

Bureau International des Poids et Mesures

Consultative Committee for Thermometry (CCT)

21st Meeting (September 2001)

Note on the use of the English text

To make its work more widely accessible the International Committee for Weights and Measures publishes an English version of its reports.

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

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MEMBER STATES OF THE METRE CONVENTION AND ASSOCIATES OF THE GENERAL CONFERENCE

as of 12 September 2001

Member States of the Metre Convention

| | |
|------------------------|-------------------------------|
| Argentina | Korea (Dem. People's Rep. of) |
| Australia | Korea (Rep. of) |
| Austria | Malaysia |
| 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 |
| Greece | Switzerland |
| Hungary | Thailand |
| India | Turkey |
| Indonesia | United Kingdom |
| Iran (Islamic Rep. of) | United States |
| Ireland | Uruguay |
| Israel | Venezuela |
| Italy | Yugoslavia |
| Japan | |

Associates of the General Conference

| | |
|------------------|-----------|
| Cuba | Latvia |
| Ecuador | Lithuania |
| Hong Kong, China | Malta |

THE BIPM AND THE METRE CONVENTION

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

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

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

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

The BIPM operates under the exclusive supervision of the International Committee for Weights and Measures (CIPM) which itself comes under the authority of the General Conference on Weights and Measures (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), time scales (1988) and to chemistry (2000). To this end the original laboratories, built in 1876-1878, were enlarged in 1929; new buildings were constructed in 1963-1964 for the ionizing radiation laboratories, in 1984 for the laser work, and in 1988 for a library and offices. In 2001 a new building for the workshop, offices and meeting rooms 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, the *Director's Report on the Activity and Management of the International Bureau of Weights and Measures*, gives details of the work in progress.

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

The Consultative Committees have common regulations (*BIPM Proc.-Verb. Com. Int. Poids et Mesures*, 1963, **31**, 97). They meet at irregular intervals. The 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 ten such committees:

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

- 2 the Consultative Committee for Photometry and Radiometry (CCPR), new name given in 1971 to the Consultative Committee for Photometry (CCP) set up in 1933 (between 1930 and 1933 the CCE dealt with matters concerning photometry);
- 3 the Consultative Committee for Thermometry (CCT), set up in 1937;
- 4 the Consultative Committee for Length (CCL), new name given in 1997 to the Consultative Committee for the Definition of the Metre (CCDM), set up in 1952;
- 5 the Consultative Committee for Time and Frequency (CCTF), new name given in 1997 to the Consultative Committee for the Definition of the Second (CCDS) set up in 1956;
- 6 the Consultative Committee for Ionizing Radiation (CCRI), new name given in 1997 to the Consultative Committee for Standards of Ionizing Radiation (CCEMRI) set up in 1958 (in 1969 this committee established four sections: Section I (X- and γ -rays, electrons), Section II (Measurement of radionuclides), Section III (Neutron measurements), Section IV (α -energy standards); in 1975 this last section was dissolved and Section II was made responsible for its field of activity);
- 7 the Consultative Committee for Units (CCU), set up in 1964 (this committee replaced the “Commission for the System of Units” set up by the CIPM in 1954);
- 8 the Consultative Committee for Mass and Related Quantities (CCM), set up in 1980;
- 9 the Consultative Committee for Amount of Substance (CCQM), set up in 1993;
- 10 the Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV), set up in 1998.

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

- *Report of the meetings of the General Conference on Weights and Measures;*
- *Reports of the meetings of the International Committee for Weights and Measures;*
- *Reports of the meetings of Consultative Committees.*

The BIPM also publishes monographs on special metrological subjects and, under the title *The International System of Units (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 *Director's Report on the Activity and Management of the International Bureau of Weights and Measures*.

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 12 September 2001

President

H. Ugur, member of the International Committee for Weights and Measures,
Ulusal Metroloji Enstitüsü [UME], Gebze-Kocaeli.

Executive Secretary

M. Stock, International Bureau of Weights and Measures [BIPM], Sèvres.

Members

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

CSIR - National Measurement Laboratory [CSIR-NML], Pretoria.

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

Institute for Physical, Technical and Radiotechnical Measurements
[VNIIFTRI], Gosstandart of Russia, Moscow.

Istituto di Metrologia G. Colonnetti, Consiglio Nazionale delle Ricerche
[IMGC-CNR], Turin.

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

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

National Institute of Metrology [NIM], Beijing.

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

National Measurement Laboratory, CSIRO [NML-CSIRO], Lindfield.

National Metrology Institute of Japan, National Institute of Advanced
Industrial Science and Technology [NMIJ/AIST], Tsukuba.

National Physical Laboratory [NPL], Teddington.

National Research Council of Canada [NRC], Ottawa.

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

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

Singapore Productivity and Standards Board [PSB], Singapore.

Slovak Metrology Institute/Slovenský Metrologický Ústav [SMU],
Bratislava.

