Comité consultatif de thermométrie (CCT)

Consultative Committee for Thermometry (CCT)

Rapport de
la 19e session
(septembre 1996)
Report of
the 19th Meeting
(September 1996)

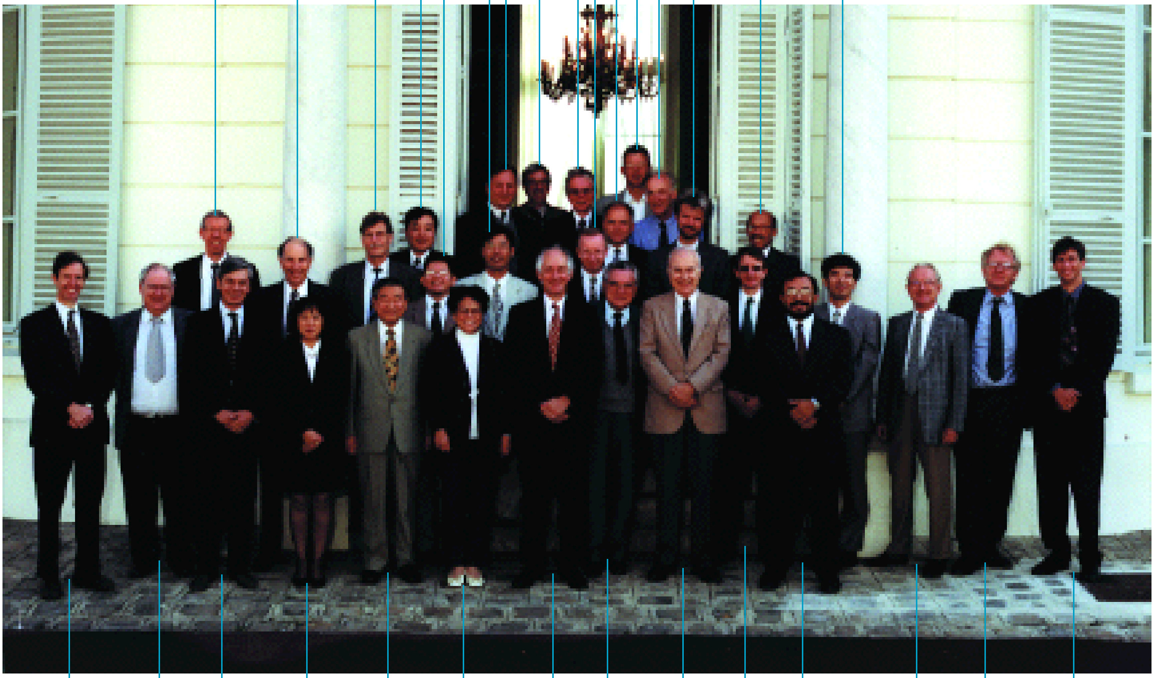
Bureau
international
des poids
et mesures

Organisation
intergouvernementale
de la Convention
du Mètre

Comité consultatif de thermométrie ▮ 19e session (septembre 1996)
Consultative Committee for Thermometry ▮ 19th Meeting (September 1996)

Comité consultatif de thermométrie
19e session (18-20 septembre 1996)

R. Köhler
R. Pello K. Hill
G. Bonnier A.I. Pokhodun
K.H. Kang P.P.M. Steur
E. Méndez M. Durieux
B.W. Mangun Duan Yuning S. Duris K. Nara
K. Grohmann P. Marcarino
R.E. Bedford



R.L. Rusby T.J. Quinn M. de Groot
J. Nicholas Zhao Qi P. Giacomo H.-J. Jung
T. Ricolfi C. Rhee R.P. Hudson J. Valencia P. Bloembergen
Wang Li M. Ballico

Bureau International des Poids et Mesures

Consultative Committee for Thermometry (CCT)

19th Meeting (September 1996)

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

MEMBER STATES OF THE METRE CONVENTION

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

THE BIPM AND THE METRE CONVENTION

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

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

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

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

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

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

- discuss and initiate the arrangements required to ensure the propagation and improvement of the International System of Units (SI), which is the modern form of the metric system;

- confirm the results of new fundamental metrological determinations and various scientific resolutions of international scope;
- take all major decisions concerning the finance, organization and development of the BIPM.

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

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

Some forty-five physicists or 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 γ rays, electrons), Section II (Measurement of radionuclides), Section III (Neutron measurements), Section IV (α-energy standards); in 1975 this last section was dissolved and Section II was made responsible for its field of activity);
7. The Consultative Committee for Units (CCU), set up in 1964 (this committee replaced the "Commission for the System of Units" set up by the CIPM in 1954);
8. The Consultative Committee for Mass and Related Quantities (CCM), set up in 1980;
9. The Consultative Committee for Amount of Substance (CCQM), set up in 1993.

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

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

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

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

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

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

LIST OF MEMBERS OF THE CONSULTATIVE COMMITTEE FOR THERMOMETRY

as of 18 September 1996

President *ad interim*

T.J. Quinn, Bureau International des Poids et Mesures [BIPM], Sèvres.

Executive secretary

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

Members

All-Russian Research Institute for Physical, Technical and Radiotechnical Measurements [VNIIFTRI], Moscow.

Bureau National de Métrologie, Paris: Institut National de Métrologie [BNM-INM] du Conservatoire National des Arts et Métiers, Paris.

CSIRO, National Measurement Laboratory [CSIRO], Lindfield.

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

Istituto di Metrologia G. Colonnetti [IMGC], 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.

National Research Laboratory of Metrology [NRLM], Tsukuba.

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

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig and Berlin.

Slovenský Metrologický Ústav [SMU], Bratislava.

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

CONSULTATIVE COMMITTEE FOR THERMOMETRY

REPORT OF THE 19TH MEETING

(18-20 September 1996)

TO THE COMITÉ INTERNATIONAL DES POIDS ET MESURES

Agenda

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

2 Documents presented to the meeting.

3 Studies concerning the ITS-90:

- 3.1 Non-uniqueness;
- 3.2 Reproducibility of the fixed points;
- 3.3 Questions relating to the interpolating instruments;
- 3.4 New information on $(T - T_{90})$;
- 3.5 Uncertainty of ITS-90 realization;
- 3.6 Reports of working groups:
  - 3.6.1 Working group 1: defining fixed points and interpolating instruments,
  - 3.6.2 Working group 2: secondary fixed points and techniques of approximation to the ITS-90,
  - 3.6.3 Working group 3: international equivalence in temperature measurements and corresponding international comparisons,
  - 3.6.4 Working group 4: thermodynamic temperature determinations and extension of the ITS-90 to lower temperatures,
  - 3.6.5 Working group 5: joint CCT/CCPR working group on thermodynamic-temperature determinations for high-temperature black bodies,
  - 3.6.6 Working group 6: humidity measurements.

