

REPORT
of the
BIPM WORKING GROUP ON THE STATEMENT OF UNCERTAINTIES
(1st meeting - 21 to 23 October 1980)

to the
COMITE INTERNATIONAL DES POIDS ET MESURES

by R. KAARLS, Rapporteur

Abstract

A meeting of experts from eleven national standardizing laboratories was held at the Bureau International des Poids et Mesures, Sèvres, from October 21 to 23, 1980. This Working Group on the Statement of Uncertainties discussed recent proposals made for arriving at a uniform and generally acceptable way of assigning uncertainties to experimental data. The new approach, which abandons the traditional distinction between "random" and "systematic" uncertainties, recommends instead the direct estimation of quantities which can be considered as valid approximations to the variances and covariances needed in the general law of "error propagation". The large amount of agreement reached is formally expressed in a Recommendation, consisting of five parts, which will be presented to the Comité International des Poids et Mesures for ratification.

A Working Group meeting convened at the Bureau International des Poids et Mesures, Sèvres, from October 21 to 23, 1980, in order to discuss the assignment of uncertainties of experimental data and attempt to reach agreement on practical recommendations.

Attended the meeting:

Delegates of the following laboratories:

Bureau National de Métrologie [BNM]: Institut National de
Métrologie [INM] du Conservatoire National des Arts
et Métiers [CNAM], Paris, France (P. RIETY).

Istituto di Metrologia "G. Colonnetti" [IMGC], Torino, Italy
(S. SARTORI).

National Byureau of Standards [NBS], Washington, USA
(R. COLLE).

National Institute of Metrology [NIM], Beijing, China
(Y. JIANG).

National Physical Laboratory [NPL], Teddington, United Kingdom
(A. WILLIAMS).

National Physical Laboratory of India [NPLI], New Delhi, India
(K. CHANDRA).

National Physical Research Laboratory [NPRL], Pretoria, South
Africa (R. LAKE).

Office Fédéral de Métrologie [OFM], Bern, Switzerland
(P. KOCH).

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig,
Federal Republic of Germany (F. MELCHERT).

Statens Provningsanstalt [SP], Borås, Sweden (O. MATHIESEN).

Van Swinden Laboratorium [VSL], Delft, The Netherlands
(R. KAARLS).

The Director of the Bureau International des Poids et Mesures
(P. GIACOMO).

Were also present: T. J. QUINN, Deputy-Director of BIPM,
A. ALLISY, P. CARRE and J. W. MULLER (BIPM).

Dr. Giacomo acted as Chairman of the meeting and Mr. Kaarls was
designated as Rapporteur.

1. Introduction

The Chairman welcomes all the participants and expresses the wish that the meeting will be successful. He then explains the reasons why BIPM became actively engaged in the field of the assignment of uncertainties* to experimental data. In August 1977, Dr. E. Ambler (NBS), a member of the Comité International des Poids et Mesures (CIPM), drew the attention of CIPM to the problem of how the uncertainty associated with the result of a measurement should be stated. BIPM was thought to be in a good position to deal with such a question which was known to be complex but of great practical importance. In fact, the problem is an old one and it has turned up several times in the work of BIPM,

* The word "uncertainty" is used here in its general sense which may differ from the restricted meaning sometimes attached to it by convention. "Uncertainty" seems to be clearly preferable to "error"; some of the reasons are explained in the NPL answer to the BIPM enquiry (see [1]).

especially in discussions of several Consultative Committees. As a consequence, CIPM entrusted BIPM with studying the relevant problems in detail.

The lack of uniformity in the presentation of uncertainties has indeed become a serious problem for practical work. In particular, the analysis of international comparisons sometimes proved to be nearly impossible for lack of clarity in the statement of the claimed precision. This difficulty is well known to anybody engaged in the analysis of experimental data of various origins. A uniform concept upon which calculations can be based is also urgently required, for instance for the assignment of uncertainty limits or tolerances in legal and industrial metrology. The situation has become increasingly complicated in recent years due to the fact that various bodies have produced contradictory recommendations. It seems urgent, therefore, that BIPM try to arrive at generally acceptable recommendations before the situation becomes irredeemable.