Ulusal Metroloji Enstitüsü/National Metrology Institute of Turkey [UME],
Gebze-Kocaeli.

The Director of the International Bureau of Weights and Measures [BIPM],
Sèvres.

Observers

Centro Español de Metrología [CEM], Madrid.

Centro Nacional de Metrología [CENAM], Querétaro.

Instituto Nacional de Tecnología Industrial [INTI], Buenos Aires.

Instituto Português da Qualidade [IPQ], Caparica.

Consultative Committee for Thermometry

Report of the 21st meeting

(12-14 September 2001)

to the International Committee for Weights and Measures

Agenda

- 1 Opening of the meeting; appointment of the rapporteur; approval of the agenda.
- 2 Documents presented to the 21st meeting of the CCT.
- 3 Reports of the working groups:
 - 3.1 Working Group 1: defining fixed points and interpolating instruments;
 - 3.2 Working Group 2: secondary fixed points and techniques of approximation to the ITS-90;
 - 3.3 Working Group 3: uncertainties;
 - 3.4 Working Group 4: thermodynamic temperature determinations and extension of the ITS-90 to lower temperatures;
 - 3.5 Working Group 5: radiation thermometry;
 - 3.6 Working Group 6: humidity measurements;
 - 3.7 Working Group 7: key comparisons;
 - 3.8 Working Group 8: calibration and measurement capabilities.
- 4 Reports of the CCT key comparisons:
 - 4.1 Key comparison CCT-K1: realizations of the ITS-90 from 0.65 K to 24.5561 K using rhodium-iron resistance thermometers;
 - 4.2 Key comparison CCT-K2: realizations of the ITS-90 from 13.8 K to 273.16 K using capsule-type standard platinum resistance thermometers;
 - 4.3 Key comparison CCT-K3: realizations of the ITS-90 over the range 83.8058 K to 933.473 K;
 - 4.4 Key comparison CCT-K4: aluminium and silver fixed points;
 - 4.5 Key comparison CCT-K5: realizations of the ITS-90 between the silver point and 1700 °C using vacuum strip lamps as transfer standards;
 - 4.6 New key comparisons.

- 5 Studies concerning the ITS-90.
- 6 Establishment and composition of the working groups:
 - 6.1 Working Group 1: defining fixed points and interpolating instruments;
 - 6.2 Working Group 2: secondary fixed points and techniques of approximation to the ITS-90;
 - 6.3 Working Group 3: uncertainties;
 - 6.4 Working Group 4: thermodynamic temperature determinations and extension of the ITS-90 to lower temperatures;
 - 6.5 Working Group 5: radiation thermometry;
 - 6.6 Working Group 6: humidity measurements;
 - 6.7 Working Group 7: key comparisons;
 - 6.8 Working Group 8: calibration and measurement capabilities;
 - 6.9 Working Group 9: thermophysical properties;
 - 6.10 Activity of working groups.
- 7 Other business.
- 8 Report to the CIPM and recommendations.
- 9 Next meeting.

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

The twenty-first meeting of the Consultative Committee for Thermometry (CCT) took place at the International Bureau of Weights and Measures (BIPM), Pavillon de Breteuil, Sèvres, on 12, 13 and 14 September 2001.

The following were present: M. Arai (NMIJ), M. Ballico (NML-CSIRO), M. Battuello (IMGC-CNR), G. Bonnier (BNM-INM), Y. Duan (NIM), S. Duris (SMU), B. Fellmuth (PTB), J. Fischer (PTB), M.J. de Groot (NMI VSL), K.D. Hill (NRC), P. Huang (NIST), Y. Hermier (BNM-INM), C. Johnson (NIST), K.H. Kang (KRISS), H. Liedberg (CSIR-NML), G. Machin (NPL), P. Marcarino (IMGC-CNR), M. Matveyev (VNIIM), F. Pavese (IMGC-CNR), A. Pokhodun (VNIIM), T.J. Quinn (Director of the BIPM), R. Rusby (NPL), D.C. Ripple (NIST), F. Sakuma (NMIJ), A.G. Steele (NRC), G.F. Strouse (NIST), H. Ugur (UME, President of the CCT), S. Ugur (UME), Li Wang (PSB), R. White (MSL).

Invited and observers: V. Chimenti (CEM), M. Durieux (KOL), R.P. Hudson, E. Méndez-Lango (CENAM), M.E. Filipe (IPQ).

Also present: P. Giacomo (Director Emeritus of the BIPM), M. Stock (Executive Secretary of the CCT), C. Thomas (Coordinator of the BIPM key comparison database), S. Solve (BIPM).

Absent: INTI, VNIIFTRI.

The President opened the meeting and invited the Director of the BIPM to devote some words and a moment of silence to mark the tragic events on 11 September 2001 in New York and Washington. Further to this gesture of respect, on Friday 14 September the CCT joined in a Europe-wide three minutes' silence to commemorate the victims of these actions.

