardo (IEN), A.J. Wallard (President of the CCPR), B. Wende (PTB).

Observers: C. Schrama (NMi-VSL), Xu Gan (PSB), J. Sanchez-Gonzalez (CENAM).

Invited: P. Bloembergen (NMi).

Also attending the meeting: P. Giacomo (Director emeritus of the BIPM); R. Goebel, R. Köhler, M. Stock, C. Thomas (BIPM).

The President opened the meeting and welcomed the participants, noting new observers: the PSB (Singapore) and the CENAM (Mexico). He reported that the CCPR had been active since the last meeting, particularly the working group on key comparisons. The Director of the BIPM extended his welcome to the participants. Dr Gardner was designated Rapporteur. The amended agenda was adopted. Dr Köhler stated that no additional working documents had been presented at the start of the meeting; the working documents were listed in Appendix P 1.

2 **PROGRESS IN THE LABORATORIES**

Dr Wallard noted that the 14th meeting did not include reports on progress in the national laboratories, and that this practice had been reinstated for this

meeting. In the previous period many laboratories had also been involved with development of the Mutual Recognition Arrangement (MRA) on measurement acceptance between member countries.

2.1 Progress on the Mutual Recognition Arrangement (MRA)

Dr Quinn presented a flow chart showing the processes which link national measurement institutes to the BIPM key comparison database through performance in key comparisons and approval of measurement capability statements. He reported that as a result of meetings at the BIPM of directors of the national metrology institutes, the CIPM, measurement specialists and the Joint Committee of Regional Metrology organizations and the BIPM (JCRB), the MRA had been developed for signature during the October 1999 meeting of the General Conference.

New guidelines for the protocol of key comparisons had been prepared in March 1999. The most significant change related to withdrawal of results. Laboratories may be notified that their submitted results appear anomalous, with no indication of the detail. They are then offered the chance to resubmit results if they find a simple numerical error. If no numerical error is found then the result remains in the report of the comparison. Dr Quinn stated that the full text of the guidelines for key comparisons were available on the BIPM website (<http://www.bipm.fr>). He said that new guidelines were not applied to comparisons already in progress.

2.2 Review of progress made by the national laboratories since the 13th meeting

Dr Wallard noted that most laboratories had presented written submissions on this topic, and offered each laboratory the opportunity of speaking to their submission.

Dr Rastello reported that the IEN has based its candela on a room-temperature electrical substitution radiometer and trap detectors. They are comparing goniophotometric and absolute sphere methods for luminous flux. The IEN has an active programme in photon standards, measuring quantum efficiency and radiance by parametric amplification; they are also using Josephson tunnel junctions as bolometric detectors.

Dr Nemeček reported that the SMU is concentrating efforts on spectral responsivity, particularly on those aspects related to radiometric temperature measurement.

Dr Onuki mentioned that the ETL had developed new capabilities in detector calibration in the range 200 nm-400 nm using undulator radiation and a room-temperature electrical substitution radiometer, with plans to extend measurements to 100 nm with a ^3He -cooled radiometer.

Mr Dézsi commented that the OMH now uses a detector-based method for spectral irradiance; they have improved methods for aperture measurement and also for gloss measurement, based in part on improved knowledge of refractive index.

Dr Bittar reported ongoing work at the MSL on modelling of the internal quantum efficiency of silicon for use at UV wavelengths; 3-, 4- and 5-element traps have been compared as part of this investigation. He also noted that deposits of sodium chloride had been identified on the surface of some silicon detectors and concluded that this had affected the uniformity of response.

Mr Nettleton remarked that the NPL is developing a new system to make regular measurements of the Stefan-Boltzmann constant as a check on the long-term performance of cryogenic radiometers. Mechanically cooled cryogenic radiometers are now in regular use, including operation at wavelengths up to 10 μm with a radiometric accuracy of 0.1 %. Tunable CW lasers are now employed, covering most of the range from 200 nm to 11 μm . Plans are in hand to replace the NPL integrating sphere and a commercial goniophotometer has already been installed. Two-photon correlation work has begun and Fourier-transform spectrometers are now used for spectral radiometry. New scales have been developed for diffuse reflectance, with a small shift detectable from older values.

Dr Parr reported that the NIST Boulder laboratories had installed a cryogenic radiometer for laser power measurement for metrology needs in optical communication. At Gaithersburg, a 300 MeV synchrotron is now operating with a cryogenic radiometer, providing measurements of optical power at 0.1 % level of uncertainty from the soft x-ray to the infrared region. A new integrating sphere is in use for luminous flux. Procedures have been developed for photometry of flashing lights in response to needs within the aircraft industry. A new cryogenic radiometer is in operation, with laser sources from 200 nm through the infrared region. The NIST has re-established standards for gloss and haze which are based on goniometric measurement. Strong support is given to the NASA for pre-launch and on-board calibration of radiometric instruments.

Dr Gardner said that the CSIRO had recently linked the candela and infra-red power measurements to a cryogenic radiometer. Other effort has been

expended on uncertainty estimates and third-party accreditation of its calibration services.

Dr Boivin intimated that the NRC is developing sphere radiometers for use in the near IR with the cryogenic radiometer facility. They had also developed large field-of-view reflection trap detectors for use with this facility in the UV and the visible. Room-temperature electrical substitution radiometers have been used to calibrate liquid-nitrogen cooled InSb detectors for measurements of spectral responsivity up to 3000 nm.

