

# Comité consultatif de photométrie et radiométrie (CCPR)

Consultative Committee  
for Photometry and Radiometry (CCPR)

Rapport de  
la 14<sup>e</sup> session  
(juin 1997)  
Report of  
the 14th Meeting  
(June 1997)



Bureau  
international  
des poids  
et mesures

Organisation  
intergouvernementale  
de la Convention  
du Mètre

Comité consultatif de photométrie et radiométrie ■ 14<sup>e</sup> session (juin 1997)  
Consultative Committee for Photometry and Radiometry ■ 14th Meeting (June 1997)

Comité consultatif de photométrie et radiométrie  
14<sup>e</sup> session (10-11 juin 1997)

P. Giacomo  
A. Corróns In Won Lee  
E. Ikonen  
P. Bloembergen  
P. Martin  
P. Blaser B. Wende  
R. Saunders  
G. Dezsi  
Chen Xiaju  
J.L. Gardner  
D. Nettleton  
B.F. Denner  
J. Bastie



N.P. Fox  
P. Nemeček  
R. Goebel  
T.J. Quinn  
M. Stock  
H. Onuki  
A.J. Wallard  
R. Köhler  
L.P. Boivin  
J. Metzendorf  
M.-L. Rastello  
P. Soardo  
A. Bittar  
A.C. Parr

Bureau International des Poids et Mesures

# Consultative Committee for Photometry and Radiometry (CCPR)

14th Meeting (June 1997)

### Note on the use of the English text

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

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

## TABLE OF CONTENTS

Photograph of participants attending the 14th meeting of the Consultative Committee for Photometry and Radiometry	2
Member States of the Metre Convention	50
The BIPM and the Metre Convention	51
List of members of the Consultative Committee for Photometry and Radiometry	55
<b>Report to the Comité International des Poids et Mesures, by J.L. Gardner</b>	<b>57</b>
Agenda	58
1 Opening of the meeting; designation of a rapporteur; approval of the agenda	59
2 Current state and provisional results of comparisons under way	60
2.1 Cryogenic radiometers using trap detectors as transfer standards	60
2.2 Luminous responsivity of photometers	60
2.3 Luminous intensity and luminous flux	61
2.4 Aperture area	62
2.5 Spectral radiance	62
3 Identification of key comparisons in radiometry and photometry	63
3.1 General introduction	63
3.2 Draft report of the CCPR working group on key comparisons	65
3.3 Links with regional groups	69
3.4 Role of the CCPR in monitoring comparisons	69
4 Short reports	71
4.1 Radiometric and photometric work at the BIPM	71
4.2 CIE activities	71
4.3 CCPR working group on air-UV spectral radiometry	71
4.4 CCT/CCPR working group	72

4.5 Comments concerning activities within regional metrology organizations	73
5 Other business	74
6 Date of next meeting	75
<b>Appendix P 1. Working documents submitted to the CCPR at its 14th meeting (see page 39)</b>	<b>77</b>
<b>List of acronyms used in the present volume</b>	<b>79</b>





## 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 m<sup>2</sup>) of the Pavillon de Breteuil (Parc de Saint-Cloud) placed at its disposal by the French Government; its upkeep is financed jointly by the Member States of the Metre Convention.

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

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

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

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

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

The CIPM has eighteen members each from a different State: at present, it meets every year. The officers of this committee present an annual report on the administrative and financial position of the BIPM to the Governments of the Member States of the Metre Convention. The principal task of the CIPM is to ensure worldwide uniformity in units of measurement. It does this by direct action or by submitting proposals to the CGPM.

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

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

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

The Consultative Committees have common regulations (*BIPM Proc.-Verb. Com. Int. Poids et Mesures*, 1963, **31**, 97). They meet at irregular intervals. The president of each Consultative Committee is designated by the CIPM and is normally a member of the CIPM. The members of the Consultative

Committees are metrology laboratories and specialized institutes, agreed by the CIPM, which send delegates of their choice. In addition, there are individual members appointed by the CIPM, and a representative of the BIPM (Criteria for membership of Consultative Committees, *BIPM Proc.-Verb. Com. Int. Poids et Mesures*, 1996, **64**, 124). At present, there are nine such committees:

1. The Consultative Committee for Electricity and Magnetism (CCEM), new name given in 1997 to the Consultative Committee for Electricity 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  $\gamma$  rays, electrons), Section II (Measurement of radionuclides), Section III (Neutron measurements), Section IV ( $\alpha$ -energy standards); in 1975 this last section was dissolved and Section II was made responsible for its field of activity);
7. The Consultative Committee for Units (CCU), set up in 1964 (this committee replaced the “Commission for the System of Units” set up by the CIPM in 1954);
8. The Consultative Committee for Mass and Related Quantities (CCM), set up in 1980;
9. The Consultative Committee for Amount of Substance (CCQM), set up in 1993.