4 Temperature scales below 1 K and the possible extension of the ITS-90 below 0.65 K.

5 Establishment and composition of working groups.

6 Recommendations and report to the CIPM.

7 Other business.

8 Next meeting.

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

The nineteenth meeting of the Consultative Committee for Thermometry (CCT) took place at the Pavillon de Breteuil, Sèvres, on 18, 19 and 20 September 1996.

Present: M. Ballico (CSIRO), R.E. Bedford (NRC), P. Bloembergen (NMi-VSL), G. Bonnier (BNM-INM), M. de Groot (NMi-VSL), Duan Yuning (NIM), S. Duris (SMU), K. Grohmann (PTB), K. Hill (NRC), H.-J. Jung (PTB), K.H. Kang (KRISS), B.W. Mangum (NIST), P. Marcarino (IMGC), N. Moiseeva (VNIIM), K. Nara (NRLM), A.I. Pokhodun (VNIIM), T.J. Quinn (Director of the BIPM, President *ad interim*), C. Rhee (KRISS), T. Ricolfi (IMGC), R.L. Rusby (NPL), P.P.M. Steur (IMGC), Zhao Qi (NIM).

Invited: M. Durieux (KOL), P. Huang (NIST), R.P. Hudson, E. Méndez and J. Valencia (CENAM), J. Nicholas (IRL), Wang Li (PSB).

Also present: R. Köhler and R. Pello (BIPM).

Absent: VNIIFTRI.

In commemoration of Prof. Luigi Crovini, President of the CCT, who died suddenly on 21 October 1995, Dr Quinn reads the introduction to the special issue of *Metrologia* dedicated to his memory (*Metrologia*, 1996, **33**, No. 4). This introduction describes the many aspects of the work undertaken by Luigi Crovini in the realm of thermometry, in particular his key role in the development of the ITS-90 and the activities of the CCT.

Dr Quinn mentions that a copy of the special issue, which had just been published, was presented to Mrs Toya Crovini at Tempmeko'96 in Turin on 11 September 1996. He also mentions the great assistance he received from Dr Ricolfi and Dr Rusby in editing the special issue.

Because the CIPM has not yet appointed a new president, Dr Quinn presides at the present meeting of the CCT; he remarks that he would be happy to do so, were it not for the sad circumstances which lead him to take the chair.

Dr Durieux is appointed as rapporteur.

The provisional agenda is changed slightly and then approved.

2 DOCUMENTS PRESENTED TO THE MEETING

A BIPM “Note for discussion on international equivalence of national measurement standards” and twenty-eight other documents were received before the meeting. Another six documents and a copy of the report of the working group on humidity measurements are distributed during the meeting. All documents are listed in Annexe T 1. It is agreed that particular documents will be discussed under the appropriate items of the agenda. The president notes that copies of the documents will be retained at the BIPM where they are available on request; bound copies will be sent to committee members.

3 STUDIES CONCERNING THE ITS-90

3.1 Non-uniqueness

At the meeting of the CCT in 1993 it was observed that the concept of non-uniqueness had become “a little fuzzy”. Dr Mangum explains how the report of Working group 1 (CCT/96-8), which is preliminary to a planned updated form of the *Supplementary Information*, identifies three types of non-uniqueness. These are: the uncertainties in reported values of T_{90} arising from the application of different interpolation equations in overlapping ranges using the same thermometer (type 1); the use of different kinds of thermometers in overlapping ranges (type 2); the use of real thermometers (type 3). Type 1 non-uniqueness was, in the case of standard platinum resistance thermometers (SPRTs), formerly described as subrange-inconsistency. Type 3 non-uniqueness was the only form to occur in the IPTS-68 and its predecessors.

Mr Bonnier emphasizes that the non-uniqueness under discussion refers to “significant” differences in reported values of temperature over and above those inherent in the measurements. Dr Bedford draws attention to Dr Ancsin's document CCT/96-10, part 2, which suggests that the type 3 non-uniqueness of SPRTs in the range 0 °C to 660 °C may be reduced by using slightly different (least-squares) calibration schemes and, for very good SPRTs, with high values of the resistance ratio $W(T)$, fewer calibration points. In the ensuing discussion it is pointed out that the idea of using least-squares interpolation equations was introduced many years ago. After close study the idea was rejected because, although the non-uniqueness was reduced, the consequent small inconsistency of the values assigned to the reference temperatures was considered unacceptable.

3.2 Reproducibility of the fixed points

Results of two international comparisons of triple point of water cells are presented to the meeting. One comparison was organized by the BIPM following Recommendation T 2 (1993); the other was a EUROMET project with the BNM-INM as the pilot laboratory.

Dr Köhler explains the methodology and results of the BIPM comparison (CCT/96-1). Two sets of cells, each set consisting of three cells from different manufacturers, were circulated among the laboratories. One set was sent from the BIPM to the NPL (United Kingdom), the NIST (United States) and the BNM-INM (France), the other from the BIPM to the IMGC (Italy), the KRISS (Rep. of Korea) and the VNIIM (Russian Fed.). Later in the programme, the MSL (New Zealand), the IPQ (Portugal), the PSB (Singapore), the INMETRO (Brazil), the NMi (Netherlands) and the INM (Romania) sent cells to the BIPM. Differences between the triple-point temperatures of all cells were measured at the BIPM. For each of the two sets of three circulating cells, differences were also measured in the three laboratories to which they were sent. In total, temperature differences were obtained between twenty cells from nine manufacturers.

For the cells circulated, the temperature differences between cells measured in four different laboratories are consistent within a spread of 0.09 mK (except for one apparently unstable cell); for two cells with very high triple-point temperatures the differences measured in four laboratories even agree to within 0.015 mK. The measured triple-point temperatures of thirteen of the twenty cells lie within a band of 0.11 mK from the highest measured value; measurements from the other seven cells show lower temperatures and a larger spread.

Document CCT/96-1 concludes that, in setting up a set of reference cells, it would be wise for a national laboratory to include cells of different origin. In this way, it may be able to avoid differences from the scales of other institutes and to detect abnormalities in the behaviour of its cells. The document also suggests that a gallium cell may be used to check the stability of triple point of water cells.

