

**Bureau International des Poids et Mesures**

# **Consultative Committee for Units (CCU)**

14th Meeting (April 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 29 May 2001

**Member States of the Metre Convention**

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

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

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

- establish fundamental standards and scales for the measurement of the principal physical quantities and maintain the international prototypes;
- carry out comparisons of national and international standards;
- ensure the 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 of 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 (CEM), 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  $\gamma$ -rays, electrons), Section II (Measurement of radionuclides), Section III (Neutron measurements), Section IV ( $\alpha$ -energy standards); in 1975 this last section was dissolved and Section II was made responsible for its field of activity);
- 7 the Consultative Committee for Units (CCU), set up in 1964 (this committee replaced the “Commission for the System of Units” set up by the CIPM in 1954);
- 8 the Consultative Committee for Mass and Related Quantities (CCM), set up in 1980;
- 9 the Consultative Committee for Amount of Substance (CCQM), set up in 1993;
- 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 UNITS**

as of 19 April 2001

### **President**

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

### **Executive Secretary**

P.W. Martin, International Bureau of Weights and Measures [BIPM], Sèvres.

### **Members**

Committee of the Russian Federation for Standardization, Metrology and  
Certification [Gosstandart], Moscow.

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 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 Physical Laboratory [NPL], Teddington.

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

Organisation Internationale de Métrologie Légale [OIML].

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

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

**Observer**

Centro Español de Metrología [CEM], Madrid.

## **Consultative Committee for Units**

**Report of the 14th meeting**

(19-20 April 2001)

**to the International Committee for Weights and Measures**

## **Agenda**

- 1 Opening of the meeting; designation of a rapporteur.
- 2 Review by the President of developments since the 13th meeting of the CCU.
- 3 Responsibilities and future activities of the CCU.
- 4 Proposal to adopt the neper as an SI unit.
- 5 Possible changes to the SI base units.
- 6 Different meanings of “SI unit” and “unit of the SI”.
- 7 Possible extensions to the SI prefixes.
- 8 Symbol for the litre, nautical mile, knot and the astronomical unit.
- 9 Possible names and symbols for the unit one.
- 10 Next edition of the SI Brochure.
- 11 Date of the next meeting.

## **1 OPENING OF THE MEETING; DESIGNATION OF A RAPPORTEUR**

The Consultative Committee for Units (CCU) held its 14th meeting at the International Bureau of Weights and Measures, at Sèvres. Four sessions were held on 19 and 20 April 2001.

The following were present: A. Allisy (ICRU), J. Bastie (BNM-INM), C.A. Borghi (Università di Bologna), S. Débarbat (OP), R. Dybkaer (IFCC), J. Flowers (NPL), J.C. Gallop (NPL), V. Kose (PTB), I.M. Mills (President, also representing IUPAC), T.J. Quinn (Director of the BIPM), M. Tanaka (NMIJ), B.N. Taylor (NIST), A.J. Thor (ISO/TC12).

Also present: P. Giacomo (Director Emeritus of the BIPM), P.W. Martin (Executive Secretary, BIPM).

Observers: A. Garcia San Román (CEM), M.T. López Esteban (CEM).

Apology for absence was received from Dr B.W. Petley (IUPAP/SUN-AMCO).

Professor Mills welcomed new delegates: Mr J. Bastie, Dr J. Flowers and Prof. C. Borghi. He also extended a welcome to observers: Dr A.G. San Román and Dr M.T. López Esteban.

It was agreed that Dr Gallop should act as rapporteur for this committee meeting.

## **2 REVIEW BY THE PRESIDENT OF DEVELOPMENTS SINCE THE 13th MEETING OF THE CCU**

Prof. Mills reported on the meetings of the CIPM and the 21st CGPM (October 1999), both of which had occurred since the 13th meeting of the CCU in 1998. The CCU had submitted three proposals to the CIPM to be forwarded to the CGPM.

The first of these, concerning the adoption of the katal as an SI unit, was approved by the 21st CGPM (Resolution 12, 1999); a supplement to the 7th edition of the SI Brochure dealing with this change has been produced.