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

- *Comptes Rendus des Séances de la Conférence Générale des Poids et Mesures*;

- *Procès-Verbaux des Séances du Comité International des Poids et Mesures*;
- *Reports of Meetings of Consultative Committees*.

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

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

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

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

# LIST OF MEMBERS OF THE CONSULTATIVE COMMITTEE FOR PHOTOMETRY AND RADIOMETRY

as of 10 June 1997

## President

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

Industrial Research Limited, Measurement Standards Laboratory of New  
Zealand [IRL], Lower Hutt.

Istituto Elettrotecnico Nazionale Galileo Ferraris [IEN], Turin.

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

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.



CONSULTATIVE COMMITTEE  
FOR PHOTOMETRY AND RADIOMETRY

REPORT  
OF THE 14TH MEETING

(10-11 June 1997)

TO THE COMITÉ INTERNATIONAL  
DES POIDS ET MESURES



## Agenda

- 1 Opening of the meeting; designation of a rapporteur; approval of the agenda.
- 2 Current state and provisional results of comparisons under way:
  - 2.1 Cryogenic radiometers using trap detectors as transfer standards;
  - 2.2 Luminous responsivity of photometers;
  - 2.3 Luminous intensity and luminous flux;
  - 2.4 Aperture area;
  - 2.5 Spectral radiance.
- 3 Identification of key comparisons in radiometry and photometry:
  - 3.1 General introduction;
  - 3.2 Draft report of the CCPR working group on key comparisons;
  - 3.3 Links with regional groups;
  - 3.4 Role of the CCPR in monitoring comparisons.
- 4 Short reports:
  - 4.1 Radiometric and photometric work at the BIPM;
  - 4.2 CIE activities;
  - 4.3 CCPR working group on air-UV spectral radiometry;
  - 4.4 CCT/CCPR working group;
  - 4.5 Comments concerning activities within regional metrology organizations.
- 5 Other business.
- 6 Date of next meeting.

# 1 OPENING OF THE MEETING; DESIGNATION OF A RAPPORTEUR; APPROVAL OF THE AGENDA

The Consultative Committee for Photometry and Radiometry (CCPR) held its 14th meeting at the Bureau International des Poids et Mesures (BIPM), Sèvres, on Tuesday 10 and Wednesday 11 June 1997. Four sessions were held.

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

Invited: Messrs P. Bloembergen (NMI-VSL), E. Ikonen (HUT).

Also attending the meeting: Messrs R. Goebel, R. Köhler, M. Stock (BIPM).

The President opens the meeting. As this is the first time he has attended a meeting of the CCPR he explains his background in optics, and his view that an important aspect of the role of the President is to maintain two-way communication with the CIPM. He remarks that he sees the function of Consultative Committees as to serve the metrology user community, in particular by providing trade-driven equivalence between accreditation bodies. He notes that the CCPR is the second-oldest of the Consultative Committees, with broad interests currently centred on taking advantage of advances in technology. He acknowledges the contribution made to the work of the CCPR by the previous President Dr Blevin, a member of CIPM for thirty-two years and President of the CCPR for fourteen years.

The Director of the BIPM joins in welcoming members to the meeting.

Dr Gardner is elected rapporteur.

The amended agenda is adopted.

The working documents submitted to this meeting are listed in Annexe P 1 (page 39).

## 2 CURRENT STATE AND PROVISIONAL RESULTS OF COMPARISONS UNDER WAY

Dr Köhler summarizes current activities. He also asks that, as the Executive Secretary to the CCPR, he be kept informed of correspondence and events related to the conduct of all comparisons and to the activities of the working groups.

### 2.1 Cryogenic radiometers using trap detectors as transfer standards

Dr Köhler reports that laboratories contributing to the comparison of cryogenic radiometers using trap detectors as transfer standards are divided into three groups, one of which has completed measurements according to schedule, with the others yet to participate. Preliminary results have been circulated to the first group. The Director of the BIPM asks that the results be considered as confidential until all laboratories have completed their measurements. An interim conclusion is that the trap detectors are performing well as transfer standards.

### 2.2 Luminous responsivity of photometers

Dr Köhler reports that fifteen laboratories are participating in the comparison of luminous responsivity. This comparison uses full-filtered, temperature-compensated commercial photometers supplied by three firms. One photometer showed an interference ring-structure in the filter, apparently a delamination within the filter, which developed with time. One laboratory noted this anomaly prior to measurement, and the photometers were replaced. All laboratories obtained their own photometers; after the measurements at the BIPM had been completed, the photometers were then returned to their home laboratories to check their stability. The median result of the first measurements shows a difference of 2 parts in  $10^3$  from the BIPM candela (adopted from the 1985 comparison of luminous intensity), with a relative standard deviation of  $8 \times 10^{-3}$ .

Dr Boivin asks whether laboratories have redefined their candela since 1985. Prof. Chen says that China has done so. Dr Köhler says such laboratories will be identified in the final report.