Mr Bonnier summarizes the procedure used in the EUROMET comparison (CCT/96-22). In this programme, the BNM-INM supplied a triple point of water cell with an isothermal enclosure. This facility was sent in turn to eleven European laboratories. Each laboratory compared one or more of its cells, prepared following its own routine procedure, with the cell in the BNM-INM facility, for which it followed a specified procedure of cell preparation. The objective was not to compare cells, but rather different realizations of the fixed point. The results of the comparisons are very similar to those of the BIPM comparison: triple-point temperatures for eighteen out of twenty-two cells were shown to lie within a band of 0.11 mK from the highest measured temperature; the other four cells gave lower temperatures and a larger spread. Further analysis failed to detect any bias in the results related to the age of the cell or the procedure used to realize the ice-mantle. Full results from the two international comparisons are given in documents CCT/96-1 and CCT/96-22.

In further discussion of the reproducibility of the triple point of water, Dr Nicholas, referring to document CCT/96-14, mentions that the use of isotopically impure water in the cells makes it difficult to reproduce temperatures to better than 0.1 mK. Dr Köhler points out that it may be possible to link the results of the two comparisons because two cells were common to both. There follows a discussion centred on the uncertainties associated with the results of these comparisons, their relevance vis-a-vis the ultimate uncertainty in realizing the triple point of water, and implications for the definition of the kelvin.

3.3 Questions relating to the interpolating instruments

Dr Marcarino opens with a description of the “humidity effect” in long-stem SPRTs (CCT/96-7). The effect deals with electrical leakage, caused by the presence of water in the SPRTs, which leads to errors in indicated resistance and temperature values. The effect was long known to occur in SPRTs containing mica (*Supplementary Information for the ITS-90*, p. 87), but seems to occur also in thermometers in which sheaths and wire supports are made of silica. The effect makes itself evident, for example, by the long time taken for a thermometer to indicate a constant temperature at the triple point of water. In one study of the silver point, a decrease in the resistance corresponding to 20 mK was observed when the part of the thermometer stem outside the furnace was heated so that adsorbed water could condense in the head of the thermometer. Dr Marcarino sees desorption of water from silica (or mica) as the main source of the problem. Others suggest that water may also come from leakage through the envelope of the thermometer, the use of a hydrogen-oxygen flame when sealing the thermometer, or the reaction of hydrogen gas desorbed from the platinum wire at high temperature with oxygen in the thermometer. The meeting agrees with Dr Marcarino that it would be useful, especially for a HTPRT, to attach a small valve to the thermometer head so that water vapour can be removed when necessary. Later in the meeting, it is agreed that Dr Marcarino will prepare a design for a HTPRT fitted with a small valve and send this to Dr Quinn with a list of possible manufacturers. Dr Quinn will then look for a manufacturer willing to prepare a set of such HTPRTs for members of the CCT.

Two documents on radiation thermometry are discussed. The first (CCT/96-20) describes a radiation thermometer in which an InGaAs photodiode detector is used. It is suggested that at temperatures from 300 °C to 660 °C a temperature-scale realization within a few tens of millikelvins is achievable, with the instrument working at a wavelength of 1550 nm. A EUROMETcomparison of infrared optical pyrometers is under way. (In the discussion, it appears that not all members are aware of the complete programme of EUROMET comparisons in thermometry. Dr Quinn suggests that such information be made more readily available.) The second document (CCT/96-21) deals with a comparison of the radiance-temperature scales of the NPL and the VNIIM, as maintained on tungsten ribbon lamps in the range 900 °C to 2000 °C. Asked why the differences measured between lamps were larger than in a similar comparison in 1972, Dr Rusby suggests that the lamps used in this comparison may be less reliable than the specially-prepared ones used in 1972. Dr Bloembergen mentions that a EUROMETcomparison of ribbon lamps will begin in 1997. Dr Quinn remarks that tungsten ribbon lamps are still extremely useful.

3.4 New information on ($T - T_{90}$)

Giving the motivation for carrying out the experiment at the PTB described in document CCT/96-5, Dr Jung recalls that above 729 K the ITS-90 is based mainly on relative radiation thermometry referenced to the average of two gas thermometer results at 729 K, which differ from one another by 30 mK. This difference, by itself, propagates an uncertainty in the radiation thermometry of $(T/729\ \mathrm{K})^2 \times 15$ mK. Current radiometric temperature measurements are absolute, in that they do not assume a reference temperature. The radiant power generated by a large-aperture black body equipped with a cooled precision-aperture of 20 mm diameter has been measured using narrow-band filter radiometers, two of which were calibrated against a cryogenic radiometer. Results may be expressed by the relation $T - T_{90} = (T/729\ \mathrm{K})^2 \times 18.15$ mK, where T is the temperature determined with the radiometer. Uncertainties vary from 17 mK at 773 K to 39 mK at 1235 K. The results are consistent, within their uncertainties, with older measurements if referred to the gas thermometer results of Edsinger and Schooley at 729 K: this is not the case if they are referred to the mean of the two available results. After expressing their satisfaction with the results of this important work, several members take part in a discussion on the remaining uncertainties in the PTB results.

3.5 Uncertainty of ITS-90 realization

It is noted that uncertainties in an actual realization of the ITS-90 come from four sources:

1. the non-uniqueness of the scale (type 1 and 2 non-uniqueness, see Section 3.1);
2. the realization of the fixed points;
3. the interpolating instruments (e.g. uncertainties arising from a possible humidity effect in PRTs);
4. the realization of the scale by the interpolating thermometer (the type 3 non-uniqueness and propagated uncertainties in fixed-point realizations).

Document CCT/96-11 on the realization of the ITS-90 at the NIST serves as a basis for the ensuing discussion. Expanded uncertainties of the realizations of the fixed points at the NIST, ranging from 0.03 mK for the triple points of oxygen and argon, to 0.06 mK for the triple point of water and the melting point of gallium and 1.1 mK for the freezing point of silver, are listed in the document. A lengthy discussion follows in which several members suggest that the uncertainties may be underestimated. They exemplify this by reference to the uncertainties arising from the use of impure samples when measuring the freezing points of metals.

In answer to a query about the reproducibility of temperature measurements with interpolating gas thermometers, Dr Mangum refers to a Tempmeko'96 paper on gas thermometry at the NIST. Dr Grohmann, referring to document CCT/96-24, gives 0.7 mK as the maximum difference between the PTB dielectric-constant gas thermometer and the NPL gas-thermometer scale between 4 K and 25 K.

3.6 Reports of working groups

3.6.1 Working group 1: defining fixed points and interpolating instruments

Dr Mangum (Chairman of Working group 1) summarizes the report of Working group 1 (CCT/96-8) which was written as a first step in updating the *Supplementary Information*. After defining non-uniqueness (Section 3.1), the report lists “General criteria for optimal realization of the fixed points of the ITS-90”. There follows a lengthy and rather contentious discussion in which the majority view is that these criteria are over-specified and far too restrictive. The forthcoming revised *Supplementary Information* should, like its predecessors, be “advisory” not “mandatory” or “restrictive”. If the best method of realizing a particular fixed point is not evident, alternatives should be given.