2. The BIPM enquiry on the statement of uncertainties

In order to be fully informed on the various positions taken by the national laboratories in this field, BIPM decided to prepare a questionnaire covering the main problems involved. Since the way that some of the basic questions were raised was probably new and somewhat unexpected for several of those who received them, one could expect at the same time that the enquiry would provoke fruitful discussions within the various scientific bodies. Such a clarification of the basic issues was in any case thought to be necessary prior to reaching some possible international agreement.

The enquiry was sent to 32 national standardizing laboratories which were known to have a special interest in the subject. The questionnaire was also forwarded for information to five international organizations. The Chairman recalls that Dr. Müller played an essential part in setting up the enquiry and in the analysis of the replies and he thanks him for his contribution. By the end of 1978 answers had been received from 21 laboratories. One additional partial reply arrived only a few weeks before the meeting [10].

Dr. Müller gives a brief summary of the outcome of the enquiry. He recalls that one of the main objectives was to select topics suitable for a later discussion by a Working Group. Among the introductory questions there was the problem whether a random uncertainty should be expressed by a standard deviation or with the help of confidence limits. A clear majority was in favour of the first proposal provided that the number of degrees of freedom be added. Any transformation to corresponding confidence intervals relies on the choice of an arbitrary probability level and in practice has to assume the existence of an underlying normal population. It is therefore preferable to use the concept of a standard deviation which is independent of these additional hypotheses.

More difficult were the subsequent questions concerning the need to distinguish several types of uncertainties and the best way to characterize them. As a consequence, the respective replies presented a large spread. As far as "systematic" uncertainties are concerned, there was also much hesitation in choosing maximum limits, confidence intervals or standard deviations as the most appropriate quantity for their expression. Most of the participating laboratories consider it important to arrive at an internationally-agreed-upon rule for combining the so-called "random" and "systematic" uncertainties to a single "overall" uncertainty. Generally speaking, one could get the impression in analyzing the replies to the various questions that there might well be something like a "silent majority" waiting for clear guidance in these much-discussed matters concerning experimental uncertainties. A summary of all replies is contained in Rapport BIPM-80/3, where the complete answers given by NBS, BNM, PTB and NPL are included as appendices. This document [1] should be consulted for further details.

The Chairman stresses that the main goal of the meeting is to arrive at some clear and simple rules applicable to the statement of uncertainties. They should be based on convincing arguments and be generally applicable and acceptable to a large majority of users. Arbitrary rules, if needed at all, should be kept to a strict minimum. It would also be highly desirable to find prescriptions which can be used at any level of metrology. This may be difficult to achieve because the real needs differ greatly. On the other hand, the basic principles of the evaluation of uncertainties can be assumed to be essentially the same in most cases. The discussion should therefore try to throw some light on these common features and not to get lost in details, although these may also be of great practical importance.

It is obvious that any attempt to describe a series of measurements with a few parameters necessarily implies a loss of information. If this is considered unacceptable, the complete set of data should be retained, but in most cases this will be unpracticable and undesirable. Statistics offers as a possible solution the use of the moments, especially those of lowest order. This then leads to the well-known habit of characterizing a set of data by such quantities as mean values, variances and covariances. The question arises whether this mathematical approach provides a useful model for real-life situations.

3. Uncertainties determined by statistical methods

For the case of random uncertainties which can be evaluated by means of series of repeated measurements, the Working Group is unanimously of the opinion that they should be expressed in terms of estimated variances (s_i^2) or in the form of "standard deviations" (s_i), always adding the corresponding number of degrees of freedom ν_i . If measu-

rements are expected to be correlated, one should also determine and indicate the corresponding covariances, provided that the importance of the problem justifies the additional work.

A discussion then takes place on the role of confidence intervals and their connection with the recommended standard deviations. One of the participants is of the opinion that for the highest level of accuracy there is little need of a statement implying a confidence level.

For a known distribution function it is always possible to determine the corresponding interval. If the population can be taken as normal, as it is frequently assumed to be, the correspondence is well known and its inclusion does not give any new information. However, such an indication may be needed for situations where, for instance, the measured uncertainty has to be compared with a legally-imposed tolerance limit or with prefixed test tolerances and specifications in industry.

Dr. Melchert points out that the draft for the new German standard DIN 1319, part 3, is based on the use of Student's t-table and therefore assumes quite generally the applicability of the Gaussian distribution law. Even if this draft may be criticized from the strictly scientific point of view, it provides at least a useful guide in the field of legal metrology.

In conclusion, the Working Group recommends stating such an uncertainty component in terms of standard deviation, estimated by the quantity s_i of the sample, adding the corresponding number of degrees of freedom ν_i .