Mr Nettleton notes that the expected reduction in uncertainty in the realization of the unit is not reflected in the result. Dr Köhler says this is mostly due to non-uniformity and instability among the filtered detectors. The BIPM aims to reduce uncertainties by combining a precision aperture with a trap detector. Mr Nettleton notes that the reference photometers at NPL have been shown to be stable to about 2 parts in  $10^3$  over a period of about ten years. In response to Dr Boivin, he says that the filters have not been cleaned. Dr Köhler quotes a CIE Technical report which shows that some photometers were stable, but that others drifted with time.

Dr Bloembergen asks about the delamination. Dr Boivin and Dr Gardner describe their experiences, and report that the detectors showed a series of interference rings in the aperture, not always centred in the aperture, which developed with time. One photometer at the CSIRO had developed the rings as it was heated for use, the rings then disappeared when the heating current was removed. Dr Köhler says that the manufacturer confirmed the existence of a problem with cementing of the layers of the filter: this had its origin in the method used to apply pressure for the elimination of bubbles from the cement.

Dr Gardner and Dr Parr question whether dispersed or line-monochromatic radiation should be used for the comparison; Dr Köhler replies that the final result requires comparison with incandescent lamps.

## 2.3 Luminous intensity and luminous flux

Prof. Metzdorf says seventeen laboratories have indicated a desire to participate in the luminous intensity and luminous flux comparisons, but no lamps have yet been received at the PTB from participants. He notes that there have been delays in the acquisition of lamps, but notes that WI41G production has now returned to Germany. He thinks it will not be possible to achieve the scheduled completion date of June 1998. The Committee agrees that the comparison should proceed as quickly as possible, so as to provide a strong link to the results of the luminous responsivity comparison, and that at least some flux results should be available by the time of the next CCPR meeting. The PTB and the BIPM will undertake some extra bilateral comparisons to provide a robust link between the results of this comparison and those of the 1985 comparison.

## 2.4 Aperture area

Dr Parr notes that only four laboratories have expressed interest in the comparison of aperture areas. Apertures are being diamond-turned at the NIST, but measurements will have to wait until 1998 as the NIST facilities are being relocated. In response to questions, Dr Parr says that the aperture profile is such that contact methods of measurement may not be possible. The NIST uses a mixture of methods: contact for large areas and optical for comparison. Dr Quinn remarks that advances in contact methods mean that measurements can now be made to within a few tens of nanometres, and notes that the BIPM may in the future be able to participate. Prof. Ikonen says Finland is also interested. Dr Saunders suggests that another request for participation should be prepared, as others may also be interested. In response to Mr Nettleton's suggestion that diffraction experts should be consulted early in the process, Dr Parr says that his NIST colleagues dealing with infrared measurements are well versed in diffraction matters.

## 2.5 Spectral radiance

Dr Sapritsky says that the spectral radiance comparison facilities at the VNIIOFI are being prepared, with narrow-channel graphite and pyrolytic graphite black bodies for reference. New mirror optics for the lamp comparisons are being produced, to reduce aberrations when comparing lamps. Orders for the Polaron lamps used in the comparison require a six month lead time, but the comparison could begin in September/October 1998. The Committee decides that the wavelength range for the comparison should be 240 nm to 2500 nm: a lower limit of 220 nm would require the use of deuterium lamps as well as the Polaron quartz-halogen lamps. Dr Köhler notes that only four laboratories have expressed interest; a new proposal with the new details will be circulated by the CCPR secretary. An inverted star comparison is suggested: laboratories will each submit two sets of three lamps, with different operating temperatures for different wavelength ranges.

### 3 IDENTIFICATION OF KEY COMPARISONS IN RADIOMETRY AND PHOTOMETRY

#### 3.1 General introduction

Dr Quinn notes that there is an increasing need to define equivalence of measurement between countries. This need is primarily driven by trade, rather than by scientific interest.

The international equivalence of measurement provided by national calibration certificates (many now provided by laboratories with the calibration service backed by a documented quality system) is now largely in place but is not systematically documented. The objective in identifying key comparisons is to select a set of measurements such that data obtained by one laboratory may be compared closely with those of other laboratories so as to establish the capabilities of that laboratory, in some particular field, relative to those of the other laboratory taking part in the comparison. Although the key comparisons represent no more than a modest subset of the measurements undertaken in a particular field, they are chosen so that they make demands on high-level skills and so extend some confidence to related measurements undertaken by the laboratory.

Key comparisons are organized by the Consultative Committees and then repeated in regional comparisons. A regional comparison always includes at least one laboratory that has participated in a comparison organized by the Consultative Committee. While bilateral comparisons are not excluded from this system, the mechanism of key comparisons is seen as a more efficient method of obtaining measurement equivalence over a large number of laboratories.

The Consultative Committees are considered to act as technical experts in the evaluation of key comparisons. For each key comparison, an appropriately weighted mean of the results or their median, as well as an uncertainty which

takes into account the effect of correlations, are used to provide a reference value. This is taken to be a close approximation to the best value expressed in SI units, and is referred to as the SI reference value. Dr Quinn uses the recent spectral responsivity comparison as an example. In this case, different conclusions may have been drawn for different wavelength ranges. In the UV range, the problem arising from the presence of an outlier may be handled by using the median of the result, rather than the mean. He notes that the BIPM is considering this problem as part of a study in “robust statistics”.