Prof. Metzdorf mentioned that much of the effort in photometry at the PTB Braunschweig had been expended in the role of pilot laboratory for key comparisons. High power laser radiometry was now established. Prof. Wende reported that the PTB Berlin continues to use synchrotron radiation with cryogenic radiometers. Silicon and Pt-Si photodiodes are routinely calibrated in the range of photon energies from a few eV to 1 keV at the storage ring BESSY I. Radiometric techniques with the synchrotron are promising to provide an accurate reference for radionuclide calibrations and x-ray dosimetry. Dr Parr said that the NIST has similar capabilities and would be interested in collaborating. Further discussion on this topic was deferred to later in the meeting.

Dr Lee announced that the KRISS has almost completed re-establishing the candela with a cryogenic radiometer and trap detector. The laboratory is developing an electrically calibrated calorimeter for high power laser measurements. An argon mini-arc triggered with a laser pulse has shown stability at UV wavelengths better than 1 % over an hour. Instrumentation for absolute reflectance is being developed, based on a monochromator and an array detector. This uses diffuse incidence and 0° detection geometry.

Dr Corróns reported that the IFA now links its candela to a cryogenic radiometer, and a goniophotometer is being developed to measure flux. The laboratory has noted problems in uniformity of response of silicon photodiodes at UV wavelengths measured with a He-Cd laser. In response to questions, he replied that these are S1337 photodiodes operated at 325 nm, and that the lack of uniformity appears in reflectance measurements.

Dr Blaser reported that the OFMET is planning to move to new premises and that general improvements had been made to techniques and equipment.

Mr Bastie remarked that at the BNM-INM a number of standards are now referenced to a cryogenic radiometer. A He-Cd laser is used at 325 nm. Large-area trap detectors are used as transfer standards. Also UV irradiance

standards based on relatively broadband filters and GaP and Ga-As-P photodiodes are being developed.

Dr Lin advised that the NIM is currently linking its base standards to a cryogenic radiometer. They have two beam lines for metrology on a synchrotron operated in collaboration with Chinese universities.

Prof. Ikonen commented that the HUT is using filter radiometers calibrated against its cryogenic radiometer for spectral radiance and irradiance in the wavelength range from 280 nm to 900 nm, with the main application being measurements of solar irradiance. Some problems due to inter-reflections remain to be solved, especially in the wavelength range 280 nm to 300 nm. The laboratory has also developed a direct optical method for aperture area measurement. The method uses a uniform irradiance distribution which is formed as a dense, two-dimensional superposition of equally spaced, identical laser beams. In practice the superposition is accomplished by moving the aperture between regularly spaced measurement points in a plane perpendicular to the laser beam.

Mr Denner reported that the CSIR had recently obtained a cryogenic radiometer. Facilities for calibration of UV A, B and C meters had recently been upgraded in response to client needs. At the CSIR, measurements of optical power for fibre-optic communications had been relocated to the time and frequency section.

Dr Köhler mentioned that the BIPM now realizes its own candela and is realizing the lumen based on an absolute sphere calibration. A sodium heat-pipe black body is being purchased as an infra-red source. He invited the participants to visit the laboratories in a period scheduled during the meeting.

Dr Xu stated that the PSB had established new radiometry facilities for spectral responsivity in the 200 nm-1600 nm wavelength range, referenced to a mechanically cooled cryogenic radiometer and Kr laser lines. A major concern of the laboratory is the calibration of UV radiometers for the semiconductor industry, where large discrepancies have been found on commercial instruments.

Dr Sanchez indicated that the CENAM has a new cryogenic radiometer and is developing facilities in fibre optics and spectrophotometry.

Dr Schrama reported that the NMi has a monochromator-based cryogenic radiometer using trap detectors in vacuum for spectral responsivity in the visible range. Facilities have been developed for applications in low-temperature pyrometry, with thin-film thermopiles for transfer to 20 μm . Spectral responsivity measurements are being extended below the visible to

190 nm; with nitrogen flushing of the system this will be extended further to 150 nm.

Dr Köhler commented that this review is an important record of developments in radiometry, with the bibliography attached to the reports especially useful. Dr Gardner requested that the bibliography include applications in radiometry that might be outside the core interest of metrology, which some but not all laboratories had provided. Dr Quinn noted the need for an annual upgrade of the bibliography, and that the record could be maintained on the BIPM website.

Mr Nettleton asked whether the questions directed to the laboratories in the report should be reviewed. Dr Wallard said that suggestions should be communicated to Dr Köhler, and thanked all for their reports, both written and oral.

3 DISCUSSION OF THE RESULTS OF KEY COMPARISONS

Dr Quinn introduced Dr Claudine Thomas, the BIPM staff member responsible for maintaining the BIPM key comparison database. He described the proposed numbering system for key comparisons, including identifiers for Consultative Committees, regional bodies or bilateral comparisons which flow from a particular key comparison.

3.1 Report from the key comparison working group

Dr Wallard recounted the terms of reference of the working group on key comparisons (WGKC). The group held 4 meetings and had extensive discussions via e-mail in seeking a robust and defensible outcome from key comparisons. The group had considered mean and median values for the key comparison reference value, but had preferred a mean weighted by the square of the inverse uncertainty of each laboratory. Detection of outliers and their exclusion in estimating the reference value had been discussed. The group agreed that reliable estimates of uncertainty were required, and that these were not always present in comparison data, past and present data being used as examples. The WGKC had reservations about some claims of low uncertainty, and had suggested a cut-off uncertainty in the absence of more

complete information. This would normally be nominated at the planning stage, representing perceived state-of-the-art measurement, with any laboratory nominating a lower value to be asked to provide detailed justification. For existing key comparisons, an agreed cut-off had been designated to limit excessive weighting of the results of any one laboratory. The group had considered spectral data, but the complex issues raised were yet to be resolved.