Michael Stock of BIPM succeeded Rainer Köhler as Executive Secretary of the CCT.

M. de Groot was appointed rapporteur.

The agenda was approved with minor modifications.

2 DOCUMENTS PRESENTED TO THE 21st MEETING OF THE CCT

Forty-four documents were presented to the meeting. These documents are listed in Appendix T 1.

Documents that are deemed relevant for specific discussion at the meeting will in future be identified by the working groups of the CCT prior to the meeting. Those documents that are not so identified will be submitted to the CCT via the President and the Executive Secretary. A timetable for submission and consideration of documents will be set prior to every CCT meeting. Authors of CCT documents will be encouraged to identify their intended purpose, either as an item for discussion or as a supplementary background article relevant to a specific agenda item. Documents will be maintained on the BIPM website for general information.

3 REPORTS OF THE WORKING GROUPS

3.1 Working Group 1: defining fixed points and interpolating instruments

Dr Ripple summarized the plans of Working Group 1 as described in document CCT/01-29. CCT members were called upon to submit a recent bibliography and any suggestions relevant to the revision of the *Supplementary Information for the ITS-90* to the working group. The submissions were requested by February 2002, so that a preliminary draft document could be prepared by May or June 2002, including a list of identified deficiencies in the International Temperature Scale of 1990 (ITS-90). The deadline for submissions to the working group is October 2002 (for the Temperature Symposium, in Chicago) and a circulating draft document will be available at the end of the year 2002.

The CCT considered it valuable to revive the BIPM-web bibliography of publications relevant to thermometry. The BIPM can link to appropriate NMI webpages, and allow access through the BIPM search engine. Laboratories

were requested to send the URL (Universal Resource Locator) of their bibliography web pages to the Executive Secretary.

The report of Working Group 1 was approved by the CCT.

3.2 Working Group 2: secondary fixed points and techniques of approximation to the ITS-90

With reference to document CCT/01-37, Dr Steele called for laboratories to send relevant information for the revision of the *Techniques for Approximating the ITS-90*. There is no deadline for submission of information. Instead, the working group will produce documents as they become available. During discussion, it was generally accepted that the uncertainty budgets for secondary realizations of the ITS-90 could be an important tool that would enable the Regional Metrology Organizations (RMOs) to evaluate Calibration and Measurement Capabilities (CMCs) submitted for inclusion in Appendix C of the MRA.

The report of Working Group 2 was approved by the CCT.

3.3 Working Group 3: uncertainties

Dr Bonnier presented document CCT/01-10 containing a proposed guideline for the uncertainty analysis of standard platinum resistance thermometers (SPRTs) calibrated at the defining fixed points of the ITS-90 (no vapour pressure points). It was agreed that the guideline should be called *CCT guidance document on uncertainties of SPRT calibrations*, after revision and review before the end of December 2001. Laboratories can submit their comments and suggestions to the chairman of the working group before 15 October 2001. The working group will also refer to document CCT/01-02, which contains uncertainties put forward at a Working Group 3/EUROMET meeting during its revision of the uncertainty guidelines. The guidance document can be accepted by the CCT by correspondence once the revision process has reached the stage where there are no further comments. A consensus recommendation from the working group is required, meaning that there is agreement without sustained and important objections.

The report of Working Group 3 was approved by the CCT.

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

Dr Rusby summarized the working group report (CCT/01-13) and added a reference to recent work of Moldover *et al.* on virial coefficients. Laboratories that have performed thermodynamic gas thermometer measurements are called upon to review their measurements on the basis of these new data. The deviation of T_{90} from thermodynamic temperatures as discussed in Figure 1 of CCT/01-13 was compared with that in Figure 5 of CCT/01-03.

The Provisional Low Temperature Scale from 0.9 mK to 1 K, PLTS-2000, was adopted by the CIPM in October 2000 in its Recommendation 1 (CI-2000), and presentations on it have been made at the TempMeko 2001 and at the recent Quantum Fluids and Solids Conference.

It was agreed that Working Group 4 should provide Working Group 1 with a short text for the revised *Supplementary Information* giving information about the PLTS-2000. It will refer to the possible inconsistency between the ITS-90 below 1 K, using ^3He vapour pressure thermometry, and the PLTS-2000, employing ^3He melting pressure thermometry, with a statement recommending preference for the latter.

The report of Working Group 4 was approved by the CCT.

3.5 Working Group 5: radiation thermometry

The CCPR accepted the CCT recommendation to dissolve the Joint CCPR/CCT Working Group on Thermodynamic Temperature Determinations for High-Temperature Black Bodies, provided that the CCT Working Group on Radiation Thermometry continues the liaison with the CCPR. Dr Fischer reviewed the working group report (CCT/01-16). Also, the working group, along with EUROMET and CCT Working Group 3, has been involved in the workshop on uncertainties in radiation thermometry, held on 7 September 2001, which resulted in a document giving conclusions and recommendations to the working group. In response to a technical question from Working Group 7, the Working Group 5 considered the protocol for a recent APMP key comparison in radiation thermometry. The working group concluded that from a technical point of view, the APMP comparison can serve as confirmation of the traceability scheme of ITS-90 in this RMO equivalent to the purpose of CCT key comparison CCT-K5.