Dr Wallard reminds the Committee that the number of key comparisons is limited, that the Committee must develop a protocol for each, and that the task represents a considerable effort for the laboratories concerned. He invites discussion of Dr Quinn’s presentation.

Dr Gardner believes that the SI unit should be evaluated separately within the comparison and not simply be taken as the mean. Only laboratories independently realizing a unit should be considered. Dr Quinn replies that this was the intent of his statement on correlations. Responding to a question from Dr Parr on the driving force for the process, Dr Quinn says that the BIPM has been asked by international accreditation bodies for an explanation of the agreements which exist among the national laboratories. Publication in *Metrologia*, in the format previously used, is seen as not sufficient: there is need for a clear statement on equivalence as the world trade organizations seek to reduce technical barriers to trade. Dr Wallard comments that European agreements are seen outside Europe as restricting and protectionist. While a Memorandum of Understanding may be in place, it is likely to be restricted in its application. Prof. Soardo remarks that accreditation systems base their recognition agreements on confidence in methods, gained by visits and comparisons and points out that there is also a need for non-expert countries to be able to participate in agreements, so that they can formally accept measurements made in other countries. Dr Boivin expresses concern about the political nature of statements of equivalence, and the expansion to a second level of calibration certificates. Dr Quinn replies that the outcome of a comparison is a technical statement, which sets the minimum level of equivalence between national laboratories. Mr Nettleton says that users will most likely be unconcerned about outliers: calibration certificates will generally have a large uncertainty relative to that given for the realization of primary standards by national laboratories.

Dr Parr remarks that it is not the role of the Consultative Committees to define the equivalence of accreditation systems, and expresses concern that there

may be legal problems with the SI reference value. As an example, he notes that the representation of the SI units provided by the NIST is a legal entity under US law. Dr Quinn replies that the proposals seek minimum interference with national systems. Mr Denner sees advantages in the new system since it removes the need for bilateral agreements between individual countries: these are expensive, particularly for countries outside the Metre Convention.

Dr Quinn confirms that the result of each key comparison will be published, as a technical result, and laboratories will be named. Laboratories will be given an opportunity to correct obvious errors. No further analysis or comment will be made by the BIPM, and no comment will be made on the agreement between particular laboratories.

Mr Nettleton sees problems in providing a constant representation of an SI unit when uncertainties are large. Dr Metzdorf questions the methods used to derive a mean from a comparison and to treat outliers. He refers to a recent comparison which involved thirteen participant laboratories, of which only four calibrated their equipment against primary standards. Prof. Soardo says the market is concerned only with equivalence between certificates, not with reference to the SI unit. Dr Bloembergen agrees: he asks whether, in seeking equivalence, the reference to the value of the SI unit is lost. Dr Quinn wants to place more importance on the use of SI units. The SI reference value and statements of equivalence can be seen as separate outcomes of a comparison. Similarly, a high level of constancy can be maintained as an outcome, when this is required by industrial users. Prof. Wende is concerned that, in some cases, the result of a comparison will produce a reference value representing an artefact, rather than the SI reference value.

A vote is taken on the use of the term “SI reference value” as an outcome of every key comparison. Opinions are evenly divided.

### 3.2 Draft report of the CCPR working group on key comparisons

Dr Parr mentions document CCPR/97-3, stressing that the discussion centred on key comparisons relates to trade, not to scientific issues. He remarks that the use of electronic mail had been very successful in promoting discussion. The five comparisons seen as key by the working group are spectral irradiance, spectral responsivity, luminous intensity (and/or luminous responsivity), luminous flux and spectral diffuse reflectance. Dr Wallard thanks Dr Parr and members of the working group for their efforts, and calls for discussion.

Dr Gardner says that the listed areas favour laboratories with well-developed measurement capabilities. He notes that a laboratory which provides measurements



for lighting but has no spectral measurement capability may have difficulty in specifying distribution temperature, although this can be derived from spectral irradiance. It is agreed that where the need arises, the regional metrology groups could organize comparisons of such quantities as distribution temperature. Dr Wallard notes that laboratories other than national metrology institutes could be invited to participate in regional comparisons. Prof. Soardo asks whether laboratories from the regional groups, but not represented on the CCPR, could participate in the main comparisons. Dr Quinn replies that, in general, this would be unmanageable. In fact, the criteria for membership of the CCPR should ensure that all national laboratories of high technical competence are members. It is possible for observers of Consultative Committees, not fulfilling the full requirements for membership, to participate in Consultative Committee comparisons. The requirement is that the laboratory is at the national level, with a record of research in standards and a record of participation in comparisons. Dr Lee asks that the number of key comparisons be kept small as resources are limited. Prof. Metzdorf says that a number of conditions are unstated, for example the luminous flux and luminous intensity are understood to be that from incandescent lamps, not from discharge or fluorescent lamps. Dr Rastello says the same is true of the range of measurement: comparisons typically specify 2500 lm, but many measurements are made at lower values. Dr Quinn replies that key comparisons cover no more than a small set of measurements: their function is to provide confidence that measurements made in related areas and ranges, extending beyond the actual quantities compared, are of acceptable quality.