The possible need to associate a statement of uncertainty with a given confidence level, as is often the case in industrial or legal metrology, as well as the possible ways to achieve this, will be briefly discussed in Section 5.

4. Uncertainties which cannot be determined by statistical methods

When experimental uncertainties can be evaluated on the basis of a series of measurements, as is assumed in the previous section, no serious problems arise since well-established procedures can be applied for their determination. However, there are many important cases where this is not feasible. This then leads us, as suggested for instance by Dr. Collé, to distinguishing between the following two major categories of uncertainty components:

- Group A: the evaluation can be based on (objective) statistical methods,
- Group B: the estimation must rely on "other methods"; this inevitably implies some element of subjective appreciation.

The traditional distinction between "random" and "systematic" uncertainties (or "errors", as they were often called previously) is purposely avoided here, mainly because the "systematic" contributions have been defined in the past in quite different (and often incompatible) ways. The Working Group recommends that this term not be used since its meaning is often ambiguous, inconsistent and incorrectly interpreted. Whereas "group A" would no doubt correspond in most cases to what was previously called "random", "group B" may be quite different from what was usually meant by "systematic". To clarify the difference of the approaches, one could perhaps say that, whereas the traditional classification was based on the effect a given uncertainty component has on the final result, the new groups are based on the way an uncertainty is arrived at. Since an experimental result can be used in various ways, it could (and actually did) happen that an uncertainty, originally thought to be random, became of a systematic nature, or vice-versa, and this has caused a good deal of trouble in practice. Such changes not only produced problems for setting up an unambiguous classification, but they also made it impossible to assign a "total" or "final" uncertainty when contributions from both types had to be taken into account for a given result and when it was assumed that the two types required a different mathematical treatment. Mr. Williams reports serious difficulties were encountered in trying to obtain a logical method of combining "random" and systematic" uncertainties when the "systematic" components had been derived on a basis which is different from the one used for the "random" components. In the new classification, the grouping is not influenced by the way a quantity is used later on.

After discussion, the Working Group came to the conclusion that the best way to take into account our limited knowledge of the value of a so-called "systematic" component is to treat it according to a probabilistic model. If sufficient time (or money) and other methods (or different equipment) were available, our knowledge would be improved and the dispersion used in the model would, in general, be reduced.

It has been made clear in the discussion that under no circumstances should the uncertainty of a measurement (independently of the group to which it belongs) be mixed up with the concept of corrections: it is assumed throughout that all known corrections have already been taken into account to the best of the experimenter's knowledge. However, these corrections may be not sufficiently well known. In such a case it is their additional uncertainties which will have to be considered. They are assumed to have a random character and they may belong to group A or B.

In general, the uncertainties of group A will be better known than those of B, but this may not necessarily be so. Likewise, in most cases group A will be uninfluenced by the evaluator, but again the objective nature is not an absolute one since there may be several possible statistical methods available for analyzing the data, and the choice among them is clearly a subjective one. Hence, the distinction between the groups A and B is not necessarily a sharp one

and there may well be cases where one can hesitate on the classification. We shall see later, however, that this is of no real consequence. In fact, the distinction between the two groups A and B may be considered to be rather of a practical than of a "fundamental" nature. It should help the evaluator to be aware of the various problems with which he is confronted in choosing a numerical value characterizing the uncertainty. Thus, this subdivision may also contain some pedagogical justification.

The Chairman wonders whether it would be possible to characterize the components of groups A and B in a similar way. The situation seems to be as follows: whereas the uncertainties of group A, which will be abbreviated hereafter by s_i , may be rightly considered as estimated standard deviations in the statistical sense, this is not true for case B, for which the symbol u_j is proposed. In spite of this, Mr. Koch suggests, for the sake of simplicity, to use indiscriminately the term "variance" for both s_i^2 and u_j^2 and likewise "standard deviation" for s_i and u_j . However, Dr. Collé strongly insists that the quantities u_j should not be called standard deviations since this would be unacceptable to statisticians. After some discussion, the Working Group fully accepts this point of view in the interest of avoiding any disturbing interference with well-defined concepts. Even the use of the verb "estimate" to arrive at a value for u_j may be objectionable and it is only used here for lack of a more appropriate term. Expressions like "guestimate" in American or "apprécier" in French would no doubt come closer to what is actually meant.