The report of Working Group 5 was approved by the CCT.

3.6 Working Group 6: humidity measurements

There has been a request from VNIIM to charge the CCQM with the responsibility for humidity measurements. The CCT unanimously agreed to continue humidity measurements as part of the CCT activities, given that at least one of the principal techniques in the field relies upon temperature measurement, and that the recent expansion of the TempMeko conference series to include topics in humidity has proven so successful.

Dr Huang submitted the working group report (CCT/01-20). A protocol for CCT key comparison CCT-K6 of humidity standard generators has been submitted to Working Group 7. The CCT agreed to a total of ten participants, including three from the APMP, six from EUROMET and one from the SIM. This participation list was designed to allow adequate linking to the laboratories with humidity capabilities in each of the regions: APMP (ten), COOMET (one), EUROMET (twenty-one) and the SIM (two laboratories). The regions will nominate the participants to the CCT key comparison. One requirement is that participants in the CCT key comparison must be willing to take part in a corresponding RMO key comparison as needed to complete the linking to other laboratories in their region. In addition, the participants are required to have the necessary technical competence in the specific methods used in the key comparison. The NPL will be the pilot laboratory for this key comparison, with NMIJ serving as co-pilot. The pilots and participants in the key comparison will use the existing protocol and the comments by Working Group 7 to draft and submit the final protocol to Working Group 7 for approval.

The report of Working Group 6 was approved by the CCT.

3.7 Working Group 7: key comparisons

Dr Pavese summarized the activities of Working Group 7 as described in the report (CCT/01-14 and supplement CCT/01-44). The CCT dealt with the actions requested in this documents under the appropriate agenda items. The accumulated experience of the pilots of CCT-K2 and CCT-K3 is recorded in the appendices of CCT/01-14. The working group will amend the documents to include remarks concerning the approval of the APMP key comparison as advised by Working Group 5. Dr Quinn will take the question on the definition of significant unresolved deviations to the Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB). A policy was accepted that key comparisons in areas covered by an existing working group will be proposed through that group. In cases where no working group exists,

new key comparisons may be proposed by interested parties directly to Working Group 7, with a draft protocol, rationale, and suggestions concerning the need or otherwise for a corresponding working group. The final approval of any and all new key comparisons remains the responsibility of the CCT, and may be based upon a consensus recommendation from Working Group 7.

The report of Working Group 7 and its supplement were approved by the CCT.

3.8 Working Group 8: calibration and measurement capabilities

The chairman requested that he resign from the working group, as it has been inactive since the last CCT meeting. The CCT agreed to form a new task force to finalize the list of services for calibration and measurement capabilities as contained in MRA Appendix C (see item 6.8).

4 REPORTS OF THE CCT KEY COMPARISONS

4.1 Key comparison CCT-K1: realizations of the ITS-90 from 0.65 K to 24.5561 K using rhodium-iron resistance thermometers

Dr Rusby reported that there had been a second run of measurements including thermometers from the VNIIFTRI and the KRISS. These measurements have been completed successfully and the thermometers were sent back to the participants. The pilot will establish the uncertainty budgets with the participants prior to writing draft A. Participants were asked to submit their uncertainty budgets and (where applicable) other measurement data on the thermometers.

There are no RMO key comparisons related to CCT-K1 in progress, planned or anticipated.

4.2 Key comparison CCT-K2: realizations of the ITS-90 from 13.8 K to 273.16 K using capsule-type standard platinum resistance thermometers

Dr Steele reviewed the final report of the key comparison (CCT/01-11) and the summary entry to Appendix B of the MRA (CCT/01-15) that the CCT had already accepted by correspondence. This comparison is the first to have moved through all required processes to final acceptance. It is noted to be a classic example of a CCT key comparison with most excellent results. The participants have identified some discrepancies from the measurement results where an ambiguity occurs between the results in the two loops of the key comparison. As a result of this, a study is under way on the dependence on the catalyst and on the isotopic composition of the triple point of equilibrium hydrogen.

There are bilateral key comparisons anticipated in the follow-up to this key comparison. No RMO key comparisons related to CCT-K2 are in progress, planned or anticipated.

