

BUREAU INTERNATIONAL DES POIDS ET MESURES



COMITÉ CONSULTATIF
DES UNITÉS

Rapport de la 11^e session
Report of the 11th Meeting

1995

COMITÉ CONSULTATIF DES UNITÉS

SESSION DE 1995

MEETING OF 1995



BUREAU INTERNATIONAL DES POIDS ET MESURES



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LISTE DES SIGLES UTILISÉS DANS LE PRÉSENT VOLUME
LIST OF ACRONYMS USED IN THE PRESENT VOLUME

1. Sigles des laboratoires, commissions et conférences
Acronyms for laboratories, committees and conferences

BIPM	Bureau international des poids et mesures
CCDS	Comité consultatif pour la définition de la seconde
CCPR	Comité consultatif de photométrie et radiométrie
CCU	Comité consultatif des unités
CEI/IEC TC 25	Commission électrotechnique internationale, Comité d'études n° 25 : Grandeurs et unités, et leurs symboles littéraux/ International Electrotechnical Commission, Technical Committee 25: Quantities and units, and their letter symbols
CGPM	Conférence générale des poids et mesures
CIE	Commission internationale de l'éclairage/International Commission on Illumination
CIPM	Comité international des poids et mesures
GOST	Comité d'État de la Fédération de Russie pour les normes/The State Committee of the Russian Federation for Standardization, Metrology and Certification, Moscou (Féd. de Russie)
IAU	<i>voir</i> UAI
ICRU	International Commission on Radiation Units and Measurements
IEC	<i>voir</i> CEI
ISO TC 12	Organisation internationale de normalisation, Comité technique 12 : Grandeurs, unités, symboles, facteurs de conversion/ International Organization for Standardization, Technical Committee 12: Quantities, units, conversion factors
IUPAC	<i>voir</i> UICPA
IUPAP	<i>voir</i> UIPPA
NIM	Institut national de métrologie/National Institute of Metrology, Beijing (Rép. pop. de Chine)
NIST	National Institute of Standards and Technology, Gaithersburg (É.-U. d'Amérique)
NPL	National Physical Laboratory, Teddington (Royaume-Uni)
NRLM	National Research Laboratory of Metrology, Tsukuba (Japon)
OIML	Organisation internationale de métrologie légale
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig et Berlin (Allemagne)
STU Commission	Commission on Physicochemical Symbols, Terminology and Units of the IUPAC/UICPA

SUN-AMCO Commission UAI/IAU	Commission for Symbols, Units, Nomenclature, Atomic Masses and Fundamental Constants of IUPAP/UIPPA Union astronomique internationale/International Astronomical Union
UICPA/IUPAC	Union internationale de chimie pure et appliquée/International Union of Pure and Applied Chemistry
UIPPA/IUPAP	Union internationale de physique pure et appliquée/International Union of Pure and Applied Physics
VNIIM	Institut de métrologie D.I. Mendéléév/D.I. Mendeleyev Institute for Metrology, Saint-Pétersbourg (Féd. de Russie)

2. Sigles des termes scientifiques **Acronyms for scientific terms**

CGS	Système d'unités mécaniques à trois unités de base : centimètre, gramme, seconde/System of units based on three base units: centimetre, gram, second
SI	Système international d'unités/International System of Units

COMITÉ CONSULTATIF DES UNITÉS

MEETING OF 1995

Note on the use of the English text

To make its reports and those of its various Comités Consultatifs more widely accessible the Comité International des Poids et Mesures has decided to publish an English version of these 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.

Note sur l'utilisation du texte anglais

Afin de faciliter l'accès à ses rapports et à ceux des divers Comités consultatifs, le Comité international des poids et mesures a décidé de publier une version en anglais de ces rapports. Le lecteur doit cependant noter que le rapport officiel est toujours celui qui est rédigé en français. C'est le texte français qui fait autorité si une référence est nécessaire ou s'il y a doute sur l'interprétation.

THE BIPM AND THE CONVENTION DU MÈTRE

The Bureau International des Poids et Mesures (BIPM) was set up by the Convention du Mètre 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.

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 Convention du Mètre*.

The task of the BIPM is to ensure world-wide unification of physical measurements; it is responsible for:

- establishing the fundamental standards and scales for measurement of the principal physical quantities and maintaining the international prototypes;
- carrying out comparisons of national and international standards;
- ensuring the co-ordination of corresponding measuring techniques;
- carrying out and co-ordinating determinations relating to the fundamental physical constants that are involved in the above-mentioned activities.

BIPM operates under the exclusive supervision of the Comité International des Poids et Mesures (CIPM) which itself comes under the authority of the Conférence Générale des Poids et Mesures (CGPM).

The Conférence Générale consists of delegates from all the Member States of the Convention du Mètre and meets at present every four years. At each meeting it receives the Report of the Comité International on the work accomplished, and it is responsible for:

- discussing and instigating 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;
- confirming the results of new fundamental metrological determinations and the various scientific resolutions of international scope;
- adopting the important decisions concerning the organization and development of BIPM.

The Comité International consists of eighteen members each belonging to a different State: it meets at present every year. The officers of this committee issue an Annual Report on the administrative and financial position of BIPM to the Governments of the Member States of the Convention du Mètre.

The activities of the BIPM, which in the beginning were limited to the 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 (1937), ionizing radiations (1960), to time scales (1988) and to amount of substance (1993). 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 a new building for a library and offices was opened.

Some forty physicists or technicians work in the BIPM laboratories. They mainly conduct metrological research, international comparisons of realizations of units and the verification of standards used in the above-mentioned areas. An annual report published

* As of 31 December 1994, forty-eight States were members of this Convention: Argentina (Rep. of), Australia, Austria, Belgium, Brazil, Bulgaria, Cameroon, Canada, Chile, China (People's Rep. of), Czech Republic, Denmark, Dominican Republic, Egypt, Finland, France, Germany, Hungary, India, Indonesia, Iran, Ireland, Israel, Italy, Japan, Korea (Dem. People's Rep. of), Korea (Rep. of), Mexico, Netherlands, New Zealand, Norway, Pakistan, Poland, Portugal, Romania, Russian Federation, Singapore, Slovak Republic, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, United Kingdom, U.S.A., Uruguay, Venezuela.

in the Procès-Verbaux des séances du Comité International des Poids et Mesures gives the details of the work in progress.