Dr Wallard suggested that the existing key comparison data be presented, and that further discussion on processing of key comparison reference values and their uncertainties then take place.

3.2 Luminous responsivity

Dr Köhler presented data from Draft B of the luminous responsivity comparison. This was initiated under superseded rules for key comparisons, and the recent changes listed in the MRA had not been applied. Fifteen laboratories plus the BIPM as coordinating laboratory had participated. The results of the KRISS were a clear outlier; the laboratory had subsequently identified an alignment problem in its reference photometer, and its results were not included in the processing for the calculation of the reference value but they would be reported in the published results of the comparison. Following the recommendations of the KCWG, a cut-off uncertainty of 0.2 % was adopted and a weighted mean calculated.

Results were also shown for median and unweighted mean values, with a small variation of the order of 0.1 % to 0.2 %. Dr Thomas questioned the calculation of the standard deviation and the standard deviation of the mean. Recommended practice was to calculate the propagated uncertainty. Dr Boivin said his preference was for an unweighted mean or a median. Prof. Ikonen asked why the median was not used. Mr Nettleton replied that use of the median implied no confidence in the uncertainty values, which contain useful information that should be applied. It was noted that the different methods of calculation yielded little difference in the reference value for this comparison, being of the same order as the uncertainty.

3.3 Luminous intensity and luminous flux

Prof. Metzdorf discussed Draft B of the report which combined the results of these two comparisons. Eighteen laboratories participated with intensity lamps and seventeen with flux lamps. He noted that two laboratories (the

INTI and UME) joined the comparison after it had begun. The meeting decided that this was not allowed by the key comparison guidelines in place at the time this comparison began, and that their results should not be normally included; such laboratories must undertake bilateral or regional comparisons according to the protocols of the MRA to gain entry to the MRA database. Dr Quinn observed that the two laboratories concerned were not members or observers of the CCPR, and hence were not able to participate in key comparisons at the Consultative Committee level on those grounds. It was suggested, however, that their participation be considered as a bilateral comparison and as such the results could be published at the same time as the rest of the comparison. However, the results of the two laboratories would not be used for the calculation of the key comparison reference value.

Dr Köhler showed amended key comparison reference values using weighted means and cut-off uncertainties of 0.25 % for luminous intensities and 0.3 % for luminous flux. The differences introduced were small. Dr Köhler also presented ratios of luminous intensity and luminous responsivity values for the two comparisons, concluding that in general the results were consistent. Prof. Metzdorf noted that Draft B contained plots of the ratio of intensity and flux units for each laboratory which revealed some inconsistencies given that flux derivations are based on intensity. Two laboratories indicated ratios greater than 0.5 %.

Dr Köhler also presented graphs of intensity and flux results for CCPR comparisons for the last sixty years, showing little reduction in scatter over time.

3.4 Discussion

Dr Wallard noted that the various methods of calculating the reference value made little difference for each of the comparisons presented. These had been discussed in detail in the WGKC, where a compromise outcome had been reached. The full committee needed to approve the method to be used in extracting key comparison reference values.

Dr Quinn pointed out that the key comparisons were to compare national measurement standards, and that the key comparison reference value should not exclude those laboratories which do not realize primary standards. Mr Nettleton mentioned that there were known correlations among laboratories, but these should be ignored for the comparisons presented here so that a conclusion could be obtained at this meeting.

Prof. Soardo requested that an equivalence value over all laboratories be extracted. Dr Quinn replied that the degree of equivalence for each laboratory as a difference from the key comparison reference value and associated uncertainty would be presented in the final report for inclusion in the BIPM key comparison database; a level within which all laboratories are equivalent within one “band” was not included.

Dr Boivin favoured an unweighted mean or the median. Dr Köhler commented that the weighted mean allows for laboratories that have a known lower accuracy to have less influence on the reference value. Prof. Metzdorf agreed, noting that this is important in spectral responsivity, for example, where some laboratories trace directly to a cryogenic radiometer. Mr Nettleton was in favour of weighted means with a cut-off, noting that the published uncertainty of the degree of equivalence would be based on the uncertainty submitted by the laboratory.

Dr Wallard noted that the committee agreed with the recommendations of the working group in extracting the reference value, but asked whether more data could be extracted from the comparisons. Dr Parr suggested that information on best measurement capability and scatter in the results was available to indicate the true state-of-the-art capability in radiometry, and that this would be useful information. The Consultative Committee would also use this information in determining the uncertainty cut-off value. Dr Gardner emphasized the need to include any known differences between disseminated and realized units, as the MRA dealt only with disseminated units but that a traditional task of the CCPR was to extract the best estimate of the true SI value from primary realizations. Dr Quinn also suggested the possibility of using CODATA methods to assist in analysis of consistency in the reported data. Prof. Ikonen was concerned that the value of uncertainty of the reference value calculated by propagation was too small, and that his preference was for a median reference value. Nevertheless, he accepted the consensus agreement for a weighted mean and propagated uncertainty, including a cut-off, but requested that reports include the alternative calculations.