4.3 Key comparison CCT-K3: realizations of the ITS-90 over the range 83.8058 K to 933.473 K

Mr Strouse reviewed the status of CCT-K3. The CCT examined and discussed the contents of the draft B report (CCT/01-35), the status report (CCT/01-34), the document that describes how to link RMO key comparisons to CCT-K3 (CCT/01-33), and the document summarizing the reasons for not including a key comparison reference value in the key comparison report (CCT/01-36). The CCT unanimously approved the draft B report (CCT/01-35) as the final report for the key comparison. Taking note of this final report and the accompanying documents, the majority of the CCT voted to reject the use of a key comparison reference value for the MRA Appendix B summary (the BIPM abstained). The Appendix B entry for this key comparison will contain bilateral summary matrices for each of the fixed points showing pair-wise differences and their uncertainties, graphs illustrating the results with no baseline, and dynamic web links to show the comparison from the point of view of each participant. When the pilot has prepared the Appendix B submission, Working Group 7 will make a recommendation, and submit the relevant document to the CCT for a majority vote by correspondence. The submitted *Metrologia* paper describing the key comparison will be revised to contain a table that allows comparison between the laboratories' entries to Appendix C of the MRA and the results

obtained in key comparison CCT-K3. A disclaimer stating that the lack of a key comparison reference value in this particular summary does not prevent the use of such a construct in other and in future comparisons will be added as a part of the Appendix B submission.

The pilot will work with Working Group 3 towards a document that shows the present state of the art in uncertainty assessment for standard platinum resistance thermometers on the basis of the experience gained in this key comparison.

The EUROMET has an ongoing RMO key comparison equivalent to CCT-K3 (EUROMET project 552) and a proposed project (EUROMET project 596) that has not been accepted by Working Group 7. The CCT could not agree whether or not project 596 is equivalent to CCT-K3 and left the matter to EUROMET to discuss. The APMP intends to complete an equivalent RMO comparison by the end of 2001.

4.4 Key comparison CCT-K4: aluminium and silver fixed points

Dr Fischer reported that a revised version of the draft A report is now circulating among the participants. A consensus approval is expected, subject to minor revisions. The participants met during the TempMeko conference in Berlin to decide on the need for a key comparison reference value. A majority voted in favour of reporting the comparison results using a key comparison reference value. Minority opinions stating the technical objections to using a key comparison reference value for CCT-K4 are expressed in an annexe to the comparison report. The key comparison reference value was calculated as a weighted mean, including an additional uncertainty component to account for the transfer standard stability. The draft A was expected to become draft B within a few weeks. The APMP plans a regional key comparison to be piloted by the KRISS, preparation of the protocol for which has begun.

4.5 Key comparison CCT-K5: realizations of the ITS-90 between the silver point and 1700 °C using vacuum strip lamps as transfer standards

Mr de Groot reported on the communication with the participants of CCT-K5 following the request by several participants to amend data. Consensus was reached on the following points: no changes to the data will be permitted; however, an explanation of anomalous data will be allowed in an annexe to the report by those participants who wish to do so; and data identified as

anomalous will not be used for the intended calculation of a key comparison reference value. Recent publications on the analysis of key comparison data are applied to analyse the data of this key comparison. The pilot intends to circulate a new version of the draft A report to the participants before the end of 2001.

The APMP has an ongoing key comparison that Working Group 7 and Working Group 5 have accepted as allowing the assessment of the equivalence of the scale realization despite the differences in transfer standards and source. The EUROMET has almost completed a key comparison identical to CCT-K5 (project 412).

4.6 New key comparisons

Apart from CCT-K6, already discussed, it was decided that a new CCT key comparison will be organized on water triple point cells. The pilot laboratory will be the BIPM with assistance from the BNM-INM, the UME, and a sponsor to be named from the SIM. Cells are to be sent to the BIPM for measurement. The draft protocol is to be ready by January/February 2002, and it is expected that the comparison will start in the spring of 2002 and be finished one year later, with a report anticipated for presentation at the next CCT meeting. There were expressions of interest to participate by seventeen national metrology institutes that are willing to submit at least one characterized triple point of water cell for measurement. This key comparison is designated CCT-K7.

It has been brought to the attention of the CCT that members of the community working on thermophysical properties believe that there is a need for comparisons in the fields of thermophysical quantities. It was decided that the CCT delegates possess insufficient knowledge of the field to address the concern. A working group was proposed to identify the needs (see item 6.9).

5 STUDIES CONCERNING THE ITS-90

No discussion of the submitted CCT documents related to this topic took place during the meeting. A proposal to hold a technical session of the CCT

at the time of the Temperature Symposium in Chicago (October 2002) was made by the President. The symposium Chair agreed to consider the logistics of such a session. Additional “satellite” meetings to discuss technical matters relevant to the CCT were proposed by the President, and might include sessions during the week of the next CCT meeting, or alongside TempMeko 2004 in Croatia.

6 ESTABLISHMENT AND COMPOSITION OF THE WORKING GROUPS

6.1 Working Group 1: defining fixed points and interpolating instruments

Working Group 1 on Defining Fixed Points and Interpolating Instruments continues with D. Ripple (NIST) as Chairman, with participants from the BNM-INM (Y. Hermier), IMGC (P. Marcarino), NMi VSL (M. de Groot), NRC (K. Hill), PTB (B. Fellmuth), and the VNIIM (A. Pokhodun). The CCT accepted that P. Bloembergen (NMi VSL, retired) and M. Matveyev (VNIIM) are providing assistance.

