

Bureau International des Poids et Mesures

Consultative Committee for Units (CCU)

Report of the 17th meeting
(29 June – 1 July 2005)
to the International Committee for Weights and Measures



Comité international des poids et mesures

Bureau
international
des poids
et mesures

Organisation
intergouvernementale
de la Convention
du Mètre

Note:

Following a decision made by the International Committee for Weights and Measures at its 92nd meeting in October 2003, Reports of meetings of Consultative Committees will henceforth be published only on the BIPM website in the form presented here.

Full bilingual printed versions in French and English will no longer appear.

T.J.Quinn,
Director BIPM,
November 2003.

**LIST OF MEMBERS OF THE
CONSULTATIVE COMMITTEE FOR UNITS
AS OF 29 JUNE 2005**

President

I.M. Mills, International Union of Pure and Applied Chemistry [IUPAC], Commission STU.

Executive Secretary

C. Thomas, International Bureau of Weights and Measures [BIPM], Sèvres.

Members

Centro Español de Metrología [CEM], Madrid.

International Astronomical Union [IAU].

International Commission on Illumination [CIE].

International Commission on Radiation Units and Measurements [ICRU].

International Electrotechnical Commission [IEC], Technical Committee 25.

International Federation of Clinical Chemistry and Laboratory Medicine [IFCC].

International Organization for Standardization [ISO], Technical Committee 12.

International Organization of Legal Metrology [OIML].

International Union of Pure and Applied Chemistry [IUPAC], Commission STU.

International Union of Pure and Applied Physics [IUPAP], Commission SUN-AMCO.

National Institute of Metrology [NIM], Beijing.

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

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

National Physical Laboratory [NPL], Teddington.

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

State Committee of the Russian Federation for Standardization and Metrology [Rostekhnregulirovaniye of Russia,], Moscow.

M. Himbert.

T.J. Quinn.

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

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

The Consultative Committee for Units (CCU)* held its 17th meeting at the International Bureau of Weights and Measures (BIPM), at Sèvres, from 29 June to 1 July 2005.

The following were present: J. Bastie (CIE), C.A. Borghi (IEC/TC 25), N. Capitaine (IAU), R. Dybkaer (IFCC), J. Flowers (NPL), K. Fujii (NMIJ/AIST), P. G r me (IEC/TC 25), M. Himbert (LNE-INM), Dr S. Karshenboim (VNIIM), A. Leitner (OIML), Zuliang LU (NIM), I.M. Mills FRS (President of the CCU, IUPAC), P. Mohr (NIST), B.W. Petley CBE (IUPAP/SUN-AMCO), T.J. Quinn CBE FRS (Director Emeritus of the BIPM), F. Raso (CEM), B. Siebert (PTB, not present on the first day), B.N. Taylor (NIST), A.J. Thor (ISO/TC 12), A.J. Wallard (Director of the BIPM), A. Wambersie (ICRU), Zhonghua ZHANG (NIM).

Invited: Ch. Bord  (Acad mie des Sciences, Paris), R.S. Davis (BIPM), M. Gl aser (PTB), J. Kovalevsky (Honorary member of the CIPM), M. Stock (BIPM), E.R. Williams (NIST) and Yan ZHAO (AQSIIQ).

Also present: P. Giacomo (Director Emeritus of the BIPM); D. Le Coz, J. Miles, C. Thomas (Executive Secretary of the CCU), and J. Williams from the BIPM.

Prof. Mills opened the meeting noting that this was a large group of people, the largest ever. He then welcomed the new comers: Dr Raso from the CEM (Spain), Dr G r me, representing the IEC, Prof. Zhonghua Zhang from the NIM (China), Dr Mohr from the NIST (United States), and Dr Karshenboim from the VNIIM (Russian Federation), and the invited guests: Prof. Bord , Dr Davis, Dr Gl aser, Dr Stock, Dr Williams, and Ms Yan Zhao, as well as Prof. Kovalevsky.

Dr Flowers was appointed Rapporteur. Professor Mills did not want the proceedings to be tape-recorded; Mrs Le Coz and Ms Miles took notes during the discussions.

Prof. Mills reported that the CIPM of October 2004 had asked us to consider and report on the redefinition of the kilogram. A paper in *Metrologia* by Mills *et al* (document CCU/05-02) had opened up this debate and a number of Consultative Committees and other bodies had commented. This consideration was the primary purpose of the meeting, the other main activity being to finalize the text of the new 8th edition SI brochure.