The report also contains a section on “General recommendations for comparisons of the fixed points of the ITS-90 at the highest level of accuracy”. A preliminary version of this text was sent to Working group 3 which is responsible for the comparisons. Members feel that these recommendations are also too restrictive; they overspecify the methodology for fixed-point comparisons and the design of triple-point cells, and give too little advice on the complete realization of the fixed points.

Dr Mangum says that, because a revised edition of the *Supplementary Information* is at least three years away, Working group 1 wishes to publish document CCT/96-8. Again, there is a division of opinion. The possibility of writing a BIPM monograph is discussed. Finally, it is left to Working group 1 to decide whether and where to have the document published.

3.6.2 Working group 2: secondary fixed points and techniques of approximation to the ITS-90

In the report of Working group 2 (CCT/96-9) four tasks are listed:

1. publishing a new list of secondary fixed points;
2. providing information on approximations to the ITS-90;
3. giving advice on the application of the ITS-90 to international standards and critical tables;
4. updating existing documents.

Dr Bedford, Chairman of Working group 2, remarks that task 1 has been completed; the new list of secondary fixed points has been published (*Metrologia*, 1996, **33**, 133-154). Regarding tasks 2 and 4, a revision of the monograph *Techniques for Approximating the ITS-90* will be a fairly major undertaking and is still a few years off. As regards task 3, liaison with the IEC has resulted in revised versions of thermocouple and industrial platinum-thermometer reference tables. Dr de Groot refers to noise temperature measurements of the palladium melting point (CCT/96-30).

Dr Quinn remarks that, of the 1500 copies printed, only 180 copies of the 1990 issue of the monograph remain. It is agreed that the monograph should be reprinted with a list of errata and amendments. Any items for this list should reach Dr Bedford before the end of 1996. Dr Quinn will ask members how many copies they require.

3.6.3 Working group 3: international equivalence in temperature measurements and corresponding international comparisons

In the report of Working group 3 (CCT/96-23) three tasks are identified:

1. to collect information on regional and bilateral comparisons;
2. to organize suitable comparisons between regional groups at the highest level of accuracy;
3. to establish procedures for the estimation of uncertainties.

Mr Bonnier, Chairman of Working group 3, mentions that a list of comparisons already completed (task 1) is given in the report, but the list is far from complete.

Under task 2, some urgent comparisons were proposed at a meeting of the working group at which not all members were present. Regarding task 3, the working group plans to write a document for presentation to Working group 1. In order to obtain more information on ongoing or proposed comparisons, a questionnaire will be sent to members of the CCT.

For discussion, Dr Quinn introduces the note on international equivalence of national measurements standards. International accreditation bodies require documented evidence of the equivalence of national measurement standards, also called international traceability of national measurement standards, within stated uncertainties. The most appropriate groups to select and organize the required *key comparisons* and publish the results of the comparisons in *Metrologia*, with appropriate interpretations, are the Consultative Committees. There is a need to carry out such a programme within, say, two years. A list of key comparisons already identified by other Consultative Committees is given in the document.

Concerning the structure of the comparisons, Dr Quinn envisages that some fifteen to twenty laboratories will take part in worldwide CCT comparisons. Robust links must be established with regional comparisons, which will be organized by two or three primary laboratories in each region. He notes that these checks will need to be repeated periodically, in particular because of staff changes in the laboratories. Periods of five to twenty years between checks have been proposed by other CCs.

It is proposed that laboratories which are not members of the CCT may also participate in the key comparisons if they have the necessary technical competence and are nominated national holders of standards.

There is some discussion about the uncertainty band within which the results of participating laboratories should lie. In the note under discussion, the use of two bands is suggested: one would be wide enough to attest to general accreditation and the other, much narrower, would admit only the most expert laboratories in the field. The meeting fears that this practice would lead to stigmatization of laboratories and political pressure to widen the uncertainty bands. Dr Quinn says that in coming months a note will be circulated collecting the various concerns that have been expressed. [In a later version of this note, the suggestion of two bands is deleted.]

Dr Quinn suggests that possible key comparisons include a comparison of calibrated thermometers: rhodium-iron resistance thermometers below the neon triple point, platinum resistance thermometers (capsule, long-stem, and high-temperature) from the triple point of hydrogen to the silver point, and, above the silver point, tungsten ribbon lamps or optical pyrometers. (An example of this type of comparison was the Ward-Compton comparison of national temperature scales in the 1970s using calibrated capsule PRTs). Several members prefer that the key comparisons will be comparisons of fixed-point realizations (an example is the EUROMET comparison of realizations of the triple point of water) because national standards laboratories do not maintain their scales on thermometers, because uncertainties can more easily be specified for fixed-point comparisons (no extra non-uniqueness arising from the thermometers) and because the cost is likely to be lower. Other members remark that comparisons of fixed-point realizations are not sufficient since they do not test the complete range of techniques required to realize the scale. It is also suggested that each laboratory calibrate a series of secondary fixed-point cells with the objective of confirming the equivalence of realizations of the scale between the defining fixed points. (If one could be confident that the realizations of the secondary reference points would be the same everywhere, it would be sufficient to compare the temperatures attributed to the secondary fixed points by each laboratory.)

For the temperature range below the Al point there seems to be no technical impediment to carrying out comparisons of thermometers, defining fixed points or secondary fixed points. For the latter, the triple points of CO_2 (217 K), Xe (161 K), and Kr (116 K) and the freezing point of Cd (321 °C) are suggested. The CO_2 point, however, is very close to the Hg triple point and the Kr point is not the most reproducible of the low-temperature fixed points. For the range from the Al point to the Ag point, the situation is more difficult: the circulation of HTPRTs is considered to be too dangerous for the thermometers and not all members are convinced that the use of Au/Pt thermocouples, suggested by Dr Mangum, will give sufficiently accurate results. Also, there are few data on comparisons of the freezing points of Al and Ag. Mr Bonnier suggests that, first, information on the accuracy (uncertainty budgets) of realizations of the Al and Ag points be obtained for each laboratory. There is considerable interest in comparisons of these two fixed points.

For the key comparisons in the radiation range, most members prefer to use ribbon lamps.