An important question has obviously to be answered first, namely what we actually intend to express by the quantities u_j , for there are clearly several possibilities, but some of them may prove to be more useful than others. It will be appropriate to recall here that the same problem has turned up in the past in the context of characterizing a "systematic uncertainty", and various solutions have been suggested. A fairly popular proposal was to choose what has been usually called "maximum limits". They were intended to embrace with a high probability the whole possible range within which the (unknown) "true" value lay. This choice may first look quite attractive since it is simple to make. However, it has two major drawbacks: the quantity is ill defined and its further practical use in connection with other uncertainties (of any type or group) is hardly possible. Indeed, there is even no simple rule for the propagation of limits when summing two quantities, the individual limits of which are known.

The only viable solution to this problem, it seems, is to follow the prescription contained in the well-known general law of "error propagation". The essential quantities appearing in this law are the variances (and covariances) of the variables (measurements) involved. This then indicates that, if we look for "useful" measures of uncertainty which can be readily applied to the usual formalism, we have to choose something which can be considered as the best available approximation to the corresponding "standard deviations".

This reasoning has led the Working Group, after some discussion, to agree that one may act as if the u_j^2 were variances. This resulted in the statement contained in paragraph 3 of the recommendation (see end of the report). The participants realize that the transposition of this somewhat enigmatic phrase into practice will often be quite a difficult task. The recommendation therefore restricts itself to indicating the goal to be achieved without explicitly saying how this can be done in practice.

This is obviously a crucial point in the new approach and one may expect various difficulties in real-life situations. Suggestions to overcome them have not been discussed in much detail for lack of time; this important topic will have to be taken up again later. Roughly speaking, possible estimations of u_j can be obtained as follows:

- One tries to guess directly u_j , for instance by means of an interval which corresponds to a confidence level of 2/3 or 70%.
- One tries to guess confidence intervals at a level of 50%. Then u_j may be taken as about 1.5 times this interval.
- One starts with a "safe" interval and tries to associate to this either a confidence level (e.g. 95% or 99%) or directly a certain multiple of the corresponding "standard deviation".

In these approaches it is necessary to make (at least implicitly) some assumption about the underlying population. It is left to the personal preference of the experimenter whether this is supposed to be for instance Gaussian or rectangular. Generally speaking, realistic estimates of the limits of uncertainties belonging to a given probability level should be aimed at, and in particular an extremely "conservative" attitude should be avoided.

It will be obvious that the above subdivision of possible approaches to arrive at u_j is quite an arbitrary one. In essence, they are equivalent and there is no real need to distinguish them. It should also be clear that in most cases the numerical value of u_j thus obtained will not be very precise; sometimes an order-of-magnitude estimate may be all we can expect. However, this circumstance should not bother us too much as it lies in the nature of guessing something for which we are largely lacking real knowledge. In particular, it should not prevent us from making a guess at all, but it will be a good habit always to remember that any conclusion drawn in such a situation can obviously be no more trustworthy than are the quantities upon which they are based.

5. Combined and overall uncertainties

Since it is agreed that contributions from both categories A and B can be treated as if they were of random nature, the Working Group cannot see any objection to handling them in the same way and in particular to combining them, where appropriate. Although it is kept in mind that the terms u_j^2 from group B are not actually variances, the general opinion is that it will be best to do this in analogy with the general law of "error propagation". In the absence of correlations one is therefore led to a combined uncertainty, the square of which is obtained by summing over all contributions due to s_i^2 and u_j^2 . For the reason given above this should again not be called a variance. The Working Group hopes that this simple reasoning will eventually put an end to the practice of adding some of the contributions to the combined uncertainty in a linear way.

Since from this point onwards the uncertainty components belonging either to group A or to group B are treated on an equal footing, it is clear that all problems related to the exact nature of this subdivision are of minor importance and in fact have no influence on the numerical value of the combined uncertainty.