In view of the extension of the work entrusted to the BIPM, the CIPM has set up since 1927, under the name of Comités Consultatifs, bodies designed to provide it with information on matters that it refers to them for study and advice. These Comités Consultatifs, which may form temporary or permanent working groups to study special subjects, are responsible for co-ordinating the international work carried out in their respective fields and proposing recommendations concerning units. In order to ensure world-wide uniformity in units of measurement, the Comité International accordingly acts directly or submits proposals for sanction by the Conférence Générale.

The Comités Consultatifs have common regulations (*BIPM Proc.-Verb. Com. Int. Poids et Mesures*, 1963, 31, 97). Each Comité Consultatif, the chairman of which is normally a member of CIPM, is composed of delegates from the major metrology laboratories and specialized institutes, a list of which is drawn up by CIPM, as well as individual members also appointed by CIPM and one representative of BIPM. These committees hold their meetings at irregular intervals; at present there are nine of them in existence:

1. The Comité Consultatif d'Électricité (CCE), set up in 1927.
2. The Comité Consultatif de Photométrie et Radiométrie (CCPR), new name given in 1971 to the Comité Consultatif de Photométrie (CCP) set up in 1933 (between 1930 and 1933 the preceding committee (CCE) dealt with matters concerning Photometry).
3. The Comité Consultatif de Thermométrie (CCT), set up in 1937.
4. The Comité Consultatif pour la Définition du Mètre (CCDM), set up in 1952.
5. The Comité Consultatif pour la Définition de la Seconde (CCDS), set up in 1956.
6. The Comité Consultatif pour les Étalons de Mesure des Rayonnements Ionisants (CCEMRI), set up in 1958. In 1969 this committee established four sections: Section I (Measurement of 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 Comité Consultatif des Unités (CCU), set up in 1964 (this committee replaced the "Commission for the System of Units" set up by the CIPM in 1954).
8. The Comité Consultatif pour la Masse et les grandeurs apparentées (CCM), set up in 1980.
9. The Comité Consultatif pour la Quantité de Matière (CCQM), set up in 1993.

The proceedings of the Conférence Générale, the Comité International, the Comités Consultatifs, and the Bureau International are published under the auspices of the latter in the following series:

- *Comptes rendus des séances de la Conférence Générale des Poids et Mesures*;
- *Procès-Verbaux des séances du Comité International des Poids et Mesures*;
- *Sessions des Comités Consultatifs*.

The Bureau International also publishes monographs on special metrological subjects and, under the title "*Le Système International d'Unités (SI)*", a booklet, periodically up-dated, in which all the decisions and recommendations concerning units are collected.

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

Since 1965 the international journal *Metrologia*, edited under the auspices of the CIPM, has published articles on the more important work on scientific metrology carried out throughout the world, on the improvement in measuring methods and standards, on units, etc., as well as reports concerning the activities, decisions, and recommendations of the various bodies created under the Convention du Mètre.

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J. DE BOER, Honorary member of the Comité International des Poids et Mesures.

Members

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INTERNATIONAL ORGANIZATION FOR STANDARDIZATION [ISO]: Technical Committee 12.

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NATIONAL INSTITUTE OF METROLOGY [NIM], Beijing.

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY [NIST], Gaithersburg.

NATIONAL PHYSICAL LABORATORY [NPL], Teddington.

NATIONAL RESEARCH LABORATORY OF METROLOGY [NRLM], Tsukuba.

ORGANISATION INTERNATIONALE DE MÉTROLOGIE LÉGALE [OIML].

PHYSIKALISCH-TECHNISCHE BUNDESANSTALT [PTB], Braunschweig and Berlin.

H. H. JENSEN, Copenhagen.

M. L. McGLASHAN, London.

L. VILLENA, Madrid.

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

AGENDA
for the 11th meeting

1. Opening of the meeting; presidency; designation of a rapporteur.
 2. Supplementary units: draft resolution for the Conférence Générale.
 3. Proposals concerning the twelve units in Table 10 (in use temporarily with the International System):
 - 3.1 Translation of “déconseillée” into “deprecated”;
 - 3.2 The ångström;
 - 3.3 The bar;
 - 3.4 The barn;
 - 3.5 The curie, röntgen, rad and rem;
 - 3.6 The are and hectare;
 - 3.7 The nautical mile and knot;
 - 3.8 The gal;
 - 3.9 The stere, the units γ and λ .
 4. CGS units with special names.
 5. Symbol for the litre, l and/or L.
 6. Astronomical units:
 - 6.1 The astronomical unit;
 - 6.2 The jansky;
 - 6.3 The day;
 - 6.4 The second of arc.
 7. The bel and decibel.
 8. Prefixes to the degree Celsius.
 9. Form of the definitions of the SI base units.
 10. Rules for writing and using SI unit symbols.
 11. To consider possible redefinition of the kilogram and the mole.
 12. Seventh edition of the SI brochure.
 13. Any other business.
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REPORT
OF THE
COMITÉ CONSULTATIF DES UNITÉS
(11th Meeting — 1995)
TO THE
COMITÉ INTERNATIONAL DES POIDS ET MESURES
by B. W. PETLEY, Rapporteur

The Comité Consultatif des Unités (CCU) held its 11th meeting at the Bureau International des Poids et Mesures, at Sèvres; four sessions took place, on 21 and 22 February 1995.

Present:

Delegates from member laboratories and organizations:

International Commission on Radiation Units and Measurements [ICRU] (A. ALLISY).

International Electrotechnical Commission [IEC]: Technical Committee 25 (C. E. KUYATT).

International Organization for Standardization [ISO]: Technical Committee 12 (A. J. THOR).

International Union of Pure and Applied Chemistry [IUPAC]: Commission STU (I. M. MILLS).

International Union of Pure and Applied Physics [IUPAP]: Commission SUN-AMCO (B. W. PETLEY).

National Institute of Standards and Technology [NIST], Gaithersburg (B. N. TAYLOR).