Dr Taylor asked that the redefinition of the mole as discussed in the paper by Mohr and Taylor (document CCU/05-29) be added to the agenda. Professor Bord  asked that the redefinition of the kelvin also be considered. The President agreed to include these with agenda item 4. The agenda was then approved.

* For the list of acronyms, [click here](#).

2 8th EDITION OF THE SI BROCHURE

Decisions on the brochure content had mainly been taken at the last meeting. An editorial meeting had been held in Reading (United Kingdom) in February 2005, with Prof. Mills, Dr Quinn, Dr Taylor, Dr Thomas, and Prof. Thor, leading to minor changes (documents CCU/05-18 to -23). Prof. Mills made it clear that he did not want to go back over last year's decisions.

Professor Mills was also concerned that a detailed review process inside this meeting would be too lengthy, and he asked for minor editorial points to be submitted to him and to the Executive Secretary in writing. A compilation would then be made and a new draft of the brochure be made available on the CCU access-restricted web site in August 2005.

Comments on the wording of the brochure started with Chapter 1. After a number of proposals and subsequent discussion, agreement was made:

- to change “electric field” to “electric field strength” in the margin note of page 2 (as well as in Table 4 of Chapter 2) and “symbol for dimension” to “dimensional symbol” in section 1.3;
- to capitalize “International System of Quantities” in section 1.2.

There was discussion over the form of the equations on page 3, whether one should keep the double circle-integral signs or remove them introducing a double-differential in the left-hand side of the equation. The decision was to leave them in the same form, but to see if large fractions writing rather than with a solidus may be preferable to clarify the meaning.

On Chapter 2, some changes were discussed and recorded, the most important were:

- to re-word the example on the ohm in section 2.1.1;
- to revise the section just below the definition of the kilogram to include the text provided by the Consultative Committee for Mass and Related Quantities (CCM);
- to add a note on the isotopic composition of water after the definition of the kelvin according to Recommendation T 1 (2005) (document CCU/05-25) of the Consultative Committee for Thermometry (CCT);
- to revise the sentence following the definition of the candela to include the expression “spectral luminous efficacy” (definitive wording provided by Dr Bastie after the meeting);
- to add the word “coherent” to the expression “derived units” any time it is necessary, especially in section 2.2.1 and in the headings of Tables 2, 3, and 4 (this word was deleted by mistake at the editorial meeting of last February).

There were no comments on Chapter 3.

Dr Bastie expressed surprise that the draft Chapter 4 on “Units for quantities that describe biological effects” had been abandoned. The President explained that it was not because it was considered unimportant, but because drafting it had led him to the conclusion that it was out of the area of expertise of the editorial committee. It was also unclear that this field had developed a consensus on issues of units and usage. Dr Bastie pointed out that it was important that something is produced before the use of non-SI units becomes entrenched. An extension to section 1.6 in Chapter 1 was

suggested, and the President agreed to draft this, but he intends to steer clear of any controversy. He will propose that the CIPM set up a working group to consider physiological quantities and units and hoped that they can produce a paper that will be the basis of a chapter like the old Chapter 4 in future editions.

More discussion of editorial points and other suggestions followed which have been recorded by the Executive Secretary, mainly:

- to add “microarcseconds” in a note to Table 6, for the measurement of very small angles;
- to extend Table 7 to natural and atomic units, as suggested by the editorial group;
- to change the note to Table 7 on the astronomical unit (wording provided by Dr Capitaine after the meeting);
- to introduce “speed” in Table 8 instead of “velocity”.

There was a discussion on the difficulty of use of the SI unit symbols in languages that had non-latin alphabets, particularly in Russian (document CCU/05-01). Dr Karshenboim said that local symbols were in common use in Russia. Professor Mills said that the symbols for units were not abbreviations, but recommendations to be used and understood internationally. He said that the use of the correct symbols for units is mandatory, and he suggested that this issue should be covered in the preface or in the introduction of the brochure. This was agreed.

There was agreement to the President’s suggestion that Chapter 5 should include an example graph similar to page 3 of the IUPAC green book 2nd edition. In section 5.3.5 it was agreed that there should be a comment on the use of coverage factor. There was discussion on the attitude that we should take to “ppm”, “ppb”, “percent” and so on. The general agreement was that as these were widely used we could not ignore them although we may discourage their use. It was agreed that Prof. Mills and Dr Quinn would draft a comment to include.