Dr Wallard questioned who should be responsible for the analysis of the uncertainty information in the key comparisons. Mr Nettleton expressed the view that this extended beyond the commitment of the pilot laboratory. Prof. Metzdorf suggested that this depended on whether the final reports were to include detailed uncertainty budgets for realizations of the units, as this information was additional to that originally defined by the KCWG and the pilot laboratory. Dr Gardner suggested that through the secretary the pilot

laboratory should receive data on uncertainties for the comparison and that the working group should receive data related to the realizations. Dr Boivin noted that it was not possible to specify uncertainty components for the realization itself, as various laboratories might use different techniques, and not all components would be common. This was particularly true for laser-based cryogenic radiometer systems compared with those which are monochromator-based.

Dr Quinn remarked that a number of laboratories were yet to complete details of their uncertainty budgets for the comparisons presented at the meeting. He noted that this is a condition of acceptance of results. Prof. Metzdorf made an undertaking for the PTB to contact participants in the luminous intensity/flux comparisons to complete details on the agreed components for those comparisons, and to send details on base units to the working group.

It was agreed that the key comparison pilot laboratories should be provided with uncertainty components related to the comparison, and with the values of any known differences between disseminated and realized units. Dr Wallard asked the executive secretary to request information on uncertainty components for realizations themselves for the three comparisons, to be provided by 15 May 1999. These will be considered by the KCWG at its next scheduled meeting in October 1999. He also asked for final reports, including any extra information required from the laboratories, to be prepared for the KCWG for endorsement by 31 August 1999. The reports would then be circulated to the full committee for approval by correspondence.

Dr Parr shared some concerns about the weighted mean, particularly where the weights could be an order of magnitude different although similar techniques were used. He perceived that the use of a weighted mean with a cut-off was a reasonable compromise, taking into account arguments outside statistics. Dr Quinn agreed that the use of an unweighted mean did not properly credit good work and that laboratories were improving their uncertainty estimates. Mr Nettleton argued that if uncertainties were not to be trusted then the median should be used, but that this then introduces problems of estimating uncertainty in the reference value. Dr Boivin requested that all methods be included, but Dr Wallard stated that while this could be done in the draft discussion, a final result was required.

According to Prof. Soardo the cut-off needed to be justified and should not be arbitrary. Dr Gardner noted that the cut-off for the present comparisons was judged on results which included a component due to uncertainty in the transfer standard; for later comparisons the cut-off would be determined on

the accuracy of the base standard only. Prof. Soardo agreed, and asked for a note describing the process used to be included in the reports of the existing comparisons.

Mr Denner enquired whether information on the state-of-the-art uncertainty would be available, as it would be important information for regional bodies. Dr Quinn said that it would be determined by the pilot laboratory and the KCWG, and be present in the reports.

The consensus was that the weighted mean, with cut-off and including laboratories that do not realize the primary unit, be used to extract key comparison reference values.

Dr Thomas questioned the CCPR use of relative values or differences from a relative value, thus close to 0 or 1, rather than values with the appropriate unit as usually done in the other committees. General discussion followed. It was stated that the CCPR key comparisons relate to base units, but may occur at different values which depend on geometric terms for instance. In addition, the relative value of a CCPR key comparison is transferred to regional comparisons, and customers are familiar with the format currently used. It was decided that the use of relative values or differences from the relative value be retained.

3.5 Previous comparisons possibly to be included in the BIPM key comparison database

Dr Quinn opened the discussion with a request for the committee to consider whether past CCPR comparisons should be included in the BIPM key comparison database. Prof. Metzdorf noted that the newly completed photometric key comparisons superseded others in photometry. It was decided that possible candidates were spectral irradiance (1992), spectral responsivity (1994) and fibre-optic detector responsivity (1990). Dr Gardner pointed out that a number of laboratories had re-evaluated their standards since these reports. Dr Köhler commented that the state-of-the-art had changed – only one laboratory had provided results based on a cryogenic radiometer for the spectral responsivity comparison. In Dr Boivin's view the comparisons represented the best evidence at this time for supporting claims in Appendix C of the MRA; Prof. Ikonen agreed, stating that a new round of spectral measurements would take some time to complete. Dr Bittar asked whether the results should be processed to extract reference values and offsets. Dr Quinn replied that this was probably too difficult and not worth the effort but if possible this should be done; anyway the complete final reports

could be available from the BIPM database. The committee supported the inclusion of the data with no reanalysis, with the option of adding comments to the data. Dr Parr suggested that the graphs of data should contain a link to the full report. The committee agreed to include the spectral responsivity data. Prof. Ikonen asked whether available EUROMET and other regional data should also be included. Dr Quinn agreed that these data should be included provided the protocol of comparisons was judged adequate and the reports were approved by the regional bodies. Future comparisons would require final approval by the CCPR key comparison working group. Prof. Metzdorf requested Prof. Ikonen to refer the question back to EUROMET.

It was agreed that results of the fibre-optic detector responsivity comparison be included in the database, and that the secretary should contact the participants to seek their approval. Dr Quinn remarked that for past comparisons participants might decide to withdraw their results.

Mr Nettleton questioned the inclusion of the spectral irradiance comparison data, with particular reference to the NPL results which should not have been included in the final report. Dr Quinn suggested that the data be included only until the new spectral irradiance comparison was completed. Mr Denner made a request that all historical reports be retained, as the history of performance is important when seeking third-party accreditation.

Dr Parr mentioned that the report forms part of the historical record; he suggested presenting the report only, with no separate table, and with the laboratories able to present comments or disclaimers. Dr Wallard said that this may apply also to the other older reports. It was agreed that all three reports should be presented, with no separate table, with the data first available on a provisional basis on a website with access limited to CCPR members for final approval.