Mr Nettleton says that the wavelength range needs to be clearly defined for all comparisons, since different techniques are used in different regions. He also suggests that spectral regular transmittance be included in the list of key comparisons, since this is the most common comparison identified by EUROMET. Prof. Metzdorf notes the need to define the geometry and wavelength range for spectral diffuse reflectance. If only a small number of laboratories have a certain measurement capability, it may not be appropriate to identify the measurement as a key comparison. Dr Quinn replies that the significance of the area is the important factor: in some areas a small number of laboratories may have a large influence. Prof. Metzdorf says that laboratories other than those represented on the CCPR are important in the measurement of diffuse reflectance. Mr Nettleton remarks that there is need for a world scale for diffuse reflectance, and that this is a current concern of the CIE. Dr Quinn says dimensionless quantities such as reflectance are important, as they represent the ratio of two samples of a same quantity.

Dr Parr repeats that the quantities chosen by the working group were selected for their commercial importance. They were not intended to be restrictive. Dr Wallard agrees that this is the correct view to take of the list, and remarks that comparisons other than those listed may be required for scientific reasons. Dr Köhler mentions the need for comparisons of spectral radiance.

Dr Saunders asks for the time-frame of the key comparisons. Dr Quinn says that they will be repeated on a regular basis. A period of ten years is generally considered to be appropriate, but this may change as technology improves.

The Committee agrees that the five topics proposed for key comparisons should be adopted. Mr Nettleton suggests the addition of spectral regular transmittance; the CCPR agrees. Dr Wallard thanks Dr Parr and the working group for their efforts. Discussion then turns to the individual topics.

### 1. Spectral irradiance

The following laboratories express interest in participating in the spectral irradiance comparison: BNM, CSIC, CSIR, CSIRO, ETL, HUT, IEN, KRISS, OFMET, OMH, NIM, NIST, NMi, NPL, NRC, PTB, SMU.

Wavelength ranges of 200 nm to 400 nm or 250 nm to 2500 nm are seen as important and involve the use of different lamps. Mr Nettleton says that a comparison in the wavelength range 200 nm to 400 nm is currently under way. There is general agreement that the wavelength range should be 250 nm to 2500 nm. The NPL and the PTB both express interest in acting as the pilot laboratory. Dr Köhler says that the BIPM is also interested, but does not currently have all the facilities required. A steering committee of NPL (convenor), NIST, PTB and BIPM is formed. A starting date of April 1998 is suggested (circulation of invitations), the work to be completed within the following three years.

### 2. Spectral responsivity

The following laboratories express interest in participating in the spectral responsivity comparison: BNM, CSIC, CSIR, CSIRO, ETL, HUT, IEN, IRL, KRISS, NIM, NIST, NMi, NPL, NRC, OFMET, OMH, PTB, SMU.

Dr Gardner asks whether the recently completed comparison is to be considered as a key comparison. Dr Quinn says that if the protocols were satisfactory, the Committee could set up a working group to express the results in key comparison form. Mr Nettleton expresses concern that laboratories may have altered their methods or standards since the comparison. Dr Boivin asks whether the current comparison using trap detectors should be considered as a

key comparison of spectral responsivity. Mr Bastie suggests that the intent is different: the goal is to compare cryogenic radiometers. Mr Fox says that comparisons of cryogenic radiometers provide a higher level of confidence than can otherwise be achieved. Dr Parr reminds the Committee that key comparisons are aimed more at the commercial than scientific demands.

The Committee agrees that a new comparison of spectral responsivity should be undertaken as more laboratories now use cryogenic radiometers and much new work in developing filtered detectors has taken place since the last comparison. Prof. Wende mentions the need for caution in the use of silicon detectors at UV wavelengths, since exposure to short wavelengths has been demonstrated to affect the stability of response at longer wavelengths. Two wavelength ranges are adopted, covering different practical technologies and allowing the effort involved to be shared among laboratories. Mr Nettleton notes that much effort went into preparing the silicon photodiodes used as artefacts in the last comparison and that they could be re-used. Dr Köhler states a preference for trap detectors, as they offer better stability, even although the number currently available is not sufficient. Dr Boivin sees problems with vignetting if trap detectors are used, and would prefer to use single photodiodes (with better windows than those provided on the commercial detectors). The NIST expresses interest in acting as a pilot laboratory for the infrared measurements and the IRL for the visible. It is decided to leave the details to a working group comprised of the BIPM (convenor), IRL, NIST, NPL, NRC and the PTB. A target date of December 1997 is suggested for initiation of the project.