There was discussion on the suggestion from the previous meeting that the BIPM under the guidance of the CCU should provide a website of conversion factors initially based on those in tables 9 and 10 of the 7th edition of the brochure. The IUPAC Green Book could also be a starting point. Dr Taylor asked whether the British/US system was included and pointed out that *NIST Special Publication 811* has many conversion factors (in Appendix B). The President suggested that the best thing was that a start should be made and that problems would be dealt with as they occur.

In Appendix 1 it was decided that the historical statements should retain their original wording: we should not correct them to use modern terminology, although a sidebar could be used to indicate modern usage. For example on page 46 “amount of electricity” would be better changed to “quantity of electric charge”. It was agreed that the sidebar on page 61 really belonged to the full text with an appropriate table of contents entry. The sidebars should be used for cross-references to decisions that have been changed due to later ones.

About Appendix 2, Dr Thomas will ask each Consultative Committee to deal with its own part. Professor Mills will review and BIPM staff will provide French versions and put the material (including the dates of update) on the web with a pointer to this in the brochure. The parts on “Length”, “Mass”, and “Temperature” are already in hand.

The President asked for comments on Appendix 3 to be submitted in writing.

Professor Kovalevsky and Prof. Himbert volunteered for working out the draft French version of the 8th brochure (documents CCU/05-31 to CCU/05-36) in collaboration with Prof. Giacomo, Mrs Le Coz, and Dr Thomas.

3 REDEFINITION OF THE KILOGRAM, AND POSSIBLY THE AMPERE, KELVIN AND MOLE

The paper by Mills *et al* (*Metrologia*, 2005, **42**, 71-80) had initiated a lot of debate on the subject of the redefinition of the kilogram. The questions to be considered are:

- Should we recommend action to redefine the kilogram?
- If so, to fix the value of the Planck constant, h , or of the Avogadro constant, N_A ?
- If so, at what date should we be planning to change the definitions?
- Should we also recommend redefining the ampere to fix the value of the elementary charge e ?
- Should we also recommend redefining the kelvin to fix the value of the Boltzmann constant k ?
- Should we also recommend redefining the mole to allow N_A to be fixed without over-constraining the system?

3.1 Review of the Avogadro project and of the watt balance experiment; other presentations and general discussion

Dr Fujii presented the status of the Avogadro project (document CCU/05-30). The more recent Avogadro result implied an uncertainty in h of 3.2×10^{-7} (dominated by the uncertainty component on the molar mass determination) and was 1 part in 10^6 discrepant with the best watt balance result, which has an uncertainty of 8.7×10^{-8} . The collaboration is presently dealing with the problem of the isotopic ratio of the silicon. This will be done by repeating the measurement but with nearly pure silicon 28, a sphere of which is now being prepared. A 150 g test mass is already available, but five kilograms of material are required in order to produce a one-kilogram sphere. The production and measurement was begun in 2004 and is expected to be completed by 2010. The target uncertainty is 2×10^{-8} . It is planned that a result with an uncertainty of 6.9×10^{-8} will be produced by 2006 and one of 2.1×10^{-8} by 2009.

Dr E.R. Willams presented a summary of the status of watt balance experiments around the world (document CCU-05/15). This included his experiment at NIST, which has just produced a new result in agreement with the previous one and presenting an uncertainty of 5 parts in 10^8 . The experimental set-up is significantly rebuilt since their 1998 result on which the CODATA value is based. In summary, by 2010 it can be expected that perhaps as many as six watt balances could be on line and there should be several results approaching an uncertainty of 2×10^{-8} .

Dr Davis argued that the watt balance experiment may be more convenient to monitor the stability of the kilogram-artefact, but he recognized that the Avogadro experiment is extremely valuable because it is independent. Dr Fujii agreed on this, but Dr Quinn expressed his surprise: once the silicon sphere is produced and characterized it should be easy to put it on a balance and then use it to weigh artefacts. Dr Fujii answered that the surface of the sphere may be contaminated and he surmised that an x-ray crystal density experiment could be done once every five to ten years. Dr Gläser briefly described his experience with ion beam accumulation, presently at an uncertainty level of 1.1×10^{-2} , but expected to improve to 10^{-3} to 10^{-4} with bismuth instead of gold ions. He recognized, however, that it may probably not become really competitive. Dr Williams pointed out that it is the independent verification that is the most important thing about having multiple methods and he included the ion beam accumulation in this.