The following assignment of key comparisons and coordinating laboratories is made:

1. realizations of the ITS-90 from 0.65 K to 24.5561 K using rhodium-iron resistance thermometers: NPL;
2. realizations of the ITS-90 from 13.8 K to 273.16 K using capsule-type standard platinum resistance thermometers (SPRTs): NRC;
3. realizations of the ITS-90 from 83.8 K to 933.5 K using long-stem SPRTs: NIST;
4. comparisons of Al-Ag fixed points: IMGC;
5. realizations of the ITS-90 between the silver point and 1700 °C using vacuum tungsten strip lamps as transfer standards: NMi.

By a show of hands the committee establishes the number of laboratories interested in the various comparisons: Rh-Fe range, 6 laboratories; capsule PRTs, 8 laboratories; long-stem SPRTs, 11 laboratories; Al-Ag fixed points, 10 laboratories; tungsten strip lamps, 8 laboratories.

The co-ordinators are asked to prepare protocols for the comparisons for which they are responsible and send them to CCT members by the end of 1996, asking for comments. Agreed protocols should be ready by 1 March 1997. When the agreed protocols are available, the BIPM will ask members of the CCT in which comparisons they intend to participate. The co-ordinators will initiate the work. The comparisons should be completed, or well advanced, by the time of the next meeting of the CCT.

Regarding the ^{3}He vapour-pressure equation, results have been published showing the thermodynamic calculations at the PTB and the KOL and the new vapour-pressure measurements at the NIST. The future extension of the ITS-90 towards lower temperatures is treated in Section 4.

3.6.4 Working group 4: thermodynamic temperature determinations and extension of the ITS-90 to lower temperatures

The specific tasks of Working group 4 are: to provide new values of ($t_{90} - t_{68}$) from 630 °C to 1064 °C; to give up-to-date information on new determinations of thermodynamic temperature T based on a primary thermometer and of ($T - T_{90}$); to correct (if necessary) the ^{3}He vapour-pressure equation in the ITS-90; and to collect information on temperature measurements and existing laboratory scales below 1 K with the ultimate goal of making a proposal to the CCT for an extension of the ITS-90.

Dr Rusby, Chairman of Working group 4, summarizes the report (CCT/96-31). Revised values for the differences ($t_{90} - t_{68}$) from 630 °C to 1064 °C have been published (*Metrologia*, 1994, **31**, 149-153). These are based on comparisons of Pt-10 % Rh/Pt thermocouples carrying the IPTS-68 with SPRTs and radiation thermometers calibrated in accordance with the ITS-90. The new differences are rather smaller than the earlier ones. New measurements of thermodynamic temperature are in progress and some have been completed. In gas thermometry, revisions of earlier results from the PTB and the VNIIFTRI have been published. Recently published results of dielectric-constant gas thermometry between 4 K and 27 K at the PTB (*Metrologia*, 1996, **33**, 341-352 and CCT/96-24) and of constant-volume gas thermometry at the NIST (Tempmeko'96) are also available. Results from experiments on acoustic thermometry in progress at the NIST (below 693 K) and at the University of London (below 430 K) are not yet available. Noise thermometry is under development at the IMGC, the NMi (CCT/96-30), the PTB, the MSL and the NRLM. In radiation thermometry, there are the new results from the PTB between 773 K and 1235 K (Section 3.4). New measurements of thermodynamic temperatures are still required, specifically in the range near 150 K. Theoretical studies of the resistance vs temperature relation of platinum in this range have been made. Dr Quinn recalls remarks at Tempmeko'96 about the possibility of redefining the kelvin in terms of a defined value of the Boltzmann constant. Expected improvements in total radiation thermometry, leading to uncertainties in T of less than 0.3 mK at 273 K, would bring this possibility within sight (*Metrologia*, 1996, **33**, 375-381). For this, it would be essential that a laboratory other than the NPL also embark on total-radiation thermometry.

Regarding the ^{3}He vapour-pressure equation, results have been published of thermodynamic calculations at the PTB and the KOL and of new vapour-pressure measurements at the NIST. The future extension of the ITS-90 towards lower temperatures is treated in Section 4.

3.6.5 Working group 5: joint CCT/CCPR working group on thermodynamic-temperature determinations for high-temperature black bodies

Dr Quinn reports on the discussions of Working group 5. High-temperature black bodies in the range from 2500 K to 3200 K are often used as calibration sources in radiometric laboratories. To characterize the spectral power distribution of a high-quality black-body source it is frequently desirable to measure its thermodynamic temperature. Working group 5 was formed to study and give advice on all aspects of these temperature measurements. Recommendations by Working group 5 listed in (CCT/96-17) are discussed by the meeting and used as the basis for a recommendation to the CIPM (Recommendation T 2). This recommendation, on the temperature of black-body sources above 2500 K, asks for the development of high-temperature fixed points, high-temperature black bodies and stable filter radiometers and pyrometers. It also asks that all available methods be used to measure the temperature of selected high-temperature black bodies with a view to comparing the results. The working group noted three distinct methods of measuring these high temperatures: 1) measurements according to the definition of the ITS-90, i.e. quasi-monochromatic radiation thermometry with the silver, gold or copper freezing point as reference; 2) absolute measurements of the radiant flux using a cryogenic radiometer; and 3) measurements of the ratio of radiant fluxes in two or more spectral bands at one temperature. A comparison of the uncertainties of the three methods is given in documents CCT/96-17 and CCT/96-26. The working group will take an active part in organizing small-scale international comparisons of filter radiometers and of black bodies; the NPL and the NIST are willing to act as pilot laboratories for these comparisons.

3.6.6 Working group 6: humidity measurements

Dr Huang explains to the meeting that in 1994 the then president of the CCT, Dr Luigi Crovini, agreed to establish a working group on humidity measurements in view of the growing importance of such measurements and standards in national laboratories. The proposed activities of Working group 6 are detailed in its report. Work on the international comparisons of dew/frost-point hygrometers has begun; the key comparison will be that of dew point temperatures. Regional comparisons in Europe, North America and Asia/Pacific will be followed by a fully-linked one. It is expected that the comparison can be finished in two years. Other activities to be undertaken by the working group include a report on recent developments in the measurement of low concentrations of water vapour and of humidity.

4 TEMPERATURE SCALES BELOW 1 K AND THE POSSIBLE EXTENSION OF THE ITS-90 BELOW 0.65 K

Dr Rusby introduces the possible extension of the ITS-90 below 0.65 K by referring to the relevant section in the report of Working group 4. It is generally accepted that the ^{3}He melting-pressure equation is the best candidate for an extension of the ITS-90 to temperatures below 0.65 K. The PTB has published a new melting-pressure equation for the range from 1 mK to 1 K (CCT/96-25). Temperatures in this equation are on the low-temperature scale of the PTB which was based, above 50 mK, on a single-crystal CMN (cerium magnesium nitrate) magnetic-susceptibility thermometer calibrated, above 1.2 K, against a rhodium-iron resistance thermometer carrying the EPT-76 temperature scale and, between 50 mK and 1 mK, on a platinum NMR thermometer. The two thermometers were compared with one another between 18 mK and 54 mK and with the PTB noise-thermometer scale above 6.5 mK.