### 3. Luminous intensity/responsivity

All eighteen laboratories attending the meeting express interest in the luminous intensity/responsivity comparison. Comparisons in this area are currently being undertaken and it is decided that these comparisons will be treated as key comparisons. Dr Saunders observes that as only fifteen laboratories are currently participating, invitations should be extended to the others expressing interest. The PTB continues as the co-ordinating laboratory for luminous intensity and the BIPM for luminous responsivity.

### 4. Luminous flux

The following laboratories express interest in participating in the luminous flux comparison: BNM, CSIC, CSIR, CSIRO, ETL, IEN, KRISS, OMH, NIM, NIST, NPL, NRC, OFMET, PTB, SMU.

This is currently under-way, with PTB as the co-ordinating laboratory. Mr Denner asks whether this is limited to laboratories with goniophotometers. Dr Köhler

replies that this is not the case, but that goniophotometer information may be used in analysing the results.

### 5. Spectral diffuse reflectance

The following laboratories express interest in participating in the spectral diffuse reflectance comparison: BNM, CSIC, ETL, IEN, IRL, KRISS, NIM, NIST, NMi, NPL, NRC, OMH, PTB, SMU.

It is agreed that 1) measurements should be restricted to the visible wavelength range; 2) this is not a measurement of bidirectional reflectance distribution factor, and 3) the exact geometry to be used should be determined by the working group consisting of the NIST(convenor), KRISS, NPL, NRC, and the PTB. An artefact will be distributed to laboratories to check the method of measurement. This comparison is not seen as a means of checking the absolute accuracy of the reference. It will begin in December 1997.

### 6. Spectral regular transmittance

The following laboratories express interest in participating in the spectral regular transmittance comparison: BNM, CSIC, CSIR, CSIRO, ETL, HUT, IEN, IRL, KRISS, NIST, NMi, NPL, NRC, OFMET, OMH, PTB, NIM.

The infrared range is seen as important as this is used widely in the pharmaceutical industry. Matters to be decided by the working group are: the wavelength range, whether to check the photometric accuracy only using neutral filters; and whether to check the wavelength accuracy. A first comparison will begin in December 1997, with the timing of subsequent comparisons to be determined from the results. A working group of the BNM (convenor), IRL, NIST, NPL and the PTB is formed.

## 3.3 Links with regional groups

Dr Wallard notes that the regional groupings APMP, EUROMET and NORAMET are well represented on the CCPR so results may easily be communicated to them. Mr Denner comments that the CSIR is the only laboratory representing the African area, but that they have links with the APMP regional group.

## 3.4 Role of the CCPR in monitoring comparisons

Dr Quinn proposes that a working group be set up to deal with key comparisons. This will determine the protocol to be followed, set a timetable, list the main uncertainty components to be included in reporting the results, and invite participation from all CCPR laboratories. (Copies of all invitations

will be sent to the CCPR executive secretary at the BIPM.) All results will be reported to the CCPR for discussion before being promulgated.

Dr Gardner asks whether industrial laboratories outside CCPR, particularly ones with expertise in reflectance/transmittance measurements, should be invited to participate. The consensus is that there are few such laboratories, and that they should be invited to participate at regional level.

A working group is formed to monitor the key comparisons its members being Dr Wallard (Chairman), Dr Köhler (Secretary) and the CSIRO, ETL, KRISS, NIM, NIST, NPL and PTB.

Terms of reference are agreed. The working group will:

- identify key comparisons;
- monitor the progress of key comparisons;
- ensure consistency in the interpretation of results obtained during key comparisons;
- identify trends or issues that emerge from the monitoring process;
- ensure consistent treatment of uncertainties and reference values;
- receive and examine the results of key comparisons carried out by the regional metrology organizations.

Initial tasks for this group are to formulate a method to analyse results in terms of a mean, median, or other, outcome, and to evaluate the report on the air-UV comparison, treated as a key comparison. Most members of the group will either be present, or will be able to name a substitute, for an initial meeting during the NEWRAD'97 conference.

## 4 SHORT REPORTS

### 4.1 Radiometric and photometric work at the BIPM

Dr Köhler refers to documents CCPR/97-5, 97-7 and 97-8. A visit to the BIPM laboratories is planned. The Committee commends the BIPM on its activities in the area of radiometry and photometry.

### 4.2 CIE activities

Mr Bastie reports that the CIE is active in generating standards related to radiometry and photometry for adoption by the ISO. These include a formal adoption of  $V(\lambda)$ , which has been classed as provisional since 1924. He lists recent technical reports and CIE publications in CCPR related areas, and notes that the CIE *International Lighting Vocabulary* is currently under review.