The President then moved the discussion onto the possibility of redefining the ampere in such a way as to fix the value of the elementary charge e . As Mohr and Taylor have pointed out (document CCU/05-26), this means that the Josephson and the von Klitzing constants, respectively K_J and R_K , become exact (if the kilogram had been previously redefined from a fixed value of the Planck constant). Electrical measurements would then be improved. Dr Flowers pointed out that they are only improved relative to the SI: many users are accustomed to the conventional values and do not take the uncertainty relative to the SI into account. Dr Williams said that the uncertainty in SI is stated on certificates. Dr Taylor pointed out that if h and e were fixed, the conventional values K_{J-90} and R_{K-90} would be abandoned, and K_J and R_K would take exact values. The change would be made so as to preserve the latest CODATA values.

Professor Mills brought the committee's attention to the papers from the CCEM (document CCU-05/06), CCQM (document CCU-05/07) and the CCM (document CCU-05/08). He summarized the consensus as in favour of the change of the definition of the kilogram, but not until the discrepancy between the experimental values of h and N_A had been resolved. His feeling was that there was general agreement that a redefinition would happen at some stage, but there was no urgency. He also judged the feeling of the meeting to be that a definition based on fixed value of h was the generally, but not universally, preferred choice. This was also his personal choice, although he recognized that an Avogadro based definition is easier to explain.

There was a discussion of the alternative definitions and the general feeling was in favour of the h based definition. Dr Borghi and others expressed concern at the extension to include fixed e , arguing that we must be careful to consider the implications of the alternative definitions. Dr Gläser expressed his personal preference for the Avogadro based definition.

Dr Taylor drew attention to the proposal of Mohr and Taylor that the mole could be redefined to allow fixing of both h and N_A (document CCU-05/29 [slightly revised version issued post meeting as document CCU/05-29R]). This is achieved by removing the restriction that the molar mass of carbon 12 be exactly 12 g mol^{-1} . Uncertainty is introduced into the molar mass of carbon 12 expressed in kilograms per mole. However the previous relationships would still be true to at least a part in 10^8 , so that in practice there would be no effect on physical chemistry calculations. It was agreed that wider consultation was needed, and Prof. Mills said that he would send the paper of Mohr and Taylor to relevant IUPAC commissions.

Professor Mills returned the debate to the kilogram definition. He agreed that the proposal of the Mills *et al Metrologia* paper was over-ambitious in suggesting a redefinition in 2007. It was agreed that 2011 was a more realistic date for which we should plan. Dr Quinn pointed out that since that paper there had been much debate and further proposals on the redefinition of the ampere, kelvin and now the mole. He agreed that it was better to take the longer view on a bigger package. There was discussion of the need to ensure that redefinition does not reduce the funding for the experimental effort on fundamental constant work. Professor Wallard said that it was clear that this work must go on, but there was a need to bring all the decision makers on board. Professor Mills pointed out that this view was reinforced by a number of submissions, such as documents CCU/05-06, -07, -08, -10, -17 and -38. Thus ended the first day of the meeting.

The discussion resumed in the morning of the second day of the meeting. Professor Bordé presented his paper on the base units of the SI (document CCU/05-10) and also the opinion expressed by the French Academy of Sciences (document CCU/05-17). He prefers a definition of the kilogram based on h/c^2 as this respects the fact that it is the mass that is Lorentz invariant and not the energy of a collection of photons, and also relates a mass to a time. Professor Mills said that he liked Prof. Bordé's wording of the definition, which involves the de Broglie-Compton frequency of a body, and there was some other support. Dr Gläser suggested the wording "frequency equivalent" of the mass. There was some discussion of the way the definition should be worded. Dr Taylor pointed out that the de Broglie-Compton frequency of a kilogram is astronomically large, of order 10^{+50} Hz, but others felt this was acceptable. Dr Karshenboim objected to a wavelength smaller than the Planck length or and energy higher than the Planck energy being incorporated in the definition as these are unphysical. There was objection to the definition based on assigning a numerical value for h as this would really define the joule and not the kilogram, and also would lose the concept of a body. Professor Bordé confirmed that the proposed formula h/c^2 actually relates to what is measured by watt balances.

Dr Gläser presented a summary of the discussion held at the last CCM meeting in May 2005. Their recommendation (document CCU/05-08) was that redefinition should await experimental agreement at the 2 parts in 10^8 level. They also recommended that a *mise en pratique* for the kilogram be drawn up that includes recommended practice for the continuing use of artefacts to disseminate the kilogram.