Several participants raise the point that it will be difficult to imagine that such a combined uncertainty can be used in some important practical applications, as for instance certificates. In addition, legal prescriptions and industrial specifications may be based on an assumed confidence interval. Some discussion takes place in the Working Group on this topic, the outcome of which can be summarized as follows. Whereas for contributions from group A the link with a confidence level is traditionally achieved by the additional assumption (which can hardly ever be verified) that they can be considered as a sample belonging to a normal population, such a hypothesis seems to be more difficult to justify for group B. It is stressed, however, that this difficulty is by no means created by the introduction of the new subdivision, but is only now more clearly brought to light. In fact, it has been possible previously to hide our ignorance behind such a fuzzy concept as "maximum error limit" or the like, but the relation of this to probability was obviously as difficult to establish as it is now. Since, in the absence of reliable checks, it would be naive to think that Nature acts merely in accord with human wishes, the Working Group, fully aware of this obstacle, prefers to adopt an open-minded position. There may be cases - especially when contributions from group B are of little importance - where the assumption of normality will be a reasonable approximation. This is also true when the Central Limit Theorem can be invoked with confidence. In general, however, the underlying distribution function is simply not known well enough to permit the calculation of confidence intervals.

In view of this situation, it seems appropriate to adopt a somewhat different and, one hopes, more realistic position. Whenever a larger range for the uncertainty is needed, it is always possible to obtain the so-called overall uncertainty by multiplying the above combined uncertainty by a certain constant factor k . Since its exact evaluation is impossible, there is little point in choosing "precise" values; it is thought that for most cases conventional values like $k = 2$ or $k = 3$ will be sufficient. Some idea on the approximate value to be chosen can be obtained by assuming, for the sake of argument, that the combined uncertainty can actually be identified with a sample standard deviation resulting from a normal population (with an appropriate number of degrees of freedom), for then k would be identical with the well-known t -factor. However, such an interpretation should not be taken too seriously. Considering the extremely wide range of possible applications, the Working Group is not of the opinion that part of its task is to fix a unique recommended value for the factor k . This should be left to the experimenter or to the evaluator (of comparisons, for instance), or to any other body concerned (e.g. OIML, ISO, IEC). The only strict requirement then is that, if such a factor is applied, its numerical value must be clearly stated.

For applications in industrial metrology it might be useful to remember that the overall uncertainty, provided that the simplifying hypothesis of an underlying normal population is accepted, corresponds in an approximate way to the traditional confidence interval. Whenever interim or final results of real importance are published (for instance fundamental research, measuring certificates, ...), a complete list of the uncertainty components should be given. Sometimes the inclusion of covariances may be justified. On the other hand, it may be sufficient for certain applications to indicate the overall uncertainty and the factor k .

6. Concluding remarks

The Chairman draws the attention of the Working Group to the importance of drafting a recommendation. It should outline in a condensed form the principles on which the proposed new way of assigning uncertainties is based. The recommendation will be presented to CIPM at its next meeting in October 1981. The CIPM can accept it, reject it or propose amendments. If endorsed, it will become an official international recommendation. It is reproduced at the end of this report in the form drafted by the Working Group.

The elaboration of the draft recommendation has been one of the major tasks of this meeting. It was not possible in the limited time to discuss all suggested topics thoroughly. Among those repeatedly proposed are the problems relating to vocabulary. Therefore, the new terms appearing in the recommendation, in particular the expressions "combined uncertainty" and "overall uncertainty", should be

considered as provisional. The same remark applies to the expressions "group A" and "group B" as well as to the symbols used for the corresponding uncertainties.

It is realized that the proposed recommendation may not give all the information needed for implementation of the new guidelines into laboratory work. For this purpose it is planned to write a "cook book" wherein a number of typical situations are fully illustrated by numerical examples. In the meantime, the national laboratories are encouraged to apply the recommendation and to keep BIPM informed on the results. No date has been fixed for a possible further meeting of the Working Group.

RECOMMENDATION
of the Working Group on the Statement of Uncertainties
presented to Comité International des Poids et Mesures

- Assignment of experimental uncertainties

RECOMMENDATION INC-1 (1980)

1. The uncertainty in the result of a measurement generally consists of several components which may be grouped into two categories according to the way in which their numerical value is estimated:

A - those which are evaluated by statistical methods,

B - those which are evaluated by other means.

There is not always a simple correspondence between the classification into categories A or B and the previously used classification into "random" and "systematic" uncertainties. The term "systematic uncertainty" can be misleading and should be avoided.

Any detailed report of the uncertainty should consist of a complete list of the components, specifying for each the method used to obtain its numerical value.

2. The components in category A are characterized by the estimated variances, s_i^2 , (or the estimated "standard deviations" s_i) and the number of degrees of freedom, ν_i . Where appropriate, the estimated covariances should be given.