4 DISCUSSION OF THE RESULTS OF THE COMPARISON OF CRYOGENIC RADIOMETERS

Mr Goebel spoke to Draft A of the report presented to the meeting. Seventeen laboratories participated in a modified star pattern, using trap detectors as transfer devices. The comparison included horizontal entry, vertical entry,

mechanically cooled and liquid helium-cooled radiometers using both monochromator and laser radiation. Seventy percent of the results were in agreement with a coverage factor $k = 1$, most within 3×10^{-4} . Beam preparation was crucial to performance in the comparison. He noted that some laboratories modified results, and one laboratory remeasured the transfer detector. Dr Boivin asked whether the reported measurements were obtained in a blind manner; Mr Goebel replied that different detectors were measured, but of course all have similar responsivity. Dr Fox was also concerned that this comparison did not follow the protocols for key comparisons. Dr Wallard replied that this was not a key comparison. Mr Nettleton suggested that repeat measurements should be made only in subsequent bilateral comparisons. Dr Parr agreed, but noted that the results of this comparison provided useful information for others, and that it would be sufficient for the final report to contain a clear identification of initial and final results, with explanations for the differences. It was decided to apply the guidelines and publish the first results obtained. For laboratories re-supplying results, those will be published as a bilateral comparison.

Dr Köhler remarked that one laboratory was required to confirm its results and then the final report could be prepared for publication in *Metrologia*.

5 REPORT ON PROGRESS OF THE REMAINING COMPARISONS

5.1 Spectral irradiance CCPR-K1

Dr Fox discussed the protocol which had been sent by the NPL as the pilot laboratory to all thirteen participants, with at least two from each regional metrology organization. Laboratories have eight weeks to complete measurements, with all to be completed by May 2000. This completion date was fixed by the scheduled move of the NPL laboratory into new premises. In response to Dr Saunders' question that it might be prudent to postpone the comparison, Mr Nettleton replied that as a key comparison the work needed to be completed as soon as possible to appear in the BIPM key comparison database. Prof. Metzdorf suggested that the NPL could provide only a single "between" measurement, rather than "before" and "after". Dr Fox pointed out that the proposed system was devised to monitor accurately the drift of the

transfer standards using a common system. Prof. Metzdorf stated that laboratories could monitor the drift, expressing his concern that the schedule had little allowance for damage or delays. Dr Fox replied that spare lamps were available in case of damage, and that the protocol insists that lamps be hand-carried to minimize damage or drift. Dr Boivin expressed concern over the requirement for hand-carriage, seeing this practice as desirable but not necessary, and prohibitively expensive. Mr Nettleton suggested that the NPL need not insist on hand-carrying if a weighted mean were to be used to determine the reference value, as laboratories with increased uncertainty due to transfer stability will have a lower weight. Dr Fox indicated that limited tests with the FEL lamps had shown drifts of 0.1 % to 0.8 % even with hand-carrying, and that the type II Polaron lamps to be used, which do not cover the whole spectral range from 250 nm to 2500 nm, had been more stable during transport. A number of laboratories indicated difficulty in arranging for lamps to be hand-carried. Dr Parr said that the uncertainties obtained would depend on available finance and/or location of laboratories, but that much of the evidence on the benefit of hand-carrying was anecdotal and that differential analysis of the results could be used to provide information to evaluate the effect. It would have to be accepted that those laboratories using personal transport might show a better performance in the comparison. Dr Gardner noted the high cost of the Polaron lamps and the requirement to purchase new lamps if this type were to be included by a particular laboratory, even though the laboratory had these lamps already available. Dr Fox replied that the Type II Polaron lamps had demonstrated improved performance over older models and that this would be an advantage in the comparison. Mr Nettleton also noted that the cost of the artefacts was much less than that of the labour to participate in a comparison. Mr Nettleton proposed that the NPL modify the protocol to accept an alternative means of transport of the lamps, and that the results be analysed separately to detect any improvement in performance due to hand-carrying. The committee agreed. The PTB Braunschweig would act as the pilot for the spectral range from 200 nm to 2500 nm, but the measurements would not begin until 2001.

5.2 Spectral responsivity CCPR-K2

Dr Parr reported that the infra-red comparison, with the NIST as the pilot laboratory, had begun and that photodiodes had been shipped. Dr Köhler indicated that fourteen laboratories wished to participate in the spectral region 300 nm-1000 nm, using photodiodes and trap detectors with BIPM as the pilot laboratory. Dr Schrama asked whether observer laboratories could

participate, to which Dr Quinn agreed provided the laboratory had demonstrated appropriate technical capability at the highest level. Dr Köhler also reported that the PTB Berlin would act as the pilot laboratory for the spectral range 200 nm-400 nm, but that measurements would not begin until 2001.

5.3 Spectral diffuse reflectance CCPR-K5

Dr Saunders announced that the protocol had been set and standards purchased for diffuse reflectance measurements to begin at the start of 2000. Laboratories could still join this comparison if they desired. Dr Boivin expressed concern that only one month had been allowed for measurements by each laboratory, and that two months would be more reasonable. Dr Saunders undertook to confirm that formal invitations for participation had been circulated. Dr Köhler said that addresses had been recently provided and that invitations were being prepared. Mr Nettleton remarked that the NPL had established a new goniophotometer technique for diffuse reflectance measurements and that the results being obtained were larger than those obtained with the older NPL sphere technique. Prof. Soardo expressed interest in collaborating with the NPL to understand the source of these differences.