Dr Flowers agreed that a *mise en pratique* was needed, as the new definition would have to be realised in a way that maintained the system of prototypes but allowed linking their value to the SI. He pointed out that in principle one could define the kilogram via h , but use the Avogadro as a realization. Dr Taylor accepted that the CCM has concerns and that the data on the kilogram needed to be improved, but thought that 2 in 10^8 was rather tight a constraint.

There was discussion of the problem of public understanding of the definition. It was generally felt that a definition based on fixed h was harder to understand than one based on elementary masses, but there was disagreement on whether this should influence the choice. Dr Williams suggested adding "allows us to calculate the number of atoms to make up a kilogram" to an h -based wording.

Dr Petley noted that an alternative to defining the kilogram to fix h was to use the product αh (where α is the fine-structure constant). He felt this is more in line with classical electromagnetism and it retains the magnetic constant, μ_0 , as an exact constant. The ohm and ampere would then be

unchanged. Dr Williams said that he prefers not to keep the old ampere and fixed magnetic constant, so as to be able to fix e as this fits so well with the Josephson volt and quantum Hall ohm. Dr Borghi strongly expressed his and the IEC preference for a fixed μ_0 . The reason is that the fixed value of μ_0 together with the value of the speed of light in vacuum, which is fixed by the definition of the metre, fixes the values of the electric constant, ϵ_0 , and the impedance in vacuum, Z_0 . Professor Thor agreed. Dr Taylor pointed out that the CCEM had no problem with an experimentally determined μ_0 (document CCU/05-06) and that Dr Mohr has consulted Prof. Jackson (the author of the classic text on electromagnetism), who also thinks that it is acceptable (see document CCU/05-26).

Dr Quinn summarized outcomes of the CCM meeting, at which he was present. He agreed that the discrepancy between the watt balance and Avogadro results must be sorted out before a new definition can be put in place. The uncertainty on the determination of h from the Avogadro experiment could soon be below a part in 10^7 : the CCU should move forward on the assumption that this will happen and not focus on the discrepancy. He agreed that a *mise en pratique* was needed for the kilogram similar to that for the metre, describing a number of realizations and their uncertainties.

3.2 CCU Recommendation U 1 to the CIPM

The President showed a draft recommendation to the meeting. The proposed text was to recommend that preparations be made for new definitions of the kilogram, ampere and kelvin in 2011.

Professor Thor wanted three separate recommendations for the redefinitions of the three units. Dr Quinn said that as we are the Consultative Committee tasked to look at the whole SI, we should do things wholemeal and not piecemeal. There was general support for this view and Prof. Thor agreed to withdraw his suggestion.

There was further discussion of the detailed wording of the recommendation, in particular on how much we should state a preference for an h based definition. Dr Gläser agreed to a preference for h being stated if tempered with “for example”.

Dr Taylor suggested that reference to the redefinition of the mole that Dr Mohr and he proposed be included in the text and this was agreed.

The Chinese delegation made some comments in writing (now document CCU/05-39).

Dr Thomas edited the agreed changes into the recommendation while the discussion took place. She agreed to circulate the final version of Recommendation U 1 in English and in French (now documents CCU/05-40 and -41).

The President assured the meeting that he would bear the comments made at this meeting in mind when presenting the recommendation to the CIPM next October.

Dr Dybkaer suggested that the International Union of Biochemistry and Molecular Biology (IUBMB) and the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC) as well as CCQM should be consulted on the proposed change to the mole. Professor Mills asked for further suggestions of bodies that should be consulted on the proposed changes to be sent to him.

4 POSSIBILITY OF A NEW NAME FOR THE KILOGRAM

Professor Thor said he felt it important to find a new name for the kilogram, as it is a base unit but its name incorporates a prefix. Dr Fujii was in agreement in principle but thought there would be many problems in following this proposal through. Dr Leitner reminded the meeting that this proposal had been on the table for many years. The President took a straw poll, which was in favour of no action.