Dr Grohmann mentions the difference between the PTB ^{3}He melting-pressure equation and that of the NIST(based on noise thermometry above 6 mK), and the difficulty which arises when one tries to extrapolate the melting-pressure equation of the NIST from 6 mK to 1 mK. Both he and Dr Rusby hope that other laboratories will perform measurements in this temperature range; specifically they suggest that a continuation of the measurements at the NIST would be very helpful.

Work on CMN thermometry is in progress at the NPL. Dr Rusby mentions the EUROMET project on ultra-low temperature thermometry in which the BNM-INM, the KOL, the NMi, the NPL, the PTB and two commercial companies are participating. The project involves the development of ^{3}He melting-pressure sensors, CMN thermometry, glass capacitance thermometers and superconducting fixed-point devices.

To connect the ^{3}He melting-pressure scale to the ITS-90, i.e. to the ^{3}He vapour-pressure scale, it will be necessary to reduce the uncertainty in the vapour-pressure scale below 1.2 K. Dr Rusby notes that he expects to have more information on all these questions in the coming two or three years. This may make it possible for the working group to present a proposal for the next meeting of the CCT (see also Recommendation T 1).

The meeting agrees that, because research at low temperatures is often carried out at high magnetic fields, laboratories should be encouraged to look into the magnetic field dependence of low-temperature thermometers and reference devices.

5 ESTABLISHMENT AND COMPOSITION OF WORKING GROUPS

Dr Quinn notes that, as a result of the deliberations at this meeting, six working groups are charged with carrying out specific tasks for the CCT or advising the CCT on subjects of particular interest. The memberships and tasks of the working groups are as follows:

Working group 1: defining fixed points and interpolating instruments.

The working group is requested:

1. to improve techniques for the realization of defining fixed points and interpolating instruments ($T_{90} \geqslant 3$ K);
2. to study non-uniqueness;
3. to update *Supplementary Information*.

Working group members are: B.W. Mangum (NIST, Chairman), P. Bloembergen (NMi), B. Fellmuth (PTB), A.I. Pokhodun (VNIIM), P. Marcarino (IMGC).

Working group 2: secondary fixed points and techniques of approximation to the ITS-90.

The working group is requested:

1. to publish a list of secondary fixed points;
2. to provide information on approximations to the ITS-90;
3. to give advice on the application of the ITS-90 to international standards and critical tables;
4. to update existing documents.

Working group members are: R.E. Bedford (NRC, Chairman), F. Edler (PTB), F. Pavese (IMGC), C. Rhee (KRISS), Zhao Qi (NIM).

Working group 3: international equivalence of temperature measurements and corresponding international comparisons.

The working group is requested:

1. to collect documented information on comparisons and summarize the results;
2. to keep under review the list of key comparisons agreed to by the CCT and propose complementary comparisons if they become necessary;
3. to advise upon procedures to estimate uncertainties.

Working group members are: G. Bonnier (BNM-INM, Chairman), M.J. Ballico (CSIRO), S. Duris (SMU), M.J. de Groot (NMi), K.H. Kang (KRISS), R. Köhler (BIPM), T. Ricolfi (IMGC), D.C. Ripple (NIST).

Working group 4: thermodynamic temperature determinations and extension of the ITS-90 to lower temperatures.

The working group is requested:

1. to study new determinations of thermodynamic temperature T and of $(T - T_{90})$;
2. to study the ^{3}He vapour-pressure scale below 3 K;
3. to study temperature scales below 0.65 K.

Working group members are: R.L. Rusby (NPL, Chairman), M. Durieux (KOL), R.P. Hudson (Maryland, United States), K. Grohmann (PTB), H.-J Jung (PTB), J.V. Nicholas (MSL), P.P.M. Steur (IMGC).

Working group 5: joint CCT/CCPR working group on thermodynamic-temperature determinations for high-temperature black bodies.

The working group is requested:

1. to make a best estimate of the uncertainties achievable by currently available methods of measuring thermodynamic temperature at temperatures above 1357 K, but particularly within the range 2500 K-3200 K;
2. to consider the likely influence on these uncertainties of foreseeable technological advances;
3. to prepare a written report on its findings and recommendations for consideration by the CCT and the CCPR (Consultative Committee for Photometry and Radiometry).

Working group members are: T.J. Quinn (BIPM, Chairman), P. Bloembergen (NMi), C. Johnson (NIST), H.-J. Jung (PTB), R. Köhler (BIPM), D. Nettleton (NPL), F. Sakuma (NRLM).

Working group 6: humidity measurements.

The working group is requested:

1. to organize an international comparison on humidity standards;
2. to report on terms and definitions for humidity measurements;
3. to report on new developments in humidity standards, with special emphasis on the measurement of low concentrations of water vapour in the gases used for semiconductor technology;
4. to report on developments in calibration standards for humidity measurements at high temperatures.

Working group members are: P. Huang (NIST, Chairman), A. Actis (IMGC), S. Bell (NPL), L. Mamontova (VNIIM), C. Takahashi (NRLM).

The first four working groups were formed in 1993, or earlier. Some of the original members have left, having retired or changed their position, and several new members with relevant expertise in thermometry have been appointed. The terms of reference of Working group 3 have been rewritten to delineate the tasks more clearly. The formation of the joint CCT/CCPR Working group 5 is in accordance with Recommendation T 2. Working group 6 was formed because humidity measurement standards are of increasing importance.

Dr Quinn emphasizes that working groups should send annual reports on their work to the BIPM.

6 RECOMMENDATIONS AND REPORT TO THE CIPM

Two topics form the subjects of recommendations of the CCT to the CIPM: Recommendation T 1 emphasizes the increasing importance of temperature measurements below 1 K, and Recommendation T 2 does the same for temperatures above 2500 K. Dr Quinn will include the two recommendations in a report on the present meeting which he will write and present to the CIPM at its meeting in September 1996.

7 OTHER BUSINESS

Dr Bloembergen announces that Tempmeko'99 will be held in Delft in the Netherlands; the date is not yet known.

Next, the meeting expresses its great concern over the termination of activities on heat-pipe systems at Ispra (Dr Bassani's work). Although there are commercial companies which provide heat-pipe systems, the research activities of Ispra in this field are considered by many members essential if the growing need for new gas-controlled heat-pipe systems is to be satisfied. Dr Quinn suggests that he write to Ispra about the subject.