The proposal to include the neper as an SI unit was approved by the CIPM but was withdrawn at the CGPM. The lack of general appreciation of the issues involved in this proposal prompted three members of the CCU (Prof. Mills, Dr Taylor and Prof. Thor) to write a paper detailing the consideration of coherence and the adoption of the radian together with the steps leading towards the choice of the neper as the coherent unit of the quantity logarithmic decay and similar quantities. This paper, entitled “*Definitions of the units radian, neper, bel and decibel*”, was submitted to *Metrologia* (Note: it has now appeared in *Metrologia*, 2001, **38**, 353-361).

A proposal to use the name “uno” as a special name for the unit 1 was discussed by the CIPM although it had been agreed in advance not to submit it to the CGPM at present.

The President noted that another significant development since the last meeting of the CCU was the publication of the latest CODATA recommended values of the fundamental physical constants by P.J. Mohr and B.N. Taylor, which has appeared in the *Journal of Physical and Chemical Reference Data*, 1999, **28**(6), 1713-1852, and in the *Reviews of Modern Physics*, 2000, **72**(2), 351-495.

### **3 RESPONSIBILITIES AND FUTURE ACTIVITIES OF THE CCU**

The President summarized the responsibilities of the CCU as the following:

- The primary activity involves the preparation of revisions to the SI Brochure. The next (8th) edition is expected to be published around 2004. This meeting provides a forum for early discussions on possible changes. If modifications proposed by the CCU are relatively minor, the CIPM can approve them; on the other hand, major changes must be referred to the CGPM.

- Another important function of the CCU is to consider recommendations for future changes in definitions of the SI base units. This committee is not the only Consultative Committee (CC) to have an interest in this activity but nevertheless has important responsibilities across the whole range of base units. Prof. Mills expressed the view that he hoped the CCU would involve itself widely with other relevant CCs and that the CCU would be in a position to consider the results of these discussions at future meetings.
- Other CCU activities include extension to the range of SI prefixes, changes to symbols, and so forth.

In the ensuing discussion several points were emphasized. Any recommendations submitted in future to the CIPM should be accompanied by sufficient background material, and suggestions for changes to definitions of SI units should be made only when a clear consensus has been achieved. A distinction should also be drawn between the definition of a unit and the possible forms of its realization. The CCU's responsibility should not be restricted solely to the SI, but should extend to other units such as the minute, hour, etc. In addition, it would be desirable for the CCU to become involved in promulgating the correct use of the SI and the proper expression of quantities. Such topics could usefully be expanded in future editions of the Brochure.

The issue of the decimal marker and the need for its standardization was raised. While a majority of countries worldwide employ the comma, actually more people use the dot on the line. To facilitate the reading of numbers with many digits, the ISO 31-0 states that these may be separated into suitable groups, preferably of three, counting from the decimal sign towards the left and right, and that the groups should be separated by a small space, and never by a comma or a point, nor by any other means. However, it was pointed out that this practice was unacceptable to banking and financial institutions. After a lively discussion, no definitive conclusion was reached, but the President reported that he continues to press the ISO to return to the recommendation that a dot and a comma are equally acceptable alternatives for the decimal marker, with the choice being made according to customary usage in the language of the document concerned.

#### 4 PROPOSAL TO ADOPT THE NEPER AS AN SI UNIT

A lengthy discussion took place on the proposal to adopt the neper as an SI unit, in the light of the forthcoming article in *Metrologia* on the definition of the neper by Mills, Taylor and Thor (see section 2). The need for its introduction was underscored by a growing demand for measurements of logarithmic decay and similar quantities in such sectors as communications and acoustics. In their article Mills *et al.* emphasize the important role of the equations defining physical quantities in obtaining coherent derived units such as the radian and argue that in the case of logarithmic decay a similar defining equation shows that the neper is the natural choice for the coherent derived unit.

Some of the arguments put forward at the previous meeting of the CCU were re-examined, including the position that the neper, unlike the radian, is not a coherent derived unit as it is not obtained by mathematical operations involving only multiplication or division. Refuting this point of view, examples were mentioned where units were derived from operations involving trigonometric and Bessel functions.

In passing, the meeting agreed that one should be careful not to deprecate the use of non-SI units (such as degree, minute, etc.), as exemplified in Table 6 of the SI Brochure.

Following a rewording by a small sub-group, consisting of Dr Flowers, Dr Taylor and Prof. Kose, of the former Resolution on the neper submitted to the 21st CGPM, the meeting achieved a consensus on the form of the proposal to be forwarded to the CIPM, submitted as Recommendation U 1 (2001). Prof. Mills agreed to prepare a presentation to be given at the CIPM meeting using a summary of the *Metrologia* article as background material.