Dr Quinn reminded coordinating laboratories that detailed uncertainty budgets were required as part of the Guidelines for key comparisons. Dr Boivin requested that comparisons CCPR-K5 and CCPR-K6 be coordinated so as not to overlap in the one laboratory. Dr Saunders and Mr Bastie agreed to coordinate time scales.

5.4 Regular transmittance CCPR-K6

Mr Bastie reported that 50 mm × 50 mm filters, with five neutral density values in the range 0.1 % to 92 % over 380 nm-1000 nm had been selected for the measurements. A parallel beam, 20 mm diameter at zero degree incidence with a bandwidth of 1 nm was recommended. Nineteen laboratories had expressed interest. The BK7 and NG5 glass filters were tested prior to specification of the filters. Dr Quinn observed that Turkey could not participate as the laboratory was not represented nor had an observer at CCPR meetings.

5.5 Spectral radiance

This is a supplementary comparison, to cover the range 220 nm-2500 nm, using strip lamps. Prof. Sapritsky reported that six laboratories were participating. The VNIIOFI had upgraded their facilities to act as the pilot laboratory. The NIST currently had the lamps for measurement. All measurements were due to be completed by November 1999.

5.6 Aperture area

Dr Saunders reported that diamond-turned apertures of high quality, with and without lands, had been prepared by the NIST but that the comparison had been delayed as the laboratory involved was moving to a new location. Five laboratories were participating; the apertures might be available for other laboratory measurements after completion of the initial comparison. Apertures with lands might be measured either optically or mechanically, and those without measured only optically.

5.7 Future working programme of the CCPR

Dr Wallard asked whether other comparisons were to be considered. The committee's response was that existing commitments already demanded a heavy workload. Mr Nettleton suggested that if the CCPR were to return to four-yearly intervals between meetings then other programmes would need to be considered now. Dr Quinn replied that a two-year period was more appropriate at this stage.

Dr Wallard remarked on the usefulness of Dr Köhler's note on the state of comparisons of a year ago, and asked that this practice be continued between meetings. Dr Köhler said that this would be possible only if he were kept informed by the pilot laboratory, and that updates could be added to the BIPM web page. The President commended the secretary for his report.

6 REPORT FROM THE WORKING GROUP ON AIR-UV SPECTRAL RADIOMETRY

Prof. Wende reported that measurements on deuterium and tungsten lamps in the range 200 nm-400 nm had been undertaken. The absolute performance of

the deuterium lamps was disappointing, although relative spectral values were satisfactory. Spectral radiance measurements proved better than spectral irradiance, for which agreement was worse than that reported in the 1992 comparison. Therefore only the results of the spectral radiance comparison had been submitted for publication to *Metrologia*. The 1997 meeting in Berlin had decided that the working group should concentrate on detector-based measurements, particularly using PtSi-n-Si Schottky diodes. In order to make rapid progress in the field the working group had stimulated a EUROMET project and an EC project aimed at improving the accuracy of UV radiometry. The projects showed that uncertainties of 0.1 % to 0.3 % were achievable for the calibration of the spectral sensitivity of photodiodes in the 200 nm-400 nm range. Prof. Wende remarked that a workshop would be held in conjunction with the NEWRAD meeting in Madrid to report the results. Dr Fox mentioned that the NPL claimed uncertainties of 0.5 % above 210 nm and 1.5 % below had now been improved by the use of an argon mini-arc source with its monochromator system. Prof. Ikonen was surprised that the NPL did not use a laser-based source. Dr Fox replied that a laser is used at 407 nm to provide an absolute reference for the spectral region.

Dr Schrama informed the meeting that the NMI is about to contribute results referenced to a monochromator-based cryogenic radiometer. In reply to Dr Boivin's question he said that uncertainties of 0.2 % could be achieved by monitoring drift during the measurement period.

Dr Parr was concerned that the work of the CCPR group appeared to have become a EUROMET project and that laboratories outside that region had not had the opportunity to participate. Dr Quinn was similarly concerned. Prof. Wende explained that the working group had sought partners to share the workload and that the NIST was a partner in the EUROMET project.

Dr Wallard noted that regional representatives needed to keep the CCPR secretary well informed so that cross-regional collaboration could be obtained. Dr Bittar asked whether work was continuing above 250 nm, as the report had concentrated on the region below 250 nm, where the PtSi photodiodes offer advantages in stability. Prof. Wende referred to previous work showing that Si p-n diodes were stable above 250 nm, and suggested that for key comparisons of spectral responsivity, the 200 nm-400 nm range should be split into two, at about 250 nm. Dr Köhler inquired about the reliability of supply of the Pt-Si photodiodes as they are prepared in a university department. Prof. Wende replied this is in principle no different from being supplied from small companies. Prof. Metzdorf reported that his laboratory has seen delays in supply as well as some failed Pt-Si diodes.

Mr Nettleton said that the working group had prepared a long-term programme in a detailed report as originally requested, and that this programme was now to be carried through step by step. Dr Wallard requested the Madrid workshop to produce a report to the CCPR on the priorities of future work. A meeting of the working group was planned immediately following this meeting to discuss details of the Madrid workshop.

