Recommendations on Application of the Document "Guide to the Expression of Uncertainty in Measurement" in Russia

V.A.Slaev, VNIIM, Russia

In the last few years the process of integration of Russia into the world community has been significantly grown, and this requires a harmonization of standards and other normative documents (among them those in the fields of metrology, calibration of measuring instruments, certification of products) in order to remove the barriers in commerce, industry, scientific and cultural exchanges, and in cooperation.

However home normative documents do not practically use the concept "*uncertainty* of measurement" and are oriented toward the traditional and fully formed approach based of the concepts "*error*" and "*characteristics of error*". Here it will suffice to mention written standards and specifications on general technical requirements for measuring means, methods of verifications, procedures for carrying out measurements, testing methods and standards and norms of the State measurement traceability system and so on.

Thus there is a contradiction between the Guide and the system of home normative documents. Along with this Recommendation 1 (CI-1981) of the CIPM suggests "…that other interested organizations be encouraged to examine and test these proposals and let their comments be known to the BIPM" and the Guide [1], in its turn, says: "…users of this Guide are invited to send their comments and requests for clarification to any of the seven supporting organizations.

Among the arising question, mention may be made of the following ones: how much would the home normative base system agree with the Guide and in what does a disagreement lie?; what are merits and demerits of the both?; whether the Guide is to be used as the basis for revising the existing home normative system?; how much would the approach used as the bases for the Guide be scientifically justified and practically recommended?; whether the Guide is in agreement with the national interests of our country?; to what does the Guide spread – only to the highest levels of hierarchical calibration schemes, i.e. to measurement standards, or to all other measuring instruments?; who should use provisions of the Guide in Russia in practice?; how must proceed the verification officers of the State metrology service, who carry out routine works on checking the consistency of parameters of measuring means with the values given in written standards and norms, specifications, passports and so on, i.e. wherever the characteristics of an *errors* and not of an *uncertainty* are used, etc. [2].

The Guide [1], and this is its corner-stone, suggests, firstly, to abandon, where possible, using the concepts "*error*" and "*true value of a measurand*" in favour of "*uncertainty*" and

"*estimated value of a measurand*" and, secondly, to use the classification into uncertainty categories A and B (according to the way in which numerical values of uncertainties are estimated, that is, those evaluated by methods of mathematical statistics and those evaluated by other means.) instead of the previously used classification into "random" and "systematic" uncertainties.

The main concept used in the Guide is the "*uncertainty* of measurement", which is interpreted in two different senses: narrow and broad.

In its broad sense the *uncertainty* is treated as "doubt", e.g. "…when all of the known or suspected components of *error* have been evaluated and the appropriate corrections have been applied, there still remains an *uncertainty* about the correctness of the stated result, that is, a *doubt* about how will the *result of the measurement* represents the *value of the quantity being measured*".

In a narrow sense, the "*uncertainty of measurement*" is a "**parameter, associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the measurand**". The second interpretation exactly corresponds to the definition of the term "*uncertainty of a measurement*" given in the VIM (International Vocabulary of Basic and General Terms in Metrology) [3]. The *uncertainties* are described using a statistical approach regardless of the way in which they are evaluated (in so doing, it is thought that all systematic errors or effects have already been corrected for).

There is a definite correspondence between the characteristics of "*an error*" and "*an uncertainty*" of measurement results, i.e. the root-square deviation (standard deviation) corresponds to the *standard uncertainty* and confidence limits – to the "*expanded uncertainty*".

The way of estimating the confidence levels of *the error of a measurement result* is practically identical to a calculation of the "*expended uncertainty*". The methodological difference which is observed in the approach to the definition of a *coverage factor*, corresponding to a coefficient *K*, which is traditionally used in the home normative documentation, *slightly* influence the results of estimating *the characteristics of error (uncertainty)* of a measurement in practical measurement tasks.

When the both approaches are compared, it is apparent that the procedure of calculating the coverage factor used in the home normative documents has been much better formalized than abroad, and thus, it is more suitable in practice.