Note: This recommendation was discussed by the CIPM at its meeting in October 2001 and adopted as Recommendation 1 (CI-2001), and the CIPM agreed to pass it on to the CGPM at its next meeting in 2003 for its approval.

## **5 POSSIBLE CHANGES TO THE SI BASE UNITS**

### **5.1 The kilogram**

Prof. Mills briefly summarized the possibilities regarding the redefinition of the kilogram and the situation concerning its realization. At present the determination of the Avogadro constant by x-ray methods has an uncertainty of 4 parts in  $10^7$  and progress towards higher precision has been rather slow. It would appear that the precision obtainable with the watt balance measurement is already higher and still improving.

The question was raised whether the CCU was exceeding its remit in considering a topic which was primarily the concern of the Consultative Committee for Mass and Related Quantities (CCM). The President acknowledged that the CCM was indeed the appropriate vehicle for matters relating to the definition and realization of the kilogram, but maintained that the CCU has a clear role to play in the discussion of unit definitions.

The committee members expressed a variety of views. It was suggested that the definitions of SI units should be kept as simple as possible and timeless in nature, and that a distinction should be made between their definition and realization. An opposing view held that, apart from the metre, all other definitions are linked to their realizations. A lengthy debate ranged over the merits of alternative definitions (based, for example, on fixing the Planck constant), but no decisions were deemed necessary at this stage.

### **5.2 The second, the ampere and the kelvin**

Opening the discussion, Prof. Mills began by saying that he believed the definition of the second deserved the highest priority. The most likely direction was a definition based on an optical (PHz) frequency standard with line-widths less than 1 Hz.

In the discussion that followed, several points emerged. It was mentioned that Dr D.B. Sullivan (NIST) had already suggested the adoption of secondary representations of the second as an interim position and that there was a preference for optical transitions to be included in the scheme. With the advent of comb technology, it was pointed out that comparisons linking microwave and optical frequencies were now feasible. It was noted, however, that a transition always has an associated line-width with a concomitant uncertainty and any change should not compromise this level of

uncertainty. In this regard, the  $\text{Yb}^+$  and  $\text{Hg}^+$  visible transition lines are both much narrower in fractional and absolute terms than the hyperfine transition in Cs used in the existing definition. The question was raised whether the CCU was satisfied with the form of the definition of the second and if not, was this the time to consider a different form? A view was expressed that the CCU must ensure that the definition should not impose a method for its realization, and that the situation concerning the kilogram should be monitored before introducing any changes.

With regard to the kelvin, Prof. Mills remarked that it is still realized with a relative uncertainty that is one to two orders of magnitude lower than that obtained for the Boltzmann constant; the situation may be expected to change, however, so it needs to be followed.

Regarding the ampere, the present definition is chosen to fix the value of the magnetic constant,  $\mu_0$ , and for this reason is not likely to be changed. The practical realization requires a mechanical experiment, since the units of  $\mu_0$  are newtons per ampere squared ( $\text{N A}^{-2}$ ). Because such mechanical experiments that use a watt or volt balance combined with a calculable capacitor are very complex and time consuming, we use the Josephson and quantum-Hall effects to provide a practical method of realizing the ampere in terms of the conventional values for the Josephson and von Klitzing constants. These have a reproducibility of parts in  $10^9$  or better but their accuracy in terms of the SI units is limited by the accuracy of the corresponding mechanical experiments and is one or two parts in  $10^7$ .

## 6 DIFFERENT MEANINGS OF “SI UNIT” AND “UNIT OF THE SI”

Prof. Mills drew attention to comments from colleagues in the United States who had pointed out the confusion arising from different meanings of the terms “SI unit” and “unit of the SI”, the former referring only to coherent SI units and the latter to coherent as well as incoherent units such as the km, etc. This form of usage was discussed by the CCU in 1990 but no action was taken. Acknowledging that a problem exists, Prof. Mills said that it would appear in the first place to be contrary to the rules of English grammar to attach a different meaning to “SI units” and “units of the SI”; in the second

place, most people find it very odd to be told, for example, that the centimetre and the millimetre are not SI units.