National Physical Laboratory [NPL], Teddington (J. GALLOP).

National Research Laboratory of Metrology [NRLM], Tsukuba (H. IMAI).

Organisation Internationale de Métrologie Légale [OIML] (R. GALLE).

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig (V. KOSE).

Members *ad personam*:

M. L. McGLASHAN, London.

L. VILLENA, Madrid.

W. R. BLEVIN, Vice-President of the CIPM, Chairman of the CCPR.

J. KOVALEVSKY, Secretary of the CIPM, Chairman of the CCDS.

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

(T. J. QUINN).

Also present: D. A. BLACKBURN, R. S. DAVIS, D. LE COZ, J. MONPROFIT (BIPM).

Apologies for absence were received from:

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

International Commission on Illumination [CIE].

Prof. H. H. JENSEN, Copenhagen.

Absent:

International Astronomical Union [IAU].

National Institute of Metrology [NIM], Beijing.

1. Opening of the meeting; presidency; designation of a rapporteur

The Director of the BIPM welcomed the participants and read a letter from Prof. Jan de Boer, President of the CCU, in which he presented his regrets and apologies at not being able to be present. In his letter he also announced his decision to resign as President of the CCU, saying that he now realized that it would be increasingly difficult for him to preside at future meetings. Dr Quinn reminded members that Prof. de Boer had served with great distinction as President of the CCU from its first meeting in 1967 and, with the agreement of those present, proposed to defer paying tribute to him until the end of the meeting. In the absence of the President, Dr Quinn informed members that the bureau of the CIPM had asked Prof. Mills to chair the meeting.

Members then introduced themselves and Dr Quinn explained the role of the BIPM staff who were attending the meeting. Dr Petley was appointed Rapporteur to be assisted by Dr Blackburn. The agenda was adopted.

Document CCU/95-2 by Prof. de Boer summarizes the views expressed by member organizations on the principal points of the agenda. It was frequently consulted during the meeting and the views initially expressed by the delegates are not repeated here.

2. Supplementary units: draft resolution for the Conférence Générale

Dr Taylor introduced documents CCU/95-1 and 2. The original initiative to treat the radian and steradian as dimensionless derived quantities came from the IUPAP and the ISO/TC-12. Dr Thor asked why the word “dimensionless” is used in connection with the radian and steradian since the CGPM does not refer to the dimensions of other units. The CIPM uses the term dimensionless in its 1980 recommendation and the present decision of the CCU follows this precedent. After discussion it was decided that, although the radian and steradian have properties which puzzle some users, there will be no further explanation concerning the properties of dimensionless units in the SI brochure other than that on page 75 of the 6th edition.

In discussion of dimensionless quantities Prof. Mills drew attention to the need for a unit of dimension one. Prof. McGlashan put the view that, in the long term, units of dimension one are superfluous to the SI: they should therefore be kept out of the text as far as possible. Prof. Kose asked why Table 3 bis was split and Dr Taylor drew attention to the paper by Nelson and Ruby on physiological units (CCU/95-5).

Conclusions:

1. The draft resolution for the CGPM was adopted, that is, the separate designation of the radian and steradian as supplementary units is abandoned and the radian and steradian are henceforth to be considered as derived units.
2. That part of the existing text of the SI brochure dealing with the radian and steradian should be put in the form of a footnote, with the words “also described as derived units of dimension one” to be added after “dimensionless derived units”.
3. The radian and steradian should be placed at the head of the, necessarily revised, Table 3.

3. Proposals concerning the twelve units in Table 10 (in use temporarily with the International System)

3.1 Translation of “déconseillée” into “deprecated”

The CCU, at its second meeting in 1969, defined three types of units outside the SI:

en usage avec le SI,
maintenues temporairement,
à déconseiller.

These correspond to the units of Tables 8-9, 10 and 11-12 respectively.

Dr Petley asked about the translation of the definitive French “déconseillée” as “deprecated” in the English version of the sixth and earlier editions of the SI brochure. He noted that the word has an important role in interactions between those who use the SI units and those who consider that they have good reason to use non-SI units, and suggested that a better translation of “déconseiller” would be “to advise against”.

Discussion followed: it was clear that all members of the CCU want to encourage the use of the SI, and ultimately to abandon the non-SI units. Some argued that stronger wording would achieve this, others that stronger wording would be counterproductive. Prof. Mills noted that some members want the title of Table 12 to be prescriptive while others want it to be advisory. Dr Thor, supported by Dr Taylor, Dr Kuyatt and Prof. McGlashan, held that a heading such as “Units preferably to be avoided” is too weak for standardization purposes.

Dr Petley suggested that most users of non-SI units have largely adopted SI units, but sometimes see a particular SI unit as rather clumsy and inelegant when compared with the non-SI unit to which they adhere. They need help rather than condemnation if they are to be persuaded to abandon their use of such non-SI units. This view was generally supported by Prof. Mills, Prof. Allisy, and Prof. Villena. Dr Kuyatt, Dr Thor, Dr Taylor and others argued that the word “deprecated” should be retained, and the French version amended accordingly.

It was decided at this stage of the meeting that the heading of Table 12 should read “Other units to be avoided”, as representing the correct translation of the definitive French wording. Several members preferred that it should be changed, along with the definitive French version, to “Units no longer accepted for use with the SI”. (This point was discussed again, later in the meeting.)

3.2 The ångström

In document CCU/95-4 Prof. Mills drew attention to the case presented by crystallographers for retention of the ångström. Discussion revealed two differing approaches within the CCU as to the most effective way of phasing out this non-SI unit. All recognized that this is an incoherent unit and agreed that the SI makes adequate provision, through the nanometre and picometre, for the expression of length measurements on this scale. Most considered that the user community is small. By a majority it was agreed that there is insufficient cause to continue to retain the ångström in Table 10.

Conclusion:

The ångström should be moved to Table 12 in the next edition of the SI brochure.