The terms of reference are:

- to improve techniques for the realization of defining fixed points and for interpolating instruments ($T_{90} \geq 3$ K);
- to study non-uniqueness;
- to update the *Supplementary Information for the International Temperature Scale of 1990*.

The working group will provide a web-based document of the duly revised *Supplementary Information*. It will incorporate documents that result from the efforts of Working Group 3 on Uncertainties as separate component documents of the *Supplementary Information*.

The title of the *Supplementary Information* will be amended to include reference to the Provisional Low-Temperature Scale of 2000.

6.2 Working Group 2: secondary fixed points and techniques for approximating the ITS-90

Working Group 2 on Secondary Fixed Points and Techniques for Approximating the International Temperature Scale of 1990 continues with A. Steele (NRC) as Chairman, and includes the MSL (R. White), the NIM (Duan Yuning), NMIJ (Y. Yamada) and the PTB (F. Edler). The CCT accepted the CSIR-NML (H. Liedberg), the IMGC (P. Marcarino), and the KRISS (Yong-Gyoo Kim) as new members. In addition P. Bloembergen (NMI VSL, retired) and M. Gotoh (Tamagawa University) are providing assistance as co-opted members.

The terms of reference are:

- to continue the survey for a revision of the *Techniques for Approximating the ITS-90*;
- to achieve this goal, specifically consider the existing literature related to AuPt and PtPd thermocouples, and try to formulate a proposal for an internationally agreed reference function for these devices. Similar effort will be directed towards the high-temperature fixed points, with a view to assigning agreed-upon secondary reference temperatures.

6.3 Working Group 3: uncertainties

Working Group 3 on Uncertainties continues with G. Bonnier (BNM-INM) as Chairman, together with the IMGC (F. Pavese), NIST (C. Meyer), NMI VSL (A. Peruzzi), NMIJ (M. Arai), NML-CSIRO (M. Ballico), and the PTB (J. Seidel) and the SMU (S. Duris). M. Stock will be the representative from the BIPM. The CCT accepted the IPQ (E. Filipe), MSL (R. White), UME (A. Diril) and the VNIIM (A. Ivanova) as new members. R. White will liaise between Working Group 2 and Working Group 3 on matters related to uncertainties of approximating techniques.

The terms of reference are: to establish recommended methods for quoting uncertainties in realizing the ITS-90.

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

Working Group 4 on Thermodynamic Temperature Determinations and Extension of the ITS-90 to Lower Temperatures continues with R. Rusby (NPL) as Chairman. Members of the working group are the MSL (R. White), the NIST (M. Moldover), the PTB (J. Fischer replacing M. Kühne), and

R.P. Hudson. W. Fogle (NIST) will continue to provide expert assistance as a co-opted member until the text for the *Supplementary Information for the PLTS-2000* is produced. M. Durieux (KOL) withdrew as a member, but remains available to provide assistance with the grateful appreciation of the CCT. The CCT accepted the IMGC (P. Steur) and the NRC (L. Reesink) as new members.

The terms of reference are: to review and make recommendations concerning thermodynamic temperature determinations and extension of the ITS-90 to lower temperatures.

6.5 Working Group 5: radiation thermometry

Working Group 5 on Radiation Thermometry continues with J. Fischer (PTB) as Chairman, with participants from the IMGC (M. Battuello), KRISS (Seung Nam Park), MSL (P. Saunders), NIM (Yuan Zundong), NIST (C. Johnson), NMi VSL (E. van der Ham), NMIJ (F. Sakuma), NML-CSIRO (M. Ballico), NPL (G. Machin), PSB (Wang Li), and the VNIIM (M. Matveyev). The CCT accepted the BNM-INM (M. Sadli) and the UME (S. Ugur) as new members.

The terms of reference are:

- to develop and improve optical methods for temperature measurement in the framework of the ITS-90;
- to maintain good links/interface with the radiometry community;
- to provide a formal liaison between the CCT and the CCPR.

6.6 Working Group 6: humidity measurements

Working Group 6 on Humidity Measurements continues with P. Huang (NIST) as Chairman, and includes the NPL (S. Bell), BNM (B. Cretinon), IMGC (V. Fericola), KRISS (Hyun-Soo Nham), NMIJ (C. Takahashi), NRCCRM (Y. Hong), PSB (Wang Li), and the VNIIM (G. Mamontov). The CCT accepted the MSL (J. Lovell-Smith), NMi VSL (J. Nielsen), PTB (G. Scholz), and the UME (S. Ugur) as new members.

The terms of reference are: to advise the CCT on matters relating to humidity.