He proposed three possible solutions:

- 1 We might say that the present recommendations should stand unchanged.
- 2 We might recommend that the names “SI units” and “units of the SI” should both be taken to refer to only the coherent SI units, and then devise a new name for what are presently called “units of the SI”, to include multiples and sub-multiples as well as base and derived units. (Prof. Mills has not at present been able to think of a simple and appropriate name.)
- 3 We might recommend that when we wish to refer to only the base units and derived units without prefixes they should be called the “coherent SI units”, and recommend that the names “SI units” and “units of the SI” should be taken to include also the units with multiple and sub-multiple prefixes.

After a long discussion, the following proposals were accepted by Prof. Mills on behalf of the meeting.

The CCU suggests that:

- the phrase “coherent SI units” should be used when it is desired to restrict the meaning only to base units and the coherent derived units;
- the phrases “SI units” or “units of the SI” be regarded as descriptions that include both the base units and the coherent derived units, and also all units obtained by combining these with the recommended multiple and sub-multiple prefixes.

Noting that any change in the wording of the SI Brochure needs CIPM approval, the committee agreed that a background paper should be prepared for the next meeting of the CIPM requesting that this new usage be adopted.

Note: The CIPM, at its meeting in October 2001, approved these recommendations of the CCU on the interpretation of the words “SI units” and “units of the SI”. The CIPM expects the CCU to propose appropriate changes to the wording in the next edition of the SI Brochure, to recognize these changes.

## 7 POSSIBLE EXTENSIONS TO THE SI PREFIXES

### 7.1 Proposals from the American Association of Physics Teachers (AAPT) and the CCU

Prof. Mills reminded the meeting that the proposed extensions had been discussed regularly at several previous CCU meetings. There were two different proposals on the table, one originating from the AAPT and the other from a sub-group of the CCU. In past discussions it had been agreed that so few people would need to use the extended range of prefixes that it was not worth making a change at present. The committee felt that making changes to the SI, even small changes, has the potential to result in confusion, and hence that changes should be resisted unless the case for change is strong.

Three drawbacks to the AAPT proposal were noted:

- 1 It requires compound prefixes.
- 2 It would be necessary to eliminate two prefixes that have already been adopted by the CGPM.
- 3 The range extends only to  $10^{42}$ .

The committee agreed not to proceed further at this stage.

### 7.2 Prefixes k, h and da

Prof. Mills put forward another possible modification to the present prefixes, namely that K, H and D be permitted to stand alongside k, h and da. This would have the advantage that all prefixes of multiples would be upper case and all prefixes of sub-multiples would be lower case. Initially these upper case letters might be an alternative to the lower case prefixes. With this change in place, it would be possible just to allow the system to evolve.

After some discussion the CCU decided to recommend no change. It was felt that any modifications of this kind are liable to cause doubt and confusion amongst users, and the CCU is opposed to “tinkering” with the rules of the SI without very good reasons. In this case the reasons were judged to be insufficiently strong.

Prof. Thor requested that it should be noted in the minutes that the six prefixes for binary multiples have been accepted by the IEC (see IEC 60027-2, second edition, 2000-11, and A.J. Thor, *Metrologia*, 2000, **37**, 81). These prefixes are: kibi (Ki), mebi (Mi), gibi (Gi), tebi (Ti), pebi (Pi), and exbi (Ei) for  $2^{10}$ ,  $2^{20}$ ,  $2^{30}$ ,  $2^{40}$ ,  $2^{50}$  and  $2^{60}$ , respectively.

## **8 SYMBOLS FOR THE LITRE, NAUTICAL MILE, KNOT AND THE ASTRONOMICAL UNIT**

### **8.1 The litre**

Prof. Mills mentioned that for the past twenty-two years both “l” and “L” have been acceptable symbols. Originally “l” was preferred as upper case letters were reserved solely for units derived from proper names, and there had been no Mr or Mrs Litre. However, the objection is that in many type fonts the letter “l” and the numeral “1” are almost indistinguishable and this may lead to potential problems, for example, in pharmacy. This argument had been accepted by a previous meeting of the CCU, but what is the present situation?

Although some committee members were unhappy with a situation in which two alternative symbols for the same quantity are regarded as acceptable, the general feeling was that no change was necessary. The current practice has been accepted for more than ten years now, and appears to cause no confusion. Consequently no change was recommended.