### 4.3 CCPR working group on air-UV spectral radiometry

Prof. Wende introduces document CCPR/97-1. Comparisons of spectral radiance in the range 200 nm to 400 nm, averaged over 9 deuterium lamps, show that the NIST, NPL and PTB agree to within one standard deviation at 200 nm, with NPL drifting slightly more at 400 nm. Mr Nettleton says the agreement has improved since the introduction of a correction for the ageing of the lamps. The results are considered acceptable, given the current level of technology, and show that deuterium lamps are more suitable for the comparison and the maintenance of a scale of relative spectral power distribution than for an absolute scale. Their performance is better for spectral radiance than for irradiance, possibly because the higher signal levels improve the repeatability. Both the NPL and the PTB noted that for radiance measurements, however, the long-term stability (over several years) of selected lamps is better when such lamps are used as a group and aligned for maximum signal strength.

Mr Nettleton presents further results for irradiance. Here, differences between the NIST and the PTB are more significant, and larger than seen in the 1990

NIST/PTB bilateral comparison. As expected, preliminary results from the CSIRO agree with those of the NIST, since their scales are not independent of each other. Mr Saunders comments that the Polaron lamps had lower irradiance levels than the FEL lamps used in 1990, and that the NIST encountered problems with alignment of the Polaron lamps. He also says that the NIST found good internal agreement between their synchrotron and black-body references. It is concluded that large relative uncertainties of 0.15 to 0.20 must still be assigned to UV quantities and it is remarked that the space community in particular requires better accuracy.

Dr Parr uses the comparison to illustrate the difficulties of interpreting the expression an “SI reference value”. Mr Nettleton suggests that the comparison provides a good example for the working group on key comparisons: in question is how the results would be interpreted if this were a key comparison. Dr Wallard says that the spectral irradiance working group should decide how to handle the results. At this stage the results are incomplete and need further correction. As a new comparison of spectral irradiance has already been planned (250 nm-2500 nm), it is decided that the working group should also be responsible for all further work in spectral irradiance, using all the available information in its planning. Dr Quinn says that if the results from the comparisons represent state-of-the-art measurement in UV radiometry, then they should be published in *Metrologia*. Prof. Metzdorf and Dr Parr remind members that the comparison was originally conceived as a pilot study with a full comparison to follow. It was therefore agreed that results should be published as a CCPR report only. Prof. Metzdorf suggests that the air-UV working group should be discontinued. Mr Nettleton points out that the original report of the group outlined an extended programme. Dr Wallard says the group should continue until the next CCPR meeting and its future be decided then.

Prof. Wende summarizes other activities. A workshop on detector-based UV radiometry has been held. International collaboration has led to the development of a new UV detector, a Pt-Si on Si Schottky diode, which does not show degradation of response on exposure to UV radiation. The response of this photodiode is smaller, by a factor of approximately 4, than conventional diodes, but it is stable. Successful trap detectors using these photodiodes have also been demonstrated.

#### 4.4 CCT/CCPR working group

Dr Quinn reminds the Committee that the CCT/CCPR working group is instructed to consider whether direct measurements via absolute radiometry have sufficient reproducibility and accuracy to replace the ITS-90 (radiance

relative to fixed points) at high temperatures. A table of uncertainties (CCPR/97-9) concludes that the two methods have equivalent accuracy under current best practice. Dr Quinn notes that it is difficult to obtain the nominated best uncertainties on all quantities in the one measurement. Discussion by Messrs Fox, Parr and Saunders focuses on the accuracy of wavelength determination, which is critical in both methods. Dr Sapritsky suggests that operating a black body at 3000 K, instead of the proposed 2500 K, would reduce errors and that a stability of 1 part in  $10^4$  is achievable at the higher temperature.

Document CCPR/97-9 proposes two series of comparisons, one of spectral responsivity of filter radiometers (NIST to lead) and the other of methods to determine the thermodynamic temperature of a black body (NPL to lead). These comparisons are supported by document CCPR/97-10. They involve a limited number of laboratories which are members of the CCT and the CCPR. The comparisons are approved.

#### 4.5 Comments concerning activities within regional metrology organizations

Dr Bloembergen reports that EUROMET has twenty-three active projects, including comparisons and workshops. Key comparisons are planned for spectral irradiance (PTB to co-ordinate), luminance/illuminance (NPL), UV power (NPL) and high laser power (PTB). EUROMET has prepared an extensive list of quantities and instruments to be compared.

Dr Gardner reports the APMP is currently undertaking, or has planned, comparisons of spectral irradiance (KRISS, extension of the CCPR comparison), luminous intensity (CMS Taiwan) and luminous responsivity (CSIRO, extension of the CCPR comparison). A general meeting of the APMP is scheduled for November 1997.

Mr Denner reports that the African trading region is looking to improve metrology in a way similar to APMP. The initial priority is photometry.

Dr Parr reports that NORAMET intends to map the CCPR comparisons to the North American region, where the main beneficiary would be Mexico.



## 5 OTHER BUSINESS

Dr Quinn mentions the NEWRAD international radiometry conference, scheduled to be held in October 1997 in Tucson, Arizona, and suggests that there is a need to form a permanent steering group. He plans to raise this question at the conference with representatives of the metrology, solar physics, earth resources and space communities.