3.3 The bar

Initial discussion of the bar was evenly divided over whether it should be retained in Table 10 or moved to Table 12. A critical point, having a bearing on the timing of the move, is how the bar can safely lose its current approval for temporary use with the SI. Although the ISO view is that the kilopascal should replace the bar immediately, Dr Kose pointed out that a considerable body of standardization literature in Europe is written in terms of the bar. This point was confirmed by Dr Thor. Prof. McGlashan noted that he had encountered the kilopascal quite widely in travelling around Europe: other members of the CCU confirmed this observation. Dr Gallop noted that, if safety is a major consideration, the bar might be better in Table 10: otherwise, it could move to Table 12.

For reasons of safety it was accepted that, although 10^5 Pa is a perfectly acceptable SI alternative, the bar should retain its position in Table 10 for a transition period. Experience of the use of the word ‘temporary’ in the past suggested to those present that the year 2005 should be set as a time limit for this transition period.

Conclusion:

In the 7th edition of the SI brochure the bar should appear in Table 10, but the text will state that it is the intention of the CIPM to transfer the bar to Table 12 in the following edition at a date no later than 2005.

3.4 The barn

The barn is a non-SI unit used by nuclear physicists to express cross sections. It is commonly associated with the prefixes milli, micro and pico.

The representatives of the IUPAP, the IUPAC and the ICRU cautioned that the barn is widely used by nuclear physicists (the President of the IUPAP estimated that there is a global population of around 10^5 scientists and technologists who use the barn: some members of the CCU thought this an overestimate). Safety considerations obviously apply to the barn through its role in nuclear power and nuclear weapons. Prof. Allisy pointed out that, because the barn is a unit of area, the use of the present SI prefixes to the metre, in units such as pm^2 and fm^2 , means that the multiples of area change by powers of 10^6 rather than the customary 10^3 : he noted that it is unfortunate that the are is in Table 10. An appeal by Dr Petley that, as with the bar, the barn should be retained in Table 10 until 2005, on grounds of safety, was discussed briefly and rejected. Dr Galle suggested that the primary objective is to ensure that the non-SI units discussed in Table 12 and elsewhere should not appear on new equipment.

In a further attempt to meet the concerns of members representing the international scientific unions, it was suggested that Table 12 be regarded as a transition table for units on the way to abandonment as current SI practice is accepted or difficulties are resolved by alterations to the SI. Most members of the CCU felt that the heading to Table 12 had already been moderated, and that the new wording shows that the barn may still be used alone, or with other units, but not with SI units. Prof. Allisy pointed out that this latter provision may cause problems in the treatment of differential cross-sections, for users of the barn expect to use it in combination with the radian. He noted that the radian is much older than the SI and is not exclusively an SI unit.

In contrast with the bar, for which the kilopascal is the preferred alternative, the CCU was unable to suggest a unique SI alternative for the barn, since nuclear and other cross sections range over many orders of magnitude.

When it was noted that the CCU was simply debating which units could properly be used in association with the SI, agreement was reached that the barn should be moved to Table 12.

Conclusion:

The barn, along with its footnote, should be moved to Table 12.

3.5 The curie, röntgen, rad and rem

Following its 10th meeting in 1990 the CCU sought the advice of the ICRU on the continuation of the entries for curie, röntgen, rad, and rem in Table 10.

Prof. Allisy reported that the ICRU had discussed the matter, the outcome being described in documents CCU/95-3 and 4. The curie, röntgen,

rad and rem are gradually being phased out, the rate being different in different parts of the world. Their SI alternatives are increasingly being adopted and the ICRU is of the view that their temporary use alongside the SI may safely be discontinued. Dr Taylor and Dr Kuyatt argued that, especially in the United States, the curie, röntgen, rad, and rem are still widely used in fields related to human health and safety. For this reason, they should be treated in the same way as the bar.

Following discussion, the CCU took the view that it should follow the advice of the ICRU, and recommend that the curie, röntgen, rad, and rem be moved to Table 12.

Conclusion:

The curie, röntgen, rad and rem should be moved to Table 12.

3.6 The are and hectare

Discussion revealed that in many countries the are and hectare play an important role in farming, housing and so on. Prof. Villena mentioned the role of the are and hectare in Spain: Dr Blevin, Dr Galle and others confirmed their use in other countries. A further consideration, noted particularly by Dr Blevin, is that in recently metricated countries, extensive changes have been made to legal documents, and these would have to be changed again. Others mentioned the useful role of the hectare in spreading metrication to users currently outside the SI.

In discussion it was noted that the words “the sub-multiple centiare, symbol ca, equal to the metre square, is also commonly used in this context”, could usefully be added to footnote ^(b) of Table 10.

Conclusions:

1. The are should be retained in Table 10 and its associated prefixes mentioned in a footnote.
2. The hectare should be retained in Table 10 as at present.

3.7 The nautical mile and knot

The nautical mile and the knot are widely used in navigation to express distances and speeds over the surface of the Earth. The user group exerts a strong influence in metrology, and safety in navigation is of crucial importance. Following discussion, the CCU decided, for the time being, to retain the nautical mile and knot in Table 10.

In discussion the members of the CCU showed themselves reluctant to advise continued use of these units, particularly since this is inconsistent with the policy applied to the other non-SI units: they would like to see these units replaced by the equivalent SI units. The CCU noted with interest the arguments presented by Dr Thor, based on an article by Sven Stubert, that stronger emphasis on the unit of plane angle, the gon, might facilitate wider use of the metre for navigation purposes, particularly as the use of global navigation systems increases. This would serve to unify the units of land, sea, and air measure in the longer term and encourage the eventual move of the nautical mile and knot to Table 12. This would require the addition of the gon to Table 8.

Dr Blevin suggested that the CIPM would require to see a very strong case before re-introducing the gon (grade in French) since this would reverse the decision of the fifth meeting of the CCU in 1976 to exclude it. Prof. Kovalevsky mentioned that it is still used in France for some purposes and Dr Thor noted that in many countries it is used for surveying.

In further discussion the members of the CCU recognized that the experimental introduction of the gon might be useful as a long-term measure leading to the demise of the nautical mile and knot. It was considered that it would be necessary to add a footnote to Table 8 in order to make it clear exactly why this was being done.

The Chairman remarked that the suggestion has considerable merit, but further consideration is required. A working group was set up to consider the case for the introduction of the gon to Table 8.