### **8.2 The nautical mile and the knot**

Prof. Mills explained that it is anomalous that there is no symbol for these units (see the SI Brochure, Table 8), although they are still widely used in navigation, because one nautical mile on the surface of the Earth subtends an angle of one minute of arc at its centre. It is a matter of inconvenience that nautical almanacs and other documents use a variety of different symbols for these units, which are likely to continue in use for many years.

The meeting decided that it was not its responsibility to decide on symbols for these units. Attention was drawn to the fact that the continued use of the nautical mile and the knot is related to safety issues in sea and air transport. The present user community does not appear to want change. Moreover, the Institute of Navigation should be consulted. Prof. Mills agreed that proposals from the CCU should not be formulated without consulting other bodies and suggested that he enter into correspondence with other user communities.

### **8.3 The astronomical unit**

The President noted that the astronomical unit, a unit of length approximately equal to the mean Earth-Sun distance, also has no recommended symbol. The

International Astronomical Union has made no general recommendation; the symbols “au” (or AU) and “ua” are both sometimes used (see SI Brochure, Table 7).

The CCU felt that the use of the symbol “ua” should be encouraged as much as possible, as “au” could be confused with an atto-unified atomic mass unit.

## 9 POSSIBLE NAMES AND SYMBOLS FOR THE UNIT ONE

(see document CCU/01-07, which is the proposal put to the CIPM in October 1998)

The meeting was reminded that the CIPM had not approved the recommendation dealing with the uno, and that consequently it had not been forwarded to the CGPM. In fact, the proposal had been sent to the CIPM for information only, with no intention that it be submitted immediately to the CGPM.

There was a strong feeling among the CCU members that this is a worthwhile proposal and that it should be forwarded again to the CIPM. In the ensuing discussion, however, the committee was not unanimous in choosing a name and symbol. While the CCU realized that the introduction of such a unit might take some time to be adopted, it was felt that in the long term it would be an asset in clarifying scientific language. It was highly desirable to steer the world away from ambiguous units like ppm, ppb, and ppt, but this cannot be done without offering some acceptable alternative. It was pointed out that in the medical field the unit “u” has been in use for some time, and in the case of erythrocytes in blood, for example, units are expressed as 6 Tu/l (terauno per litre) rather than  $6 \times 10^{12}/l$  ( $6 \times 10^{12}$  per litre).

A prolonged debate followed on the choice of the name and symbol. In the former category the name “solo” (symbol so) was suggested as an alternative to “uno”. Candidates considered for the symbol were: numeral 1, I, u, un, U, Uno and uno, objections to each of which were raised. There was an aversion on the part of several committee members to the use of a multiple-letter symbol, especially one identical with the name. The symbol “U” was criticized as it violated the general rule that capital letters are used only for

units derived from proper names (although the exception of “L” for litre had already been noted in section 8). An objection to “u” was that it could be confused with the symbol for the atomic mass unit.

A consensus was finally reached for the choice of the name “uno” and symbol capital “U”. This will then form the basis of the recommendation to be sent on to the CIPM, to be prepared by 1 September 2001. The CCU also proposed that the recommendation should not be forwarded to the CGPM but should be regarded as a change which can be evaluated over a few years of use. Dr Dybkaer, Prof. Kose and Prof. Mills (with help from Dr Quinn) undertook to prepare a supporting paper which would be circulated in draft form to the members of the CCU.

Prof. Thor expressed the wish that the minutes record his disagreement with the choice of “U” for the uno because it is not derived from a proper name.

## **10 NEXT EDITION OF THE SI BROCHURE**

This agenda item began with a general discussion. Prof. Mills pointed out that although the new edition of the SI Brochure was planned for about three years hence, this meeting provided a timely opportunity to consider many significant changes which might be required to the current edition.

The CCU was informed by Dr Quinn that of about one thousand internet sessions which occur daily on the BIPM website around 30 % of them access the on-line edition of the Brochure.

The committee agreed that the Brochure should provide both the formal and authoritative definition of the International System of Units, and yet it should also be a user-friendly guide to the SI for laypersons. The use of hyperlinks in a web-based version will make it easier to combine these objectives, and such a system is now under consideration at the BIPM. The new edition will be planned with both a web and a paper version in mind.