5 REDEFINITION OF THE KELVIN

5.1 Clarification to the present definition of the kelvin

Dr Stock presented the outcome of the last CCT meeting held earlier in June 2005, where the necessity for a clarification of the definition of the kelvin was discussed. The results of the recent key comparison [CCT-K7](#) of water triple point cells showed discrepancies much greater than repeatability, due to the isotopic content of water. Some laboratories presently correct for this and some do not. The text of the proposal (document CCU/05-25 [CCT Recommendation T 1 (2005) to the CIPM]) to add a statement on the isotopic content of water after the current definition of the kelvin was discussed. Dr Flowers asked about the difference between using standard water and applying a correction based on its analysis: should the words “corrected for” be in the definition? Dr Stock said that the formula will be in a *mise en pratique* and that would be sufficient: the wording could stand. Dr Taylor said that the ratios of isotopes should be expressed in more precise language. Dr Dybkaer suggested the wording be changed to “the isotopic composition defined by the following amount-of-substance ratios”. Professor Mills will check our comments with the CCT and the relevant working group. Professor Wallard said that we should anticipate the approval of the CIPM and insert this clarification into the brochure.

5.2 Possibility of redefining the kelvin to fix the Boltzmann constant

Dr Stock continued by presenting the outcomes of the workshop on the determination of the Boltzmann constant held at the PTB in January 2005, reported in document CCU/05-04. The repeatability of water triple point cells is 1 part in 10^7 . The best experimental determinations of the Boltzmann constant, k , are about 2 parts in 10^6 , and expected to reach 1 part in 10^6 soon. It is unclear if any technique presently under consideration will reach 1 part in 10^7 . However, some consider that a 1 part in 10^6 determination of the Boltzmann constant is sufficient to allow the redefinition of the kelvin. The main advantage of a thermodynamic definition of the kelvin would be at temperatures away from the triple point where the uncertainty of temperatures recorded in ITS-90 quickly rises.

Professor Bordé described work on measuring the Boltzmann constant by Doppler broadening measurements. At present the accuracy of this technique is a factor of ten below the best rival measurements, but he considers it a promising technique and the experiment in his laboratory is making rapid progress. He confirmed when questioned that the technique did not require the Avogadro constant as an input and was a direct measurement of k .

Dr Quinn commented that there has been good preparation for the kelvin redefinition. It was borderline whether this could go ahead based on presently available data; an improvement of only a factor of 2 or 3 in experimental uncertainty would however ensure it.

6 THE PROJECT FOR AN SI “MINI-BROCHURE”

At the suggestion of the CIPM, which felt that the SI brochure needed to be made more accessible, Prof. Mills has prepared a “mini-brochure”, to be additional to the main brochure and published separately. There were two versions for consideration: a short two-page version (document CCU/05-13) and a longer four-page version (document CCU/05-14).

Dr Flowers thought the two-page version too brief; he wanted the units outside the SI to be included. Professor Thor and Dr Taylor thought that a two-page format was more user friendly. Professor Mills said that the four-page version could be produced on a single folded sheet of A3. Professor Himbert preferred the four page version, but thought that the order should be revised so that the unit definitions did not come first. Professor Mills likes the definitions to be upfront. Dr Siebert also preferred the four-page version, and wanted inclusion of the neper. Professor Wallard liked the promotion of the BIPM and the Metre Convention. Dr Petley didn't like the photo being of the kilogram prototype: it is the most old-fashioned technology and something that we are proposing to make obsolete. Dr Quinn thought that the more modern a photograph the quicker it will look outdated! The President took opinions from around the table: the four-page version was clearly preferred over the two-page version.

The four-page version of the “mini-brochure” was then discussed in more detail. A number of minor editorial suggestions were accepted. It was also suggested that the examples chosen should be more varied. Also the font chosen should be one in which one can distinguish the letter “ell” from the number one. The President undertook to produce a new version taking into account the many suggestions.

It was also proposed to think about another summary of the SI brochure, which could be presented as a thin-paper folder of pocket size.

7 VIEWS ON THE DRAFT NEW EDITION OF THE INTERNATIONAL VOCABULARY OF BASIC AND GENERAL TERMS IN METROLOGY (VIM)

Professor Wallard informed the meeting that the Joint Committee for Guides in Metrology (JCGM) was currently preparing a supplement to the *Guide to the Expression of Uncertainty in Measurement* (GUM) and the 3rd edition of the *International Vocabulary of Basic and General Terms in Metrology* (VIM). The BIPM would very much like to host these texts on its website, but this is still in discussion with ISO, which produces hard copies and charges for them.

Dr Thomas confirmed that the definitions of the words “quantity” and “unit” as given in the current draft of the 3rd edition of the VIM had been included in the margin note of section 1.1 in Chapter 1 of the 8th SI brochure.

Professor Giacomo said that one question strongly debated in the VIM meetings concerned the question of complex quantities, the values of which are obtained as the product of a complex number by a unit, for example a complex impedance. He asked the CCU meeting for advice on it. After a brief discussion, the President concluded that he saw nothing wrong here, but it would perhaps require some more thinking.