Conclusions:

1. The nautical mile and knot should be retained in Table 10.
2. A working group will report on the reintroduction of the gon (grade in French) ($\pi/200$ rad) to Table 8 with the objective of phasing out the nautical mile and knot.

Working group:

Dr Thor and Prof. McGlashan will produce a discussion paper on the gon in time for consideration by the CIPM at its meeting in October 1995.

3.8 The gal

The gal is a CGS unit of acceleration. It was introduced many years ago for specialized purposes in geophysics where it is not necessarily associated with SI units except in gravity gradients. After a brief discussion the CCU decided that it is now appropriate to move the gal, together with its associated footnote, from Table 10 to Table 11.

Conclusion:

The gal, together with its associated footnote, should be moved to Table 11.

3.9 The stère, the units γ and λ

Dr Thor drew attention to the last two units in the present Table 12, γ and λ , which were first mentioned in the *Procès-Verbaux du Comité International des Poids et Mesures* in 1880, on p. 56 and p. 30 respectively. Following brief discussion, the members of the CCU noted that Table 12 will be considerably lengthened by the units transferred from Table 10 and agreed that it is impracticable to list all the non-SI units that are used for specialist purposes throughout the world. These units should therefore be deleted from the table. It was agreed that the stère, a measure used mainly to express quantities of firewood and currently listed in Table 12, should also be deleted.

In discussing Table 12, Prof. Allisy indicated that the ICRU would not like some units to be moved to this table unless the title is changed, a sentiment strongly echoed by the representatives of the IUPAC and the IUPAP.

Conclusions:

1. The stère and the units γ and λ , should be deleted from Table 12; the other gamma, that relating to geomagnetism, should be retained.
2. The title of Table 12 should be: Examples of units that should preferably be avoided.

Note: As an overall decision applying to the above, the CCU also agreed that the footnotes presently associated with units in Table 10 should move with them to Table 12, with appropriate changes of wording. Members of the CCU will be informed of these changes at an appropriate time together with any consequent changes to the body of the text or the table headings. A draft revised version of the SI brochure will be prepared by the BIPM in time for discussion at the next meeting of the CCU.

4. CGS units with special names

In discussion of Table 11 a consensus was reached that the heading “CGS units with special names” should be changed by adding “preferably to be avoided”, in order to make the presentation coherent with that of Table 12.

In considering these tables together it was noted that the words “in general” appear in the introductory text to each: it was agreed that the desired emphasis would be improved by deletion of these words.

It was suggested that the gal should be included in Table 11. Following confirmation from BIPM records that the gal is indeed a CGS unit, it was agreed that this unit, complete with its footnote, should be moved from Table 10 to Table 11. The heading: CGS units with special names, preferably to be avoided, was agreed.

Conclusions:

1. The heading to Table 11 should be amended to read:
CGS units with special names, preferably to be avoided.
2. The words “in general” in the text above Table 11 should be removed so that the paragraph reads:
The CIPM considers that it is preferable not to use, with the International System, CGS units that have special names ⁽⁴⁾. Such units are listed in Table 11.
3. The words “in general” in the text above Table 12 should be removed so that the paragraph reads:
As regards units outside the International System which do not come under Sections IV.1 and 2, the CIPM considers that it is preferable to avoid them, and to use instead units of the International System. Some of those units are listed in Table 12.
4. The gal should be moved to Table 11, complete with its associated footnote ^(e).

5. Symbol for the litre, l and/or L

The litre is a specially named unit which is used with the SI. It presents problems because two symbols are used, one of which is a capital letter.

The litre is not named after an individual and therefore, following SI conventions, its symbol should normally be shown in lower case. Unfortunately the lower case symbol can be confused with the numeral one. Current practice is to take account of this by using the capital letter when confusion is possible, but this is not mandatory. After discussion it was decided to take no action and leave the symbol for the litre unchanged, as either l or L.

Dr Thor drew the attention of the CCU to current discussions in the ISO and undertook to ensure that the conclusions will be conveyed to the CCU. The CCU agreed that it would be useful to know the ISO's views on this issue.

6. Astronomical units

6.1 The astronomical unit

Document CCU/95-7 was introduced by Prof. Kovalevsky who mentioned the “natural” astronomical units of mass, length, and time and explained that, in part, the astronomers seek the advice of the CCU on their system of units, which is largely separate from the SI. He made it clear that astronomy uses values far from the base SI units and that the transfer of physical quantities from astronomical units to SI units, while becoming easier in lunar, planetary, and satellite ranging, is still difficult when quantities having large values are involved. There is also a need in astronomy to define the period of one year with an accompanying adjective as in the Julian year. Leap seconds also pose problems which need careful consideration.

In the past, since they are experimentally measured quantities, some astronomical units were included in Table 9. Prof. Kovalevsky proposed the re-introduction of the astronomical unit to Table 9. The CCU expressed itself as sympathetic to Prof. Kovalevsky’s proposal and, after discussion, agreed that the astronomical unit should be re-introduced with the symbol (roman upright) ua.

Two difficulties emerged during the discussion and Prof. Kovalevsky was delegated to resolve them and report back. These concern the definition, the exact number, the associated uncertainty and a cited reference for the astronomical unit (as in the footnotes to the electronvolt and unified atomic mass unit). The value given at the meeting was: $1 \text{ ua} = 1,495978 \times 10^{11} \text{ m}$.

Conclusions:

1. The astronomical unit should be added to Table 9, with an associated footnote, modelled on those currently used for the electronvolt and the atomic mass unit.
2. The symbol for the astronomical unit should be ua (roman upright) in both French and English texts.

Prof. Kovalevsky was delegated to report back to the CCU giving a number, uncertainty, and reference so that a footnote may be added to Table 9 in a form similar to those used for the electronvolt and unified atomic mass unit.

6.2 The jansky

The IAU also proposed the introduction of the jansky. Taking account of the earlier discussion on other units, Prof. Kovalevsky felt that this

unit would have to go straight into Table 12, where, although in good company, it would essentially be in a table containing units to be phased out. Members of the CCU expressed a desire to help strengthen the metrological links between the SI and the units of astronomy and agreed to the addition of the jansky to Table 12.