The question of how and when the new edition would be expected to appear was raised. Would the web version be more frequently updated than the paper version? Dr Quinn intimated that a web version with hyperlinks for the CCU to consider might be made available soon and that the unaltered text

version with hyperlinks could go live shortly afterwards. No substantial changes to either version could be made before 2003 or 2004.

The committee then went on to discuss in some detail specific changes to the Brochure. Prof. Thor was of the opinion that section 2.2.3, required no modification. Prof. Mills pointed out that while there are others who disagree with the first sentence of 2.2.3, there was general approval for this stance. In response to a question from Dr Taylor asking if reference to other operations beyond division and multiplication should be included, Prof. Thor replied that all of these points are covered by the sentence “All of these quantities...”.

Dr Dybkaer noted a problem in 2.2 with regard to numbers or counts in that a count is clearly not a derived unit. Agreeing that a sentence should be added to cover this point, Prof. Mills volunteered to draft an appropriate entry. Dr Taylor proposed that this would also be the correct place to add a reference to other mathematical operations.

Prof. Giacomo warned against the dangers of writing dimensional equations in the form  $L^{\alpha}M^{\beta}T^{\gamma} = \dots$ , as dimensions L, M, T are not algebraic quantities. In particular, the special case  $L^0M^0T^0 = 1$  might be controversial.

It was emphasized by Prof. Mills that a fuller explanation of coherence is required in section 1.2. He offered to draft this for the consideration of the committee members before the next CCU meeting, which is expected in about two years' time. Another useful addition would be to extend section 4.2 of the 7th edition dealing with units outside of the SI. Dr Quinn and Prof. Mills offered to collaborate on drafting this. Prof. Thor and Dr Taylor agreed to draft an extension to chapter 5 for the explanation and expression of unit symbols and prefixes.

Prof. Giacomo drew attention to the wording below Table 4 on p. 101, noting that some revision is required owing to an incorrect expression. For example, the unit J/K for heat capacity is not the same as the unit J/K for entropy, although these may have the same name. We might say “A same unit name may be used to express different quantities”.

Prof. Borghi asked if the new edition of the Brochure would appear before or after the 22nd CGPM meeting. For instance, if the CIPM accepts the CCU recommendations on the uno would this mean that changes will be required in the last line of Table 2? Prof. Mills noted that this would also have an impact on Table 3. Dr Taylor argued that the uno is to be used only with SI prefixes. However, Dr Dybkaer and Dr Quinn thought that one could not readily limit its use in this way.

Prof. Mills proposed the following outline for sections in the Brochure:

- 1 Historical note.
- 2 Two classes of SI units.
- 3 Coherent units.

Prof. Kose said that he would like to see some introductory remarks on the advantages to be gained by individuals from using the SI. He also suggested that Appendix 2 on p. 133 should be entitled “Realization of some important units”.

A proposal to insert a paragraph on chapter 2, p. 94, drawing attention to the difference between the definition and realization of a unit was made by Prof. Mills. A suggestion by Dr Dybkaer that the word “embodiment” might be better than “realization” was unanimously rejected. Dr Taylor commented that there is a difference between “practical realization of a unit” and “practical realization of the definition of a unit”. Dr Quinn disagreed that such a difference existed. Prof. Mills felt that “realization of the definition of a unit” has a clear meaning. If one considers the phrase “realizing the metre” this is clearly not understood to mean “realizing the definition of the metre”.

There followed a wide-ranging discussion which the President curtailed by suggesting that the committee needed to unravel its own misconceptions and contradictions by considering a new draft to the introduction to chapter 2. This would be considered by Prof. Kose, Prof. Mills, Dr Quinn and Dr Taylor. Any other committee members were also invited to contribute to this discussion.

Dr Taylor made some general comments on the organization of the appendices in the Brochure. He proposed that all entries should be in strict chronological order rather than chronological order within subject categories. Prof. Thor replied that some Resolutions relate to several subjects so are hard to locate. Prof. Mills asked if marginal notes would be acceptable, a suggestion which met with the approval of the meeting. He also suggested that a statement be added to each base unit definition to specify what is fixed as a result of the definition. To a question from Dr Taylor inquiring where in the Brochure the equivalence between “SI units” and “units of the SI” might best be included, he advocated section 1.2.