Mr Denner informs the Committee of a meeting on radiometry to be held in South Africa prior to the CIE congress later in 1997.

In reply to a question by Dr Saunders on the existence of a BIPM web page, Dr Quinn says that one is under development, and asks CCPR members to pass relevant links to Dr Köhler.

## 6 DATE OF NEXT MEETING

A provisional date of April 1999 is agreed for the next meeting. On behalf of the members the Director thanks Dr Wallard for his efficient conduct of the discussions of the CCPR. Dr Wallard thanks all for their participation, in particular members of the working groups. The meeting is closed.

J.L. GARDNER, Rapporteur  
July 1997  
revised April 1998



**APPENDIX P 1.**

**Working documents submitted to the CCPR at its 14th meeting**

(see the list of documents on page 39).

## ANNEXE P 1.

### Documents de travail présentés à la 14<sup>e</sup> session du CCPR

Ces documents de travail peuvent être obtenus dans leur langue originale sur demande adressée au BIPM.

#### Document

##### CCPR/

- 97-1 Report of the working group on air-ultraviolet spectral radiometry to the Comité Consultatif de Photométrie et Radiométrie, Part II, Results of a comparison of UV source measurement scales, 88 p.
- 97-2 Report of the joint CCT/CCPR working group on thermodynamic temperature measurements, 4 p.  
Note, by H.J. Jung (PTB, Berlin), 1 p.
- 97-3 Report of the working group on key comparisons in photometry and radiometry, by A. Parr, 4 p.
- 97-4 BIPM. — Note on « Equivalence of national measurement standards » and « Framework and Agreement for establishing metrological equivalence of national measurement standards and of calibration and other measurement certificates issued by national metrology institutes », by T.J. Quinn, 8 p.
- 97-5 BIPM. — Progress report on the international comparison of cryogenic radiometers, Explanatory note, by R. Goebel, M. Stock and R. Köhler, 1 p.
- 97-6 Current status of CCPR activities: International comparisons, working groups, 1 p.
- 97-7 BIPM. — Preliminary results from the international comparison of luminous responsivity, by R. Köhler, M. Stock, C. Garreau, 4 p.



## LIST OF ACRONYMS USED IN THE PRESENT VOLUME

### 1 Acronyms for laboratories, committees and conferences

APMP	Asia/Pacific Metrology Programme
BIPM	Bureau International des Poids et Mesures
BNM-INM	Bureau National de Métrologie: Institut National de Métrologie, Paris (France)
CCPR	Consultative Committee for Photometry and Radiometry
CCT	Consultative Committee for Thermometry
CIE	International Commission on Illumination
CIPM	Comité International des Poids et Mesures
CSIC-IFA	Departamento de Metrologia, Instituto de Fisica Aplicada, Madrid (Spain)
CSIR	Council for Scientific and Industrial Research, National Metrology Laboratory, Pretoria (South Africa)
CSIRO	CSIRO, National Measurement Laboratory, Lindfield (Australia)
*CSMU	Československý Metrologický Ústav, Bratislava (former Czechoslovakia), see SMU
*DSIR	Department of Scientific and Industrial Research, Lower Hutt (New Zealand), see MSL
ETL	Electrotechnical Laboratory, Tsukuba (Japan)
EUROMET	European Collaboration in 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

---

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

IRL	Industrial Research Limited, Measurement Standards Laboratory of New Zealand, Lower Hutt (New Zealand),
ISO	International Organization for Standardization
KRISS	(formerly the KSRI) Korea Research Institute of Standards and Science, Taejon (Rep. of Korea)
*KSRI	Korea Standards Research Institute, Taejon (Rep. of Korea), see KRISS
*MSL	(formerly the DSIR) Measurement Standards Laboratory of New Zealand, Lower Hutt (New Zealand), see IRL
NASA	National Aeronautics and Space Administration
*NBS	National Bureau of Standards, Gaithersburg (United States), see NIST
NEWRAD	Conference on New Developments and Applications in Optical Radiometry
NIM	National Institute of Metrology, Beijing (China)
NIST	(formerly the NBS) National Institute of Standards and Technology, Gaithersburg (United States)
NMi-VSL	Nederlands Meetinstituut: Van Swinden Laboratorium, Delft (Netherlands)
NORAMET	North American Metrology Cooperation
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)
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig and Berlin (Germany)
SMU	(formerly the CSMU) Slovenský Metrologický Ústav/Slovak Institute of Metrology, Bratislava (Slovakia)
VNIIOFI	All-Russian Research Institute for Optophysical Measurements, Moscow (Russian Fed.)

## 2 Acronyms for scientific terms

FEL	Type of lamp supplied by General Electric Co. (United States)
ITS-90	International Temperature Scale of 1990
SI	International System of Units

STEDI  
 1, Boulevard Ney, 75018 Paris  
 Dépôt légal, n°5710  
 ISSN 0069-6447  
 ISBN 92-822-2161-X  
 Achievé d'imprimer: octobre 1998  
 Imprimé en France