The CCT recommended that the working group produce a working document on principal uncertainty components in humidity measurements for input to Working Group 3.

6.7 Working Group 7: key comparisons

Working Group 7 on Key Comparisons continues with F. Pavese (IMGC) as Chairman, G. Bonnier (Chairman Working Group 3), together with the KRISS (Kee Hoon Kang) and the pilots of CCT-K1 (R. Rusby, NPL), -K3 (G. Strouse, NIST), -K5 (M. de Groot, NMi VSL) and -K6 (S. Bell, NPL). M. Stock of the BIPM is a non-voting member of the working group as Executive Secretary of the CCT and pilot of CCT-K7. The CCT accepted the NML-CSIRO (M. Ballico) and the NRC (A. Steele) as new NMI members. The PTB will from now on be represented by E. Tegeler as a regular member of the working group instead of the pilot of CCT-K4 (H. Nubbemeyer).

The terms of reference are:

- to examine, for each key comparison, all the relevant documents, starting from the protocol and ending with the draft B of the key comparison report;
- to assist the pilot laboratory in preparing the text of the entry to Appendix B of the MRA as required and to prepare a recommendation on these subjects for approval by the CCT.

6.8 Working Group 8: calibration and measurement capabilities

Working Group 8 on Calibration and Measurement Capabilities (CMCs) has not been active since the last meeting of the CCT. In its place, the CCT agreed that the working group should consist of M. de Groot (NMi VSL) as Chairman, M. Ballico (NML-CSIRO) and G. Strouse (NIST). The only task assigned to this working group is to propose a calibration and measurement capability list of services for use with the MRA Appendix C. This task is to be completed by the end of October 2001. When this action is completed, M. Ballico will be replaced by Duan Yuning (NIM) as a member of the working group, and the NPL (R. Rusby) and the IMGC (P. Steur), which were elected by the CCT in 2000, will rejoin the working group. The working group will then remain in place, ready to be called upon by the President of the CCT or by members of the JCRB, to advise on possibly occurring JCRB related issues.

6.9 Working Group 9: thermophysical properties

Working Group 9 was established as a new working group on thermophysical properties. The CCT accepted J. Redgrove (NPL) as Chairman, together with the BNM-LNE (J.-R. Filtz), IMGC (G. Bussolino),

IPQ (C. Nieto de Castro), KRISS (Sang Hyun Lee), NIST (G. Fraser), NIM (Ping Qiu), NMIJ (J. Ishii), and the PTB (S. Sarge) as members.

The terms of reference are: to advise the CCT on matters related to thermophysical properties, and to assess the need in this field for a key comparison.

6.10 Activity of working groups

The President noted that he proposed to use the activity of working group members as a measure when establishing the composition of the CCT working groups in the future.

7 OTHER BUSINESS

At the request of the President, it was agreed that a group be formed to propose a mechanism for taking decisions at the CCT. This group will consist of the President, the Executive Secretary of the CCT, the Rapporteur, and the Chairs of the working groups. The group will draft an informal document for circulation among the full Consultative Committee within six months. These discussions are intended to lead to a proposal for a set of rules of operation to be discussed at the next meeting of the CCT.

There are several items that the CCT must decide upon before the next CCT meeting. These are: 1) the list of services for Appendix C to be produced by Working Group 8; 2) the uncertainty guidance document of Working Group 3; 3) the draft B reports for key comparisons CCT-K1, -K4 and -K5 based upon the recommendations of Working Group 7; and 4) the text of entries to Appendix B of the MRA for CCT-K1, -K3, -K4 and -K5. Once a working group reaches a consensus on a document, and if it expects no serious objection to the document from the CCT, then the CCT members will be asked to vote to accept the working group recommendation by correspondence. If consensus cannot be reached in the relevant working group, or if the working group considers that important, sustained objections from CCT members could be raised in relation to the proposed documents, then the matter will await attention at the next CCT meeting.

Dr Quinn asked the representatives of the regions to note the scheme that exists for submission of CMCs for inclusion in the MRA Appendix C database. Submissions must go through the RMO chairman to Dr Quinn for discussion at the JCRB.

8 REPORT TO THE CIPM AND RECOMMENDATIONS

These minutes, together with the report (CCT/01-14) and supplement (CCT/01-44) of Working Group 7 and the final reports of CCT key comparisons CCT-K2 (CCT/01-11) and CCT-K3 (CCT/01-35) can serve to inform the CIPM of the activities and recommendations of the Consultative Committee for Thermometry.

9 NEXT MEETING

It was recommended that the next meeting be held in April 2003, close to the scheduled date for the CCPR meeting. The meeting closed at 12 h 20 on 14 September.

M. de Groot, Rapporteur

September 2001

Revised November 2001

APPENDIX T 1.**Working documents submitted to the CCT at its 21st meeting**

Open working documents of the CCT can be obtained from the BIPM in their original version, or can be accessed on the BIPM website (<http://www.bipm.org>). The complete list of documents is given on page 35.