Mr Bastie requested whether a note could be inserted to draw attention to a special form of quantity defined by an integral (for example the candela, which includes the response function of the eye). There are many electromagnetic quantities of this type, particularly in the biological field. At

Dr Quinn's request, Mr Bastie agreed to draft a note on this topic to be presented to the CCPR in the near future.

Prof. Mills reminded the meeting that Prof. Thor had raised another aspect concerning the definition of the ampere in that no clear definition is given for the direction of the current. A footnote to define the sense of direction would be appropriate. Also in Table 3 there should be a footnote dealing with the convention that the charge on the proton is positive and that of the electron negative, with the sense of the current taken as positive if it corresponds to a flow of positive charges. Prof. Mills added that the modification to Table 3 would still be required. At the request of Prof. Allisy, it would be noted in the minutes that at least one committee member strongly opposed this change. Prof. Mills proposed that the issue remain open for discussion.

Dr Flowers suggested that if the uno were accepted its use should be noted on p. 110, section 5.4. Dr Taylor wondered if prefixes for binary multiples should be referred to for information (in section 5.5, for example). Dr Flowers felt it should be part of chapter 4, "Units outside the SI". From Dr Taylor's standpoint, if prefixes are being mentioned then the bit and byte could also be included. Prof. Thor opposed this as he believed they were not physical units but mathematical entities. Dr Taylor then proposed instead that the Brochure could refer to an IEC document which defines both bit and byte and the binary prefixes. It was Dr Dybkaer's opinion that no mention should be made that these are non-physical as this is a contentious issue. Dr Taylor and Prof. Thor agreed to draft some text covering this point.

A request was made by Prof. Mills that the dalton (referred to in Table 7, footnote c) be included in the index. Also with regard to the index, Dr Dybkaer pointed out that it does not refer specifically to coherent units. It was generally agreed that the index needed careful revision and expansion, a task Prof. Martin agreed to organize.

Prof. Kose queried the inclusion in section 4.2 (p. 107) of Tables 9 and 10, arguing that their inclusion encourages their use. Prof. Allisy stated that those educated in the CGS system are now a declining minority, although theoretical physicists still use the system widely. It appeared to Dr Flowers that the labelling of a table with the sub-heading "Units whose use is not encouraged" would clarify the view of the CCU. Prof. Kose asked where a line could be drawn as there is an endless number of units in this category. The meeting agreed that this was not a sensible change to consider.

Dr Taylor remarked that the phrase "internationally agreed symbol" sounds odd to American ears. Perhaps the phrase could be reworded as

“internationally agreed upon” (see footnote a, Table 8) or “internationally approved”?

Prof. Giacomo drew attention to the use of the “corresponds to” sign in Table 9 whereas in Table 6 the “equals to” sign is used between radian and degree. Prof. Mills commented that another standpoint could readily be maintained. His view on the “corresponds to” sign was supported by Prof. Thor. Prof. Kose asked if the heading to Table 9 (p. 107) could be changed to “Conversion factors to the SI for derived CGS units with special names”, and then presumably the same would apply to Table 10.

Dr Taylor suggested that individuals be identified to start work on the drafts. Prof. Mills intimated that he would like to be involved in all of the redrafting activities. Dr Taylor and Prof. Thor would work on chapter 5. Dr Quinn and Prof. Mills would collaborate on the issue relating to the definition and practical realization of units.

## **11 DATE OF THE NEXT MEETING**

Regarding the date of the next meeting, it was suggested that the CCU should wait until the reaction to its proposals and comments had been received from the CIPM. It was agreed that no date should be set at this stage for the next meeting but it would be expected to take place sometime in 2003.

The President was thanked on behalf of all the committee members for his adroit handling of the agenda.

J.C. Gallop, Rapporteur

November 2001

revised January 2002

**RECOMMENDATION OF THE  
CONSULTATIVE COMMITTEE FOR UNITS  
ADOPTED BY THE  
INTERNATIONAL COMMITTEE FOR WEIGHTS AND MEASURES**