8 ANY OTHER BUSINESS; DATE OF NEXT MEETING

There was a discussion on whether the CCU papers should be moved to the public website. Professor Wallard said that he encouraged a move to greater openness. There were concerns expressed that some of the papers submitted were drafts unsuitable for publication and that some of the institutes had procedures for approving published material. Professor Mills promised he would think about it. [In July he decided, together with the Executive Secretary, that no documents proposed to the 17th meeting of the CCU would be moved to the public part of the BIPM website, because they are either already published, or on the way to be published, or else need to be further worked out before publication.]

The new edition of the brochure and the “mini-brochure” will be submitted for approval to the CIPM in October 2005, and bilingual publication should take place during the first semester of year 2006.

It is expected the next meeting will be in June 2007.

[The dates of 11 to 13 June 2007 for the 18th CCU meeting were decided by the CIPM at its October 2005 meeting.]

Dr J. Flowers, Rapporteur

October 2005

**RECOMMANDATION DU
COMITÉ CONSULTATIF DES UNITÉS
PRÉSENTÉE AU
COMITÉ INTERNATIONAL DES POIDS ET MESURES**

RECOMMANDATION U 1 (2005) :

Sur un éventuel changement des définitions du kilogramme, de l'ampère, du kelvin et de la mole

Le Comité consultatif des unités (CCU),

considérant

- ses responsabilités concernant :
 - le développement du Système international d'unités (SI), responsabilité qui lui a été conférée lors de sa création, en 1964, par le Comité international des poids et mesures (CIPM),
 - l'établissement des éditions successives de la brochure sur le SI, et enfin
 - son rôle de conseil auprès du CIPM sur les questions relatives aux unités de mesure ;
- l'importance d'avoir une connaissance élargie et approfondie du SI, afin de s'assurer qu'il répond aux besoins de tous ses utilisateurs, tout en reflétant les avancées de la science et la compréhension des lois de la physique ;
- les grandes améliorations en exactitude apportées à notre connaissance des valeurs de la plupart des constantes fondamentales de la physique depuis le dernier changement de la définition d'une unité de base en 1983, qui a fixé la valeur de la vitesse de la lumière dans le vide ;
- l'impact des applications de l'effet Josephson et de l'effet Hall quantique sur la métrologie ;
- le consensus actuel sur le souhait de trouver un moyen de définir toutes les unités de base du SI en fonction de constantes fondamentales de la physique, afin qu'elles soient universelles, permanentes et invariables dans le temps ;
- la Résolution 7 de la 21^e Conférence générale des poids et mesures en 1999 concernant une future nouvelle définition du kilogramme ;
- les recommandations récentes (2005) proposées au CIPM par les Comités consultatifs pour la masse et les grandeurs apparentées (CCM), pour l'électricité et le magnétisme (CCEM) et pour la thermométrie (CCT), concernant d'éventuelles nouvelles définitions du kilogramme utilisant, par exemple, une valeur fixée de la constante de Planck, de l'ampère, utilisant une valeur fixée de la charge élémentaire, et du kelvin, utilisant une valeur fixée de la constante de Boltzmann, ainsi que la recommandation du Comité consultatif pour la quantité de matière – métrologie en chimie (CCQM), qui précise les préoccupations de la communauté des chimistes ;
- la recommandation récente faite au CCU par le CODATA Task Group on Fundamental Constants, qui apporte son soutien aux nouvelles définitions mentionnées ci-dessus, et aussi à

une nouvelle définition simultanée de la mole, fondée sur une valeur fixée de la constante d'Avogadro ;

- la conclusion générale à laquelle les Comités consultatifs et le CODATA Task Group sont parvenus à l'issue de leurs discussions, à savoir que si l'on doit établir de nouvelles définitions pour le kilogramme, l'ampère et le kelvin, il serait souhaitable que ces changements soient simultanés ;
- qu'il est essentiel de disposer d'autres résultats expérimentaux avant de redéfinir ces unités de base, comme l'ont fait remarquer les Comités consultatifs dans les recommandations mentionnées ci-dessus ;
- qu'avant d'apporter ces importants changements aux définitions des unités de base du SI, il convient de diffuser largement ces propositions à la communauté scientifique et aux utilisateurs qui ne participent pas aux Comités consultatifs de la Convention du mètre, afin de connaître et de prendre en compte leur avis ;