8 NEXT MEETING

The next meeting of the CCT will be held in May or June 1999. Dr Quinn emphasizes the importance of completing the proposed international comparisons by the end of 1998. Many members find this schedule very tight.

Dr Quinn asks the rapporteur to prepare a brief report of the meeting. He notes that it is not possible to publish a report of the size that was customary for earlier meetings.

M. Durieux, Rapporteur
June 1997
revised April 1998

RECOMMENDATIONS OF THE CONSULTATIVE COMMITTEE FOR THERMOMETRY SUBMITTED TO THE COMITÉ INTERNATIONAL DES POIDS ET MESURES

1 RECOMMENDATION T 1 (1996): Temperature scale below 1 K*

The Consultative Committee for Thermometry,

considering

- that many important research activities are in progress at temperatures below 1 K,
- that these researches require an accepted temperature scale which closely represents thermodynamic temperatures,
- that the ITS-90 ^{3}He vapour pressure equation is believed to deviate from thermodynamic temperatures between 1 K and its lower limit of 0.65 K,

noting that several discrepant laboratory scales below 0.65 K have been developed,

recommends

- that the deviation of the ITS-90 ^{3}He vapour pressure equation from thermodynamic temperature below 1 K be further investigated,
- that research be undertaken to resolve discrepancies between existing ^{3}He melting pressure scales,
- that national laboratories collaborate to develop a ^{3}He melting pressure equation to serve as the basis for an extension of the ITS-90 down to a temperature of about 1 mK.

* This recommendation was adopted by the CIPM at its 85th meeting in 1996 as Recommendation 3 (CI-1996).

2 RECOMMENDATION T 2 (1996): The temperature of black-body sources above 2500 K

The Consultative Committee for Thermometry,

considering

- the report of the joint CCT/CCPR working group (document CCT/96-17) on the measurement of thermodynamic temperatures at high temperatures,
- that in establishing standards of spectral power distribution, there is a need to determine the thermodynamic temperature of black-body sources in the range above 2500 K,
- that the procedures defined in ITS-90 can be used to determine thermodynamic temperatures by monochromatic radiation thermometry using as reference the black-body radiation from any one of the silver, gold or copper freezing points, whose thermodynamic temperatures have previously been determined,
- that alternative methods are being developed to measure thermodynamic temperatures, such as absolute measurement of radiant flux in a well-characterized spectral band and the measurement of the ratio of radiant fluxes in two or more different well-characterized spectral bands,
- that a fixed point at temperatures above 2300 K having a reproducibility better than 0.1 K, is highly desirable,

recommends

- that national laboratories work to develop high-temperature fixed points,
- that national laboratories intensify work to characterize and improve high-temperature black bodies and to improve the stability of filter radiometers and pyrometers,
- that national laboratories continue to use all available methods to measure the temperature of high-temperature black bodies and compare the results obtained.

APPENDIX T 1.
Working documents submitted to the CCT at its 19th meeting

(see the list of documents on page 49).

ANNEXE T 1.
Documents de travail présentés à la 19e session du CCT

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

Document
CCT/

96-1 BIPM. — Report on the international comparison of water triple point cells, by R. Pello, R. Goebel and R. Köhler, 43 p.

96-2 VNIIM (Féd. de Russie). — Analytical and experimental study of the factors determining the temperature gradient during the calibration at the ITS-90 fixed points, by A.G. Ivanova and A.I. Pokhodun, 11 p.

96-3 KRISS (Rép. de Corée). — Thermoelectric Properties of the Au/Pd Thermocouple, by Y.G. Kim, K.S. Gam and C. Rhee, 5 p.

96-4 KRISS (Rép. de Corée). — Impurity Redistribution Effects on Phase Transition Temperatures in Oxygen as Secondary Fixed Points, by K.H. Kang, J.-J. Kim and C. Rhee, 23 p.

96-5 PTB (Allemagne). — Measurement of $T - T_{90}$ in the Range from 500 °C to 962 °C by Absolute Spectral Radiometry Employing a Cryogenic Radiometer and a Double Heatpipe Black Body, by M. Stock, J. Fischer, R. Friedrich, H.-J. Jung and B. Wende, 8 p.

96-6 PTB (Allemagne). — Present Status of Low Temperature Scales, by G. Schuster, A. Hoffmann and D. Hechtfischer, 3 p.

96-7 IMGC (Italie). — Humidity effects in long stem Standard Platinum Resistance Thermometers, by P. Marcarino, R. Dematteis and M. Arai, 6 p.

Document
CCT/

96-8 CCT Working group 1. — Recommended techniques for improved realization and intercomparisons of defining fixed points. Report to the CCT, July 1996, 28 p.

General Recommendations for intercomparisons of the fixed points of the International Temperature Scale of 1990 at the highest level of accuracy, 13 p.

96-9 CCT Working group 2. — Report of Working group 2 to the Comité Consultatif de Thermométrie, July 1996, 2 p.

96-10 NRC (Canada). — Proposals, 9 p.

96-11 NIST (États-Unis). — Realization of the ITS-90 at the National Institute of Standards and Technology, by B.W. Mangum, G.T. Furukawa, C.W. Meyer, M.L. Reilly, G.F. Strouse and W.L. Tew, 17 p.

96-12 NRC (Canada). — Extending the Platinum Resistance Thermometer Range of the ITS-90 to 1064.18 °C by Replacing the Silver Point with the Gold Point, by K.D. Hill, 4 p.

96-13 MSL (Nouvelle-Zélande). — On Platinum Thermometry, by J.V. Nicholas, 2 p.

96-14 MSL (Nouvelle-Zélande). — On the Definition of the Kelvin, by J.V. Nicholas, 3 p.

96-15 NRLM (Japon). — Pressure Dependency of the Liquid-Solid Equilibrium of Indium, by H. Sakurai, 2 p.

96-16 NRLM (Japon). — Initial temperature drift of some triple point cells of water, by H. Sakurai, 2 p.

96-17 Joint CCT/CCPR working group. — Short report of the Joint CCT/CCPR working group meeting, by R. Köhler, 4 p. Note, by H.-J. Jung, 1 p.

96-18 NPL (Royaume-Uni). — A powdered CMN thermometer for high accuracy measurements in the range 0.01 to 1 K, by P. Mohandas, D.I. Head and R.L. Rusby, 2 p.

96-19 NPL (Royaume-Uni). — Recent measurements of the deuterium triple point at NPL, by D.I. Head, 4 p.

Document
CCT/

96-20 NPL (Royaume-Uni), SIRIM (Malaysie). — An InGaAs radiation thermometer for temperature scale realisation, by R.C. McEvoy, G. Machin, N.P. Fox, E. Theocharous and I.S. Hassan, 6 p.