3. The components in category B should be characterized by quantities u_j^2 , which may be considered as approximations to the corresponding variances, the existence of which is assumed. The quantities u_j^2 may be treated like variances and the quantities u_j like standard deviations. Where appropriate, the covariances should be treated in a similar way.

4. The combined uncertainty should be characterized by the numerical value obtained by applying the usual method for the combination of variances. The combined uncertainty and its components should be expressed in the form of "standard deviations".

5. If, for particular applications, it is necessary to multiply the combined uncertainty by a factor to obtain an overall uncertainty, the multiplying factor used must always be stated.

RECOMMANDATION
 du Groupe de Travail sur l'Expression des Incertitudes
présentée au Comité International des Poids et Mesures

Expression des incertitudes expérimentales

RECOMMANDATION INC-1 (1980)

1. L'incertitude d'un résultat de mesure comprend généralement plusieurs composantes qui peuvent être groupées en deux catégories d'après la méthode utilisée pour estimer leur valeur numérique:

- A - celles qui sont évaluées à l'aide de méthodes statistiques,
- B - celles qui sont évaluées par d'autres moyens.

Il n'y a pas toujours une correspondance simple entre le classement dans les catégories A ou B et le caractère "aléatoire" ou "systématique" utilisé antérieurement pour classer les incertitudes. L'expression "incertitude systématique" est susceptible de conduire à des erreurs d'interprétation; elle doit être évitée.

Toute description détaillée de l'incertitude devrait comprendre une liste complète de ses composantes et indiquer pour chacune la méthode utilisée pour lui attribuer une valeur numérique.

2. Les composantes de la catégorie A sont caractérisées par les variances estimées s_i^2 (ou les "écarts-types" estimés s_i) et les nombres ν_i de degrés de liberté. Le cas échéant, les covariances estimées doivent être données.

3. Les composantes de la catégorie B devraient être caractérisées par des termes u_j^2 qui puissent être considérés comme des approximations des variances correspondantes dont on admet l'existence. Les termes u_j^2 peuvent être traités comme des variances et les termes u_j comme des écarts-types. Le cas échéant, les covariances doivent être traitées de façon analogue.

4. L'incertitude composée devrait être caractérisée par la valeur obtenue en appliquant la méthode usuelle de combinaison des variances. L'incertitude composée ainsi que ses composantes devraient être exprimées sous la forme d'"écarts-types".

5. Si pour des utilisations particulières on est amené à multiplier par un facteur l'incertitude composée afin d'obtenir une incertitude globale, la valeur numérique de ce facteur doit toujours être donnée.

List of documents presented to the participants of the meeting

- [1] Report on the BIPM enquiry on error statements, Rapport BIPM-80/3, 50 pages (BIPM, 1980). A French version will be published as an appendix to Procès-Verbaux des Séances du Comité International des Poids et Mesures 48 (1980).
- [2] Guidelines for estimation and statement of overall uncertainty in measurement results, by National Physical Laboratory of India, Standards and Industrial Research Institute of Malaysia, CSC (80) MS-9 (Commonwealth Science Council, London, 1980), 13 p.
- [3] Beschreibung des Fehlers eines korrigierten Messergebnisses, by H.-J. v. Martens and E. Pippig, Feingerätetechnik 28, 359-364 (1979).
- [4] On the quantitative characterization of the uncertainty of experimental results in metrology, by S.R. Wagner, PTB-Mitteilungen 89, 83-89 (1979).
- [5] Combination of systematic and random uncertainties, by S.R. Wagner, in Conference on Precision Electromagnetic Measurements (Braunschweig, June 1980), 241-246.
- [6] Some second thoughts on error statements, by J.W. Müller, Nucl. Instr. and Meth. 163, 241-251 (1979).
- [7] Les incertitudes de mesures, by J.W. Müller, in La Physique, Encyclopédie Scientifique de l'Univers vol. 4 (Gauthier-Villars, Paris, 1981), 11-17.
- [8] Comments from Istituto di Metrologia "G. Colonnetti", Torino, Italy; covering letter dated July 25, 1980, 14 p.
- [9] Comments from Amt für Standardisierung, Messwesen und Warenprüfung, Berlin, GDR; covering letter dated July 30, 1980, 9 p.
- [10] Expression des incertitudes "systématiques", comments from Office Fédéral de Métrologie, Bern, Switzerland; September 23, 1980, 10 p.

(March 1981, revised August 1981)