It was noted that the use of the jansky suggests the need for an SI prefix for 10^{-27} or 10^{-30} : this will be included in the considerations of the working group on SI prefixes.

Conclusion:

The jansky should be added to Table 12.

6.3 The day

Prof. Kovalevsky also asked for advice from the CCU concerning the day and year, in particular on the need for a definition of the latter in astronomy. There followed a brief discussion on the definition of the day in Table 8, and on whether a footnote should be added to clarify the length of time intervals, including days which contain a leap second. After discussion the CCU decided not to introduce a footnote at present. (The day is also related to the astronomical need for a unit of one year and Prof. Kovalevsky pointed out that this need is distinct from that of the unit of length termed the light year, which is used in popular accounts of astronomy. Serious astronomy uses the parsec and neither uses nor requires the light year.)

6.4 The second of arc

Prof. Kovalevsky asked whether it is permissible to associate SI prefixes with the second of arc (arc second) in Table 8. The Hipparcos satellite, for example, provides some of the most accurate measurements of angle anywhere in metrology. In astronomy, the Babylonian units of angle are still preferred to the SI ones. The angle unit is realized in space by sub-division of the period of a complete rotation. It was pointed out by Dr Blevin and others that this provides an impressive demonstration that the radian is not expressible only as $\text{m} \cdot \text{m}^{-1}$. After discussion it was agreed that there is at present no need to take account of this in connection with the definitions of the radian and steradian.

The CCU agreed that it is necessary to clarify the use of SI prefixes in connection with the units in Table 8. It was reluctant to permit SI prefixes to be assigned to the ' (minute of arc) or '' (second of arc), in part because

there seems to be no simple way of associating the prefixes with the conventional symbols for the minute of arc or the second of arc. After discussion it was decided to add a clarifying footnote to Table 8 indicating that SI prefixes may be used with the litre and tonne (and the neper, bel and gon if they are included in Table 8), but not the minute, hour or day, or degree, minute of arc or second of arc. Further, it was decided that a footnote similar to that to be added to Table 8 regarding the use of SI prefixes should also be added to Table 9 for the electronvolt and unified atomic mass unit, and for the astronomical unit if it is added to Table 9.

Conclusion:

Footnote clarifying the permissible use of SI prefixes should be added to Tables 8 and 9.

7. The bel and decibel

Under the heading bel and decibel the following were also discussed: names for dimensionless quantities, i.e. quantities of dimension one; bel, decibel, neper; units used in information technology, the byte and the bit.

Dr Galle drew the attention of the CCU to the fact that the bel and decibel are often used as units in metrology. Discussion ensued, and it was pointed out that electrical attenuation and acoustic calibrations expressed in terms of the decibel may be obtained from national standards laboratories. The proposal to add logarithmic units, such as the decibel, was discussed at the third CCU meeting (U 15). Dr Taylor mentioned that IEC TC 25 has considered the question of logarithmic units.

Discussion points by Prof. Mills, Prof. McGlashan, and Dr Petley revealed a whole class of problems concerning the need to convey the fact that an operation has been performed on a numerical value. Many SI users instinctively prefer to do this by naming quantities of dimension one and treating them as units. The SI prefixes, the bel, the byte and even the radian, may all be viewed as examples of this problem. Some people find it helpful to assign a unit to the numerical value to emphasize the fact that this value is not a simple decimal number, but a binary number (byte and bit), or the index of 10^x or e^x (the bel and neper). In the case of the permitted SI prefixes, a name is used to indicate that the numerical value has been multiplied or divided by 10^{3n} , and so on. Prof. McGlashan expressed the hope that these quantities would feature only temporarily as “units” within the SI.

It was decided to include the neper and bel in Table 8 and to set up a working group to document the reasons for this decision. The working group should report back to the CCU in time for review by mail prior to submission to the CIPM in October 1995.

In computing circles, use is made of the bit and byte as units, and SI prefixes are associated with their multiples in circumstances such that kilo, mega, giga, tera... represent 2^{10} , 2^{20} , 2^{30} , 2^{40} ... respectively. After a brief discussion of this usage, the CCU felt it important to maintain the exclusive use of the SI prefixes for integral powers of 10, and that the use of the name “kilobyte” to denote 1024 bytes (2^{10} bytes) is to be discouraged. The prefix “kilo” should denote 10^3 and not 2^{10} . It was suggested that:

- (i) the CIPM should ask the IEC to consider the matter and to make proposals for consideration by the CCU;
- (ii) a footnote clarifying this should be added to Table 7 stating that the prefix kilo should only be used to denote 10^3 , not 2^{10} : the restriction should apply to all SI prefixes, specifically mega and giga.

A working group was established to draft an appropriate resolution. This group, comprising Dr Thor, Dr Taylor and Dr Quinn, met to draft Recommendation U 1 (1995), from the CCU, inviting the IEC to make proposals to the CCU concerning binary multiples of units.

Conclusions:

1. Draft Recommendation U 1 (1995) was approved.
2. The neper and bel should be added to Table 8.
3. A footnote should be added to Table 7 to emphasize that SI prefixes are decimal multiples of quantities and that, for example, one kilobyte represents 1000 bytes and not 1024 bytes.

8. Prefixes to the degree Celsius

Dr Thor asked if it is correct to use SI prefixes with the degree Celsius ($^{\circ}\text{C}$). The CCU, after discussion, concluded that since it is presently in Table 3, it is correct to associate SI prefixes with both Celsius temperatures and with temperature differences expressed in degrees Celsius. The CCU decided that there is no need to modify this position at present.

Conclusion:

The SI prefixes may be associated with the degree Celsius and a footnote should be added to Table 3 stating this fact.

9. Form of the definitions of the SI base units

Dr Taylor pointed out that the present form of the definition of the SI base units does not permit dictionary-style usage as, for example, recommended in the International Electrotechnical Vocabulary of the IEC. In this format, the words of the SI definition are such that they may replace the name of the unit at any point where it is used in a text.