96-21 NPL (Royaume-Uni), VNIIM (Féd. de Russie). — NPL-VNIIM intercomparison of tungsten ribbon lamps, by H.C. McEvoy, K.M. Raven, A.I. Pokhodun and M.S. Matveyev, 5 p.

96-22 BNM-INM (France). — Agreed EUROMET Project. Thermometry – Intercomparison of water triple point cell Ref. No. 278, Synthesis report, by E. Renaot, coordinator, 28 p.

96-23 CCT Working group 3. — Report of Working group 3 to the CCT – International Traceability in Temperature Measurements, September 1996, 2 p.

96-24 PTB (Allemagne). — Interpolating Dielectric-Constant Gas Thermometry, by K. Grohmann, H. Luther and B. Fellmuth, 3 p.

96-25 PTB (Allemagne). — Temperature scale extension below ITS-90 based on ^{3}He melting pressure, by G. Schuster, A. Hoffmann and D. Hechtfischer, 3 p.

96-26 PTB (Allemagne). — On the determination of the thermodynamic temperature of high temperature black bodies via ITS-90 or alternative methods, by H.-J. Jung, 10 p.

96-27 KRISS (Rép. de Corée). — Temperature standards in KRISS, by C. Rhee, K.H. Kang, K.S. Gam, Y.G. Kim, J.W. Han, S.N. Park and K.H. Kim, 19 p.

96-28 NRLM (Japon). — Comments on key comparison of radiation thermometers under CCT, 3 p.

96-29 NMi-VSL (Pays-Bas). — Laboratory status of contact thermometry and humidity research, by M.J. de Groot, J. Mooibroek, J.F. Dubbeldam, H. Heimeriks and E. van Dijk, 3 p.

96-30 NMi (Pays-Bas), Forschungszentrum Jülich (Allemagne), PTB (Allemagne). — Noise thermometry measurements at fixed points, by M.J. de Groot, J.F. Dubbeldam, H. Brixy, F. Edler and E. Tegeler, 13 p.

Document CCT/	
96-31	CCT Working group 4. — Working group 4 report to the CCT, August 1996, 8 p.
96-32	European ultra-low temperature scale and traceability: A collaborative project supported by the Standards, Measurement and Testing Programme of the European Union, 1 p.
96-33	VNIIM (Féd. de Russie), Alma-Ata centre for standardization, metrology and certification (Kazakhstan). — Report on the comparison of the VNIIM (Russia) water triple-point cell and the water triple-point cell of the Alma-Ata centre for standardization, metrology and certification (Kazakhstan), by A.I. Pokhodun and I.M. Pecounova, 2 p.
96-34	VNIIM (Féd. de Russie), BNM-INM (France). — ITS-90 Approximation Using a Platinum-Palladium Thermocouple, by A.I. Pokhodun, M.S. Matveyev, G. Bonnier and H. Ronsin, 10 p.

LIST OF ACRONYMS USED IN THE PRESENT VOLUME

1 Acronyms for laboratories, committees and conferences

BIPM	Bureau International des Poids et Mesures
BNM-INM	Bureau National de Métrologie: Institut National de Métrologie, Paris (France)
CC	Consultative Committee of the CIPM
CCPR	Consultative Committee for Photometry and Radiometry
CCT	Consultative Committee for Thermometry
CENAM	Centro Nacional de Metrologia, Mexico (Mexico)
CIPM	Comité International des Poids et Mesures
CSIRO	CSIRO, National Measurement Laboratory, Lindfield (Australia)
*DSIR	Department of Scientific and Industrial Research, Lower Hutt (New Zealand), see MSL
EUROMET	European Collaboration in Measurement Standards
IEC	International Electrotechnical Commission
IMGC	Istituto di Metrologia G. Colonnetti, Turin (Italy)
INM	Institut National de Métrologie, Paris (France), see BNM
INM	Institutul National de Metrologie, Bucarest (Romania)
INMETRO	Instituto Nacional de Metrologia, Normalizaçao e Qualidade Industrial, Rio de Janeiro (Brazil)
IPQ	Instituto Português da Qualidade, Lisbon (Portugal)
IRL	Industrial Research Limited, Lower Hutt (New Zealand)
KOL	Kamerlingh Onnes Laboratorium, Leiden (Netherlands)
*KSRI	Korea Standards Research Institute, Taejon (Rep. of Korea), see KRISS
KRISS	(formerly the KSRI) Korea Research Institute of Standards and Science, Taejon (Rep. of Korea)

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

MSL-IRL	(formerly the DSIR) Measurement Standards Laboratory of New Zealand, Lower Hutt (New Zealand)
*NBS	National Bureau of Standards, Gaithersburg (United States), see NIST
NIM	National Institute of Metrology, Beijing (China)
NIST	(formerly the NBS) National Institute of Standards and Technology, Gaithersburg (United States)
NMi	Nederlands Meetinstituut: Van Swinden Laboratorium, Delft (Netherlands)
NPL	National Physical Laboratory, Teddington (United Kingdom)
NRC	National Research Council of Canada, Ottawa (Canada)
NRLM	National Research Laboratory of Metrology, Tsukuba (Japan)
PSB	(formerly the SISIR) Singapore Productivity and Standards Board (Singapore)
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig and Berlin (Germany)
SIRIM	Standards and Research Institute of Malaysia, Selangor (Malaysia)
*SISIR	Singapore Institute of Standards and Industrial Research (Singapore), see PSB
SMU	Slovenský Metrologický Ústav, Bratislava (Slovakia)
VNIIFTRI	All-Russian Research Institute for Physical, Technical and Radio-Technical Measurements, Moscow (Russian Fed.)
VNIIM	D.I. Mendeleyev Institute for Metrology, St Petersburg (Russian Fed.)
*VSL	Van Swinden Laboratorium, Delft (Netherlands), see NMi

2 Acronyms for scientific terms

CMN	Cerium Magnesium Nitrate
EPT-76	Échelle provisoire de température de 1976
HTPRT	High-Temperature Platinum Resistance Thermometer
IPTS-68	International Practical Temperature Scale of 1968
ITS-90	International Temperature Scale of 1990
NMR	Nuclear Magnetic Resonance
PRT	Platinum Resistance Thermometer
SPRT	Standard Platinum Resistance Thermometer

STEDI
1, Boulevard Ney, 75018 Paris
Dépôt légal: Imprimeur, 1998, n°5712
ISBN 92-822-2160-1
ISSN 0069-6463
Achevé d’imprimer: octobre 1998
Imprimé en France