demande que le CIPM

- approuve, en principe, la préparation des nouvelles définitions et mises en pratique du kilogramme, de l'ampère et du kelvin de telle manière que, si les résultats expérimentaux sont acceptables, en accord avec les Comités consultatifs et les autres instances appropriées, le CIPM puisse préparer des propositions qui seront présentées aux Gouvernements des États membres de la Convention du Mètre à temps pour être soumis, en vue de leur adoption, à la 24^e Conférence générale en 2011 ;
- étudie la possibilité de donner simultanément une nouvelle définition de la mole, fondée sur une valeur fixée de la constante d'Avogadro ;
- prépare un projet de Résolution à soumettre à la 23^e Conférence générale en 2007 afin d'attirer l'attention des États membres sur ces activités ;
- encourage de plus les laboratoires nationaux de métrologie à continuer à financer au niveau national les recherches appropriées, afin de faciliter les changements suggérés précédemment et d'améliorer notre connaissance des constantes fondamentales concernées, en vue de l'amélioration du Système international d'unités.

**RECOMMENDATION OF THE
CONSULTATIVE COMMITTEE FOR UNITS
SUBMITTED TO THE
INTERNATIONAL COMMITTEE FOR WEIGHTS AND MEASURES**

RECOMMENDATION U 1 (2005)

On possible changes to the definitions of the kilogram, the ampere, the kelvin and the mole

The Consultative Committee for Units (CCU),

considering

- the responsibilities of the CCU, namely:
 - those given to it at its creation in 1964 by the CIPM concerning the development of the SI,
 - its responsibility for the drawing up of successive editions of the SI brochure,
 - the further responsibility of giving advice to the CIPM on matters related to units of measurement;
- the importance of taking a broad and profound view of the SI to ensure that it meets the needs of all users while at the same time ensuring that it reflects advances in science and in the understanding of the structure of physics;
- the great improvements that have taken place in the accuracy of our knowledge of the values of most of the fundamental constants of physics since the last change in the definition of a base unit in 1983, which fixed the value of the speed of light in vacuum;
- the impact on metrology of the application of the Josephson and quantum-Hall effects;
- the consensus that now exists on the desirability of finding ways of defining all of the base units of the SI in terms of fundamental physical constants so that they are universal, permanent and invariant in time;
- Resolution 7 of the 21st CGPM, 1999, concerning a future definition of the kilogram;
- the recent (2005) recommendations from the CCM, the CCEM, and the CCT to the CIPM concerning possible redefinitions of the kilogram to fix, for example, the Planck constant, the ampere to fix the elementary charge and the kelvin to fix the Boltzmann constant, and also from the CCQM in relation to the interests of the chemical community;
- the recent recommendation to the CCU from the CODATA Task Group on Fundamental Constants supporting the redefinitions above, and also on redefining at the same time the mole in terms of a fixed value of the Avogadro constant;
- the broad view that has emerged from discussions at these meetings of Consultative Committees and the CODATA Task Group, that if changes do take place in the definitions of the kilogram, the ampere and the kelvin, they should all take place at the same time;

- that further experimental results are essential, as noted by the Consultative Committees in their Recommendations cited above, before redefinition of the base units could be implemented;
- that before such important changes are made to the definitions of base units of the SI, wide publicity must be given to the draft proposals so that the opinion of the broad scientific and other user communities, not directly touched by the Consultative Committee structure of the Metre Convention, can be obtained and taken into account;

requests that

- the CIPM approve in principle the preparation of new definitions and *mise en pratiques* of the kilogram, the ampere and the kelvin so that if the results of experimental measurements are indeed acceptable, all having been agreed with the various Consultative Committees and other relevant bodies, the CIPM can prepare proposals to be put to Member Governments of the Metre Convention in time for possible adoption by the 24th CGPM in 2011;
- the CIPM give consideration to the possibility of redefining, at the same time, the mole in terms of a fixed value of the Avogadro constant;
- the CIPM prepare a Resolution that may be put to the 23rd CGPM in 2007 to alert member states to these activities;
- the CIPM further encourage NMIs to pursue national funding to support continued relevant research in order to facilitate the changes suggested above and improve our knowledge of the relevant fundamental constants, with a view to further improvement in the International System of Units.

APPENDIX U 1.
WORKING DOCUMENTS SUBMITTED TO THE CCU AT ITS 17TH MEETING

Working documents submitted to the CCU at its 17th meeting are on restricted access.