LIST OF ACRONYMS USED IN THE PRESENT VOLUME

1 Acronyms for laboratories, committees and conferences

| | |
|------------|-----------------------------------------------------------------------------------------------------------|
| APMP | Asia/Pacific Metrology Programme |
| BIPM | International Bureau of Weights and Measures/ Bureau International des Poids et Mesures |
| BNM | Bureau National de Métrologie, Paris (France) |
| BNM-INM | Bureau National de Métrologie, Institut National de Métrologie, Paris (France) |
| BNM-LNE | Bureau National de Métrologie, Laboratoire National d'Essais, Paris (France) |
| CCPR | Consultative Committee for Photometry and Radiometry/ Comité Consultatif de Photométrie et Radiométrie |
| CCT | Consultative Committee for Thermometry/Comité Consultatif de Thermométrie |
| CEM | Centro Español de Metrología, Madrid (Spain) |
| CENAM | Centro Nacional de Metrología, Mexico (Mexico) |
| CERN | European Organization for Nuclear Research, Geneva (Switzerland) |
| CIPM | International Committee for Weights and Measures/ Comité International des Poids et Mesures |
| COOMET | Cooperation in Metrology among the Central European Countries |
| CSIR-NML | Council for Scientific and Industrial Research, National Metrology Laboratory, Pretoria (South Africa) |
| CSIRO* | see NML-CSIRO |
| EUROMET | European Collaboration in Measurement Standards |
| IMGC-CNR | Istituto di Metrologia G. Colonnetti, Consiglio Nazionale delle Ricerche, Turin (Italy) |
| INM* | Institut National de Métrologie, Paris (France), see BNM |
| INTI | Instituto Nacional de Tecnología Industrial, Buenos Aires (Argentina) |
| INTiBS-PAN | Instytut Niskich Temperatur i Badan Strukturalnych, Polska Akademia Nauk, Wroclaw (Poland) |

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

| | |
|-----------|--------------------------------------------------------------------------------------------------------------------------|
| IPQ | Instituto Português da Qualidade, Lisbon (Portugal) |
| JCRB | Joint Committee of the Regional Metrology Organizations and the BIPM |
| KOL | Kamerlingh Onnes Laboratorium, Leiden (The Netherlands) |
| KRISS | Korea Research Institute of Standards and Science, Daejeon (Rep. of Korea) |
| LNE* | Laboratoire National d'Essais, Paris (France), see BNM-LNE |
| MRA | Mutual Recognition Arrangement |
| MSL | Measurement Standards Laboratory of New Zealand, Lower Hutt (New Zealand) |
| NIM | National Institute of Metrology, Beijing (China) |
| NIST | National Institute of Standards and Technology, Gaithersburg (United States) |
| NMi VSL | Nederlands Meetinstituut, Van Swinden Laboratorium, Delft (The Netherlands) |
| NMIJ/AIST | National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology, Tsukuba (Japan) |
| NML-CSIRO | National Measurement Laboratory, CSIRO, Pretoria (Australia) |
| NPL | National Physical Laboratory, Teddington (United Kingdom) |
| NRC | National Research Council of Canada, Ottawa (Canada) |
| NRCCRM | National Research Centre for Certified Reference Materials, Beijing (China) |
| NRL | U.S. Naval Research Laboratory, Washington DC (United States) |
| NRLM* | National Research Laboratory of Metrology, Tsukuba (Japan), see NMIJ/AIST |
| PSB | Singapore Productivity and Standards Board (Singapore) |
| PTB | Physikalisch-Technische Bundesanstalt, Braunschweig and Berlin (Germany) |
| RMO | Regional Metrology Organization |
| SIM | Sistema Interamericano de Metrologia |
| SMU | Slovenský Metrologický Ústav/Slovak Metrology Institute, Bratislava (Slovakia) |

| | |
|----------|------------------------------------------------------------------------------------------------------------------|
| TempMeko | International Symposium on Temperature and Thermal Measurements in Industry and Science |
| UME | Ulusal Metroloji Enstitüsü/National Metrology Institute, Gebze-Kocaeli (Turkey) |
| VNIIFTRI | Institute for Physical, Technical and Radio-Technical Measurements, Gosstandart of Russia, Moscow (Russian Fed.) |
| VNIIM | D.I. Mendeleyev Institute for Metrology, Gosstandart of Russia, St Petersburg (Russian Fed.) |
| VSL* | Van Swinden Laboratorium, Delft (The Netherlands), see NMi VSL |

2 Acronyms for scientific terms

| | |
|-----------|-------------------------------------------|
| CMC | Calibration and Measurement Capabilities |
| ITS-90 | International Temperature Scale of 1990 |
| PLTS-2000 | Provisional Low Temperature Scale of 2000 |
| SPRT | Standard Platinum Resistance Thermometer |
| URL | Universal Resource Locator |