7 REPORT FROM THE JOINT CCT/CCPR WORKING GROUP

Dr Quinn reported that the work of this group, to compare accuracies in radiometric temperature achievable with filtered radiometers and pyrometry relative to the gold point, had been deferred owing to the workload introduced by key comparisons. A report of work at the PTB had been prepared (CCPR99-05). The group could prepare a document on current best practice for the characterization of filter radiometers as this was directly applicable to some laboratories' determinations of spectral irradiance for the related key comparison.

8 INTERNATIONAL COMPARISONS AND LINKS TO REGIONAL METROLOGY ORGANIZATIONS

Dr Wallard reminded members that regional metrology organizations needed to transfer the key comparison reference value into their regions, and asked that the CCPR secretary be kept informed of regional activities.

Dr Gardner reported that the CCPR luminous responsivity comparison was currently being repeated in the APMP region according to key comparison protocols. Previous comparisons of spectral responsivity and luminous intensity had also been repeated in the region. The common laboratories between the CCPR and regional luminous intensity comparisons did not show consistent results and the subsequent procedure to transfer the key comparison reference value was not clearly defined.

Dr Sanchez reported that the SIM was planning extensions of the CCPR key comparisons into the region, but that these might be better carried out bilaterally. Laboratories of the region were working at assessing their capabilities for the MRA Appendix C listing.

Prof. Ikonen reported that EUROMET now involved seventeen countries and had about twenty-five projects operating in radiometry. Six key comparisons were planned, each with at least two CCPR members to provide linkage to the key comparison reference value. EUROMET has identified quantities and instruments needed for measurement or calibration, cross-referenced to key comparisons. He asked whether the current key comparisons covered all quantities of interest and importance, in particular whether claims on luminance capability were properly supported by performance in luminous intensity or luminous responsivity key comparisons. Dr Quinn reminded the meeting that the key comparisons were never intended to cover all capabilities, but were chosen as a minimum but robust set to provide confidence for related measurements. Mr Nettleton supplied the example of linearity and wavelength measurements, tested in determining the candela. It was the task of the CCPR as experts to assess best measurement capabilities against experience and reasonableness.

Dr Wallard thanked the presenters, and requested that the regional metrology organizations report comparison results to the KCWG for endorsement before passing the material for inclusion in the BIPM key comparison database.

Dr Köhler inquired whether the fully-characterized detectors used for the CCPR comparison of spectral responsivity should be made available to regional groups, relabelled to preserve anonymity of their response values. Dr Parr cautioned that the CCPR comparison should be completed before this occurs. Dr Quinn agreed that reuse of the detectors was desirable.

9 LIAISON WITH OTHER GROUPS

Mr Bastie provided a detailed presentation of CIE activities. A new division (8, Imaging Technologies) had been formed. New publications related to CCPR activities and concerning CIE standard illuminants for colorimetry were entitled “Practical methods for the measurement of reflectance and transmittance”, and “Measurement of the luminous intensity of LEDS”. He

advised that the next CIE general session would be held in June 1999 in Warsaw. Dr Boivin inquired what spectral region was covered by the new committee on UV measurements. Dr Xu replied that it is limited to UVA and UVB at present.

Dr Parr reported that the next CORM meeting in Gaithersburg would concentrate on radiometry related to signalling for traffic applications. The 7th CORM survey report on perceived needs in radiometry was currently being prepared.

Prof. Soardo reported that the European Accreditation (EA) was organizing comparisons to verify claims of laboratory accreditations, including uncertainty budgets.

Mr Dézsi reported that DUMAMET, a sub-regional metrology organization of countries in the area of the River Danube, was being formed.

In reply to a question from Dr Bittar, Mr Denner replied that radiometry has a low priority in the African region, and that the CSIR participates in related APMP activities.

10 DISCUSSION OF THE RESULTS OF THE MEETING OF THE CCU CONCERNING THE Ω_0 QUESTION

Dr Quinn reported that a recent CCU meeting had proposed that if the radian and steradian were SI base units, then Ω_0 should be included in equations involving units of lumen and candela. However, the General Conference had decided that the radian and steradian were derived units and hence the current practice of not including Ω_0 should continue. This agreed with the recommendations of the ISO Standards Handbook.

Dr Parr noted that questions had been raised about the quantity “1”. Dr Quinn recognized that this matter affected the CCPR, but stated that it was not yet resolved within the CCU and CIPM.

11 REPORT TO THE CIPM AND RECOMMENDATIONS

Dr Wallard indicated that he would make a formal report to the General Conference that the meeting had approved three key comparisons and that he would include material extracted from laboratory replies to the questionnaire. No recommendations were formulated.

12 OTHER BUSINESS

12.1 NEWRAD meeting

Dr Corróns invited all members to participate in the Madrid meeting in October 1999. Dr Quinn reported on the meeting of the scientific committee for NEWRAD. A selection of the meeting presentations will be published in *Metrologia*, with full text to be submitted for refereeing at the meeting.

12.2 Optoelectronics

Dr Parr inquired whether the special radiometric needs of laboratories involved in laser power, optical storage, optical computing, UV lithography and other areas should be considered by the CCPR. Mr Nettleton remarked that the field of colour imaging technology also had requirements where the primary expertise is optical measurement. All these areas cut across the interests of other Consultative Committees, and the CCPR should possibly ask others to join in reviewing needs.

Dr Wallard mentioned that he had raised some of these matters with the CCEM, but no pressing needs were identified. Prof. Metzdorf noted that some of the factors raised were already covered by supplementary comparisons, particularly in the regional bodies. Mr Denner said that some of the electronics areas were large, but with little requirement for optical measurement. Dr Boivin asked whether Appendix C submissions including fibre measurements would be supported by the CCEM or CCPR.