**RECOMMENDATION 1 (CI-2001)\*:**

**The neper and the bel**

The International Committee for Weights and Measures,

**considering that**

- the natural logarithm is used for expressing the values of logarithmic decrement, field level and power level in the system of quantities on which the International System (SI) is based,
- quantities and quantity equations become simplified when the natural logarithm (logarithm to the base  $e$ ) is used, rather than logarithms to other bases,
- in particular, for complex quantities the only useful logarithm is the natural logarithm,
- with the use of the natural logarithm for complex quantities, the radian and neper become analogous units and should thus be given the same status in the SI,
- the 20th General Conference (1995, Resolution 8), decided to interpret the then supplementary units in the SI, namely the radian and steradian, as dimensionless derived units and consequently to eliminate the class of supplementary units as a separate class in the SI,
- the International Committee, through the SI brochure, 7th edition (1998), has accepted for use with the SI the neper, symbol  $Np$ , as a special name for the coherent SI unit number one, for expressing the values of logarithmic quantities defined using natural logarithms, and also the non-coherent unit, the bel, symbol  $B$ , as a unit for expressing the values of

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\* After brief discussion, and slight rewording of the first point under “considering”, Recommendation U 1 (2001) was adopted by the International Committee at its 90th meeting in October 2001 in the following terms.

logarithmic quantities defined using logarithms to the base ten, and has emphasized the importance of stating the reference level,

- there is a need to complete the internal consistency of the SI by formally adopting the special name neper with symbol Np for the coherent SI unit “one”, for expressing the values of logarithmic quantities in areas such as signal decay, electrotechnology, and acoustics,

**confirms** the decision of the International Committee to accept for use with the SI the unit bel, symbol B, and its commonly used submultiple the decibel, symbol dB, when using logarithms to the base ten, and

**recommends** that the special name neper with symbol Np be adopted for the number one as the SI dimensionless derived unit for expressing the values of logarithmic quantities such as logarithmic decrement, field level, or power level defined using natural logarithms.

**APPENDIX 1.**

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

(see the list of documents on page 35)

## LIST OF ACRONYMS USED IN THE PRESENT VOLUME

### 1 Acronyms for laboratories, committees and conferences

AAPT	American Association of Physics Teachers, College Park MD (United States)
BIPM	International Bureau of Weights and Measures/Bureau International des Poids et Mesures
BNM-INM	Bureau National de Métrologie, Institut National de Métrologie, Paris (France)
CC	Consultative Committee of the CIPM
CCM	Consultative Committee for Mass and Related Quantities/ Comité Consultatif pour la Masse et les Grandeurs Apparentées
CCPR	Consultative Committee for Photometry and Radiometry/ Comité Consultatif de Photométrie et Radiométrie
CCU	Consultative Committee for Units
CEM	Centro Español de Metrología, Madrid (Spain)
CGPM	General Conference on Weights and Measures/Conférence Générale des Poids et Mesures
CIE	International Commission on Illumination
CIPM	International Committee for Weights and Measures/Comité International des Poids et Mesures
CODATA	Committee on Data for Science and Technology
Gosstandart	The State Committee of the Russian Federation for Standardization, Metrology and Certification, Moscow (Russian Fed.)
IAU	International Astronomical Union
ICRU	International Commission on Radiation Units and Measurements
IEC	International Electrotechnical Commission
IEC/TC 25	International Electrotechnical Commission, Technical Committee 25: Quantities and units, and their letter symbols
IFCC	International Federation of Clinical Chemistry and Laboratory Medicine

INM*	Institut National de Métrologie, Paris (France), see BNM-INM
ISO	International Organization for Standardization
ISO/TC 12	International Organization for Standardization, Technical Committee 12: Quantities, units, conversion factors
IUPAC	International Union of Pure and Applied Chemistry
IUPAP	International Union of Pure and Applied Physics
NIM	National Institute of Metrology, Beijing (China)
NIST	National Institute of Standards and Technology, Gaithersburg (United States)
NMIJ/AIST	National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology, Tsukuba (Japan)
NPL	National Physical Laboratory, Teddington (United Kingdom)
NRLM*	National Research Laboratory of Metrology, Tsukuba (Japan), see NMIJ/AIST
OIML	Organisation Internationale de Métrologie Légale
OP	Observatoire de Paris, Paris (France)
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig and Berlin (Germany)
STU	Commission on Physicochemical Symbols, Terminology and Units of the IUPAC
SUN-AMCO	Commission for Symbols, Units, Nomenclature, Atomic Masses and Fundamental Constants of IUPAC

## 2 Acronyms for scientific terms

CGS	Three-dimensional coherent unit system based on the three mechanical units centimetre, gram and second
SI	International System of Units/Système international d'unités

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