Dr Quinn argued against any change in the formal definition of the SI units purely to give them a format compatible with current dictionary style. He said that the present definitions were drawn up with extreme care to express scientific thinking at the time they were adopted and should only be changed for scientific reasons. This view was accepted by the CCU. On a proposal by Prof. Kovalevsky, it was suggested that those who want a dictionary-style definition could simply take a current SI definition, and preface with the phrase “the SI unit of mass, length, time... is...”

Prof. Kovalevsky mentioned that the CCDS working group on relativity may have an impact on the definitions of the SI units. He mentioned, for example, that many think there are problems concerning the movement of clocks.

Conclusion:

There is no present need to revise the form of the definitions of the SI base units

10. Rules for writing and using SI unit symbols

Dr Taylor drew attention to the need to give the rules for expressing the values of quantities in units of the SI in the SI brochure. In the ensuing discussion, it was pointed out that, in the 6th edition of the SI brochure, numerical values with units are already given in several places. It was felt that this is primarily an ISO matter rather than one for the CCU. The CCU considered that, given the limited circulation of *Quantities and units*, the ISO standards handbook, it would certainly be useful to include such rules in the brochure. It was decided that this could usefully be a topic for consideration by a working party.

Prof. McGlashan argued that the brochure should give an example which includes the insertion of a multiplication symbol (other than the raised dot symbol) between the numerical value and the unit. This would serve to draw attention to the fact that SI usage follows the convention:

$$\text{physical quantity} = \{\text{numerical value}\} \times [\text{unit}].$$

The CCU felt that, while technically correct, this is implicit in present modes of description and that this aspect of SI practice should not be regarded as an essential part of the system.

A working group was set up to describe and demonstrate the correct use of SI unit symbols, as approved by the ISO and the CIPM, in a form suitable for inclusion in the SI brochure.

Conclusions:

1. A working group will compose a paragraph describing the correct use of SI units: this should be included in the 7th edition of the SI brochure.
2. The working group will comprise Dr Blackburn, Prof. McGlashan, and Dr Taylor.

11. To consider possible redefinition of the kilogram and the mole

Dr Taylor drew attention to projects in progress which have the objective of providing an alternative to the present definition for the kilogram, the unit of mass. These involve the direct realization of the watt and the determination of the Avogadro constant. Uncertainties at present are at the level of one part in 10^7 . The preliminary aim is to reach an uncertainty such that over a period of about one year any change exceeding one part in 10^8 in the mass of the international prototype of the kilogram will be detected. Subsequent discussion revealed that it is the numerical value of the Avogadro constant that could contribute to a new definition of the kilogram, since the constant has the dimension mol^{-1} . Prof. McGlashan pointed out that the mole is an independent SI base unit.

The CCU expressed its thanks to Dr Taylor and asked him to keep it informed of relevant progress.

Conclusion:

It is too soon to take action on this matter.

12. Seventh edition of the SI brochure

At this point, discussions of earlier items were related to changes required in the next edition of the SI brochure. The necessary editorial changes include:

1. Footnote to Table 7, p. 77, should emphasise that the SI prefixes refer strictly to powers of ten and that these prefixes should not be

used to indicate powers of two, for example one kilobit represents 1000 bit and not 1024 bit.

2. Table 3b. Document CCU/95-3 shows that the usage of the gray and the sievert has been changed by the ICRU:

The gray is used for: absorbed dose, specific energy (imparted), kerma.

The sievert is used for: dose equivalent, ambient dose equivalent, directional dose equivalent, personal dose equivalent, organ equivalent dose.

3. gon

The CCU set up a small working group (Dr Thor and Prof. McGlashan) to report to the CCU in time for review by mail prior to submission to the CIPM in October 1995.

4. neper and bel

The CCU set up a working group (Dr Kose, Dr Kuyatt and Dr Thor) to consider the neper and the bel, and to report to the CCU in time for review by mail prior to submission to the CIPM in October 1995.

5. In connection with the move of the radian and steradian to the head of Table 3, the column presently headed “expression in terms of other units” should be changed to “expression in terms of other SI units”.

6. In connection with Table 3, Dr Blevin emphasised the critical need of photometrists for the expression of the lumen in base units which contain: $m^2 \cdot m^{-2}$, that is

for luminous flux the entry in the penultimate column would be $cd \cdot sr$ and that in the final column $m^2 \cdot m^{-2} \cdot cd = cd$,

for illuminance the entry in the penultimate column would be lm/m^2 and that in the final column $m^2 \cdot m^{-4} \cdot cd = m^{-2} \cdot cd$.

7. (i) Appropriate portions of the present text relating to the radian and steradian in II.3 should be associated with Table 3. The alterations to the text suggested by Dr Thor should be incorporated.
 - (ii) In II.2 delete “pure” which appears twice, that is “pure number” becomes “number”.
 - (iii) Delete “supplementary” where it appears and insert “quantity of dimension one” instead.
 - (iv) Incorporate Table 6 in Table 4.
 - (v) Quantities involving the radian and steradian are to be treated as for luminous flux and illuminance.

8. Add footnote to the ° (degree) entry in Table 8:

The ISO recommends that the degree be sub-divided decimally rather than using the minute and second.

9. On p. 79, Table 9, remove the parentheses from around (unifiée) in the French version.
10. For the torr, retain the symbol torr following previous CGS practice.
11. Exclude the possibility of using SI prefixes in association with Tables 10, 11 and 12.
12. The unit horsepower should neither be added to Table 12, nor should it be mentioned elsewhere.
13. The words “the sub-multiple centiare, symbol ca, equal to the metre square, is also commonly used in this context” should be added to footnote (b) of Table 10.

13. Any other business

13.1 Tables 11 and 12

In response to comments by several members the question was asked whether it is sensible to continue to include Tables 11 and 12 in the 7th edition of SI brochure, in view of the difficulties experienced in obtaining the unanimous agreement of the members of the CCU to move all of the temporary units from Table 10 to Table 12.

It was argued that these tables do little more than list the most frequently used of the non-SI units, and then hold them up for disapprobation. It might thus be worth considering whether their continued presence in tabular form in Section IV of the SI brochure really serves any useful purpose. It might, for example, be better to include them in an appendix.