Dr Parr offered to conduct a survey into existing needs for improved radiometry in new non-traditional areas. Dr Wallard welcomed this and asked him to contact the relevant interests and to report back to the CCPR.

12.3 Links with ionizing radiation

Dr Allisy-Roberts of the BIPM ionizing radiation section joined the meeting. Prof. Wende reported that different communities were involved in the measurement of electromagnetic radiation and that they should share their knowledge. Measurements with storage rings promised to offer higher accuracy in the soft x-ray range than existing methods using radionuclide standards. At the Berlin electron storage ring BESSY 2, cryogenic radiometry was already available up to 10 keV. For a further extension up to 50 keV the design of a synchrotron radiation beam line and a corresponding cryogenic radiometer had been completed and experiments would start in 2000. Prof. Moscati, President of the CCRI, had been appraised of this work, which offers the possibility of tracing x-ray dosimetry to radiometry. Dr Allisy-Roberts said that the area of greatest need is in the spectral range 100 nm–1 nm, where uncertainties are of the order of 0.4 %.

Dr Quinn suggested that Prof. Wende should present his results to the CCRI; Dr Allisy-Roberts agreed to circulate Prof. Wende's paper to that committee. Dr Parr noted that the United States had requirements for optical power measurements in the short wavelength range and he was encouraged by the developments at the PTB.

Dr Wallard thanked Prof. Wende and Dr Allisy-Roberts for the discussion.

13 NEXT MEETING

A meeting was proposed in two years (possibly April 2001), when Draft B of the spectral irradiance key comparison would be available. The exact date is to be determined by October 1999 and circulated to members (April 2001 was provisionally mentioned).

Dr Wallard noted that Prof. Soardo, a member of CCPR since 1975, was likely to retire before the next meeting. He thanked him for his efforts and wished him well on behalf of the CCPR.

The meeting was closed.

J.L. Gardner, Rapporteur
April 1999

APPENDIX P 1.**Working documents submitted to the CCPR at its 15th meeting**

(see the list of documents on page 42)

LIST OF ACRONYMS USED IN THE PRESENT VOLUME

1 Acronyms for laboratories, committees and conferences

APMP	Asia/Pacific Metrology Programme
BESSY	Berliner Elektronenspeicherring-Gesellschaft für Synchrotronstrahlung m.b.H. (Germany)
BIPM	Bureau International des Poids et Mesures
BNM-INM	Bureau National de Métrologie, Institut National de Métrologie, Paris (France)
CCEM	Consultative Committee for Electricity and Magnetism
CCPR	Consultative Committee for Photometry and Radiometry
CCRI	Consultative Committee for Ionizing Radiation
CCT	Consultative Committee for Thermometry
CCU	Consultative Committee for Units
CENAM	Centro Nacional de Metrologia, Mexico (Mexico)
CIE	International Commission on Illumination
CIPM	Comité International des Poids et Mesures
CORM	Council for Optical Radiation Measurements (United States)
CSIC-IFA	Departamento de Metrologia, Instituto de Fisica Aplicada, Madrid (Spain)
CSIR-NML	Council for Scientific and Industrial Research, National Metrology Laboratory, Pretoria (South Africa)
CSIRO-NML	CSIRO, National Measurement Laboratory, Lindfield (Australia)
DUMAMET	Subregional metrology organization of countries in the area of the River Danube
EA	European Accreditation
ETL	Electrotechnical Laboratory, Tsukuba (Japan)
EUROMET	European Collaboration on Measurement Standards
HUT	Helsinki University of Technology, Helsinki (Finland)
IEN	Istituto Elettrotecnico Nazionale Galileo Ferraris, Turin (Italy)
INM	Institut National de Métrologie, Paris (France), see BNM
INTI	Instituto Nacional de Tecnología Industrial, Buenos Aires (Argentina)

ISO	International Organization for Standardization
KRISS	Korea Research Institute of Standards and Science, Taejeon (Rep. of Korea)
MSL	Measurement Standards Laboratory of New Zealand, Lower-Hutt (New Zealand)
NASA	National Aeronautics and Space Administration (United States)
NEWRAD	Conference on New Developments and Applications in Optical Radiometry
NIM	National Institute of Metrology, Beijing (China)
NIST	National Institute of Standards and Technology, Gaithersburg (United States)
NMi-VSL	Nederlands Meetinstituut, Van Swinden Laboratorium, Delft (The Netherlands)
NPL	National Physical Laboratory, Teddington (United Kingdom)
NRC	National Research Council of Canada, Ottawa (Canada)
OFMET	Office Fédéral de Métrologie, Wabern (Switzerland)
OMH	Országos Mérésügyi Hivatal, Budapest (Hungary)
PSB	Singapore Productivity and Standards Board (Singapore)
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig and Berlin (Germany)
SIM	Sistema Interamericano de Metrologia
SMU	Slovenský Metrologický Ústav/Slovak Institute of Metrology, Bratislava (Slovakia)
UME	Ulusal Metroloji Enstitüsü/National Metrology Institute, Marmara Research Centre, Gebze-Kocaeli (Turkey)
VNIIOFI	All-Russian Research Institute for Optophysical Measurements, Moscow (Russian Fed.)
WGKC	Working group on key comparisons

2 Acronyms for scientific terms

FEL	Type of lamp supplied by General Electric Co. (United States)
LED	Light-emitting diode
SI	International System of Units