Associated with the difficulty of persuading working scientists to abandon certain of the non-SI units a working party was set up: members are Prof. Mills, Dr Petley and Dr Taylor. Its initial task is to consider the need for additional SI prefixes beyond 10^{-24} and 10^{24} , and it was asked to report back by the next meeting. Dr Petley, as Chairman of the group, asked members of the CCU to send him suggestions relating to the interests of their organizations.

13.2 Working groups

During the meeting, several working groups were established. Their membership and tasks are as follows:

Working group 1. — Neper and bel: to report by mail to the CCU in time for consideration by the CIPM meeting in October 1995.

Dr Thor (Chairman)

Dr Kose

Dr Kuyatt

(Prof. de Boer and Prof. Mills are also involved)

Working group 2. — Gon (or grade): to report to the CCU in time for consideration by the CIPM meeting in October 1995.

Dr Thor (Chairman)

Prof. McGlashan

Working group 3. — Additional SI prefixes and use of non-SI units: to report on the case for additional SI prefixes for next meeting of the CCU.

Dr Petley (Chairman)

Prof. Mills

Dr Taylor

Working group 4. — Draft paragraph(s) for addition to the 7th edition of the SI brochure giving rules for expressing values of quantities in units of the SI.

Prof. McGlashan (Chairman)

Dr Blackburn

Dr Taylor

13.3 Tribute to Prof. de Boer

Dr Quinn began by reminding members that this was the 11th meeting of the CCU and that Prof. Jan de Boer had presided over all previous meetings. He had also been Secretary of the CIPM from 1964 to 1987. His work for the SI spanned the critical period of its formation and initial promulgation, and led to the highly successful and internationally recognized system of today.

It was doubly unfortunate that Prof. de Boer had been unable to attend the present meeting. Not only did the CCU miss his personal input on this occasion, but his absence also prevented his colleagues on the CCU from expressing their warm appreciation of his contributions, and their gratitude for the way that he had steered the deliberations of the CCU throughout the period of its existence.

The members of the CCU then expressed their strong support and endorsement of Dr Quinn's remarks. Dr Quinn was asked to convey the warm thanks and appreciation of the members of the CCU for all that he had done for international metrology, and to convey to Jan de Boer their very best wishes for the future.

13.4 Next meeting

The President of the meeting, Prof. I. Mills, expressed his thanks to the members of the CCU for their co-operation. He also expressed his thanks to the Director and staff of the BIPM for the hospitality and efficient services that they had provided to ensure the smooth running of the meeting.

Dr Quinn, speaking for all of the members of the CCU, thanked the President for taking over the conduct of the meeting at comparatively short notice. He thanked him particularly for his experienced and efficient conduct of the discussions during the meeting, and for guiding them towards acceptable compromises.

The committee agreed that the next meeting should be held in March/April 1996. (It was subsequently agreed that the meeting should be held on 16 and 17 April 1996.)

May 1995, revised July 1995

**Recommendation
of the Comité Consultatif des Unités
submitted
to the Comité International des Poids et Mesures***

Binary multiples of units used in information technology

RECOMMENDATION U 1 (1995)

The Comité Consultatif des Unités,

considering

— that the Conférence Générale des Poids et Mesures has adopted a series of prefixes to be used in forming the decimal multiples and sub-multiples of SI units,

— that there is an increasing need in information technology to express multiples of units, such as the bit and byte,

— that the use of SI prefixes in information technology to express binary multiples of such units leads to confusion,

recalling that the SI prefixes represent strictly powers of ten,

invites the International Electrotechnical Commission to propose names and symbols for prefixes denoting powers of two for use in information technology.

—————

* The Comité International des Poids et Mesures decided, as its 84th meeting in October 1995, to take no action on this recommendation of the CCU.

APPENDIX U 1

**Working documents
submitted to the CCU at its 11th meeting**

(see the list of documents on page U 23)

ANNEXE U 1

Documents de travail présentés à la 11^e session du CCU

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

Document
CCU/

- 95-1 Projet de résolution H présenté à la 20^e Conférence générale des poids et mesures (Suppression de la classe des unités supplémentaires dans le SI), 3 p.
- 95-2 Lettre du 13 mai 1994, de J. de Boer, président, adressée aux membres du CCU, 5 p.
- 95-3 ICRU. — Lettre du 12 septembre 1994, de A. Allisy, président de l'ICRU, 1 p.
- 95-4 UICPA. — Proposal to deprecate the ångström and the bar, by I. M. Mills, 5 p.
- 95-5 NIST (É.-U. d'Amérique). — Physiological Units in the SI (submitted on behalf of R. A. Nelson and L. Ruby), by B. N. Taylor, *Metrologia*, 1993, **30**, 55-60.
- 95-6 NIST (É.-U. d'Amérique). — Three Tasks Proposed for Initiation by the 11th CCU, by B. N. Taylor, 3 p.
- 95-7 Les unités en astronomie (Lettre du 23 février 1994, de J. Kovalevsky; Réponse du 14 avril 1994, de J. de Boer), 9 p.
- 95-8 ISO/TC 12. — Items to discuss at the CCU meeting on 21-23 February 1995 (Prefixes, prefixes combined with the unit degree Celsius, definitions of SI base units), by A. J. Thor, 6 p.
- 95-9 ISO/TC 12. — The SI Brochure, by A. J. Thor, 3 p.
- 95-10 VNIIM (Féd. de Russie). — Opinion of the D. I. Mendeleyev Institute for Metrology concerning the issues discussed at the 11th Meeting of the Comité Consultatif des Unités, 1 p.
- 95-11 ISO/TC 12. — The ångström, Å – a temporary unit to be deprecated, by A. J. Thor, 2 p.

Document
CCU/

- 95-12 NIST (É.-U. d'Amérique). — Other Business – Impermissibility of Alternative Definitions of the SI Prefixes, by B. N. Taylor, 2 p.
- 95-13 Comments on CCU/95-4, by M. L. McGlashan, 2 p.
- 95-14 Comments on CCU/95-6, by M. L. McGlashan, 2 p.
- 95-15 UIPPA. — Lettre du 26 mars 1994, de B. W. Petley, au Prof. J. de Boer, 1 p.
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