As the successful point, the Guide suggests the unified principle of applying the *standard uncertainty* to all of the components of *error* while in the home guides, residual systematic *errors* are usually characterized by their *bounds*, and random errors - by a *standard deviation*.

The use of the term "*uncertainty*" of measurement according to the interpretation given in "The Explanatory Vocabulary of the Russian Language" by Vladimir Dal, does not contradict to the fully formed home practice of presentation and evaluation of characteristics of "*error*" of measurement.

The use of the term "*uncertainty*", in its **broadest sense**, is not, in our opinion, advisable since it is poorly amenable to formalization and does not allow to apply a traditional mathematical apparatus for treating the results of measurements.

It is unlikely that the attempt to abandon the concept "*error*" of measurement (and, consequently, the concept, "*true value of a measurand*") can be accepted successful, for some reasons, among them the following (i) the Guide does not give a clear and comprehensive definition of the concept "*uncertainty*" in its broadest sense; (ii) the idea of introducing the new concept, as such, gives practically nothing new in the approach to a presentation and evaluation of the "*uncertainty*" of a measurement as compared to the presentation and evaluation of "*characteristics of an error*"; and (iii) a formal abandonment of the concept "*true value*" leads to a number of *unsuccessful, cumbersome and unclear* definitions.

Lastly, the Guide considers the case when all sources of *uncertainty* have been taken into account and quantitavely evaluated, and the measurement task has been correctly set. So, the *uncertainty* is here a measure of a probable *error*. The Guide further says that such a situation is the most commonly encountered situation in metrological practice and, in particular, takes place in transferring units of physical quantities.

Admittedly, the Guide has also some logical contradictions.

In particular, with all the efforts of the authors of the document to "eradicate" the concept "*error*", the term, as such, is most often met with in the text and, in essence, is used under a cover of the idiomatic phrase "systematic effects", and, sometimes, with no "cover" at all.

Since it is necessary to harmonize the normative documents on an international scale, the VNIIM was charged by the Gosstandart of Russia with:

- a translation of the Guide into the Russian language [1];
- a development of a recommendation on application of the document "Guide to the Expression of Uncertainty in Measurement".

To carry out the missions of the Gosstandart of Russia, the Guide [4] was translated at the VNIIM. Much efforts were applied, wherever possible, to make the document authentic to the English version and even to design it in an approximate correspondence with the original. The translation prepared was published in amounts of 1000 copies. In the journal "Measurement Techniques", beginning with № 8, 1999, there is information concerning the translated document

so that interested specialists and organizations could have the possibility to buy it for cash or without cash at the VNIIM.

Recommendation "МИ 2552-99 ГСИ. Application of the "Guide to the Expression of Uncertainty in Measurement" was also developed at the D.I. Mendeleyev Institute for Metrology.

The work on development of this normative document (ND) was carried out in parallel with a considerable discussion on the given subject which took place in press, at conferences and seminars, in which the authors of the ND took an active part what made it possible to acquaint a major circle of specialists with the conception of the ND and to substantially take account of their comments and proposals. A number of conciliation meetings were held. Thus, it may be thought that this recommendation of the metrology institute is a fruitful result of the work carried out by a great team of home specialists.

It is worthy of noting that opinions of the specialists about the rules of application of the Guide in Russia have considerably different and may be grouped as follows:

- the Guide is not a worldwide standard and it is not advisable to apply it in home metrology practice since the concept "error" of the results of measurements is more habitual and is much better than the concept uncertainty;
- it is advisable to apply the Guide in international comparisons of measurement standards carried out under the aegis of the CIPM and its CCs; in issuing certificates of compliance on the basis of results of testing of foreign measuring instruments with the aim to have a pattern approval; as well as in calibration of foreign measuring instruments, and in preparation of publications for them to be published abroad;
- it is advisable to apply the Guide in all fields of metrological activities interchangeably with home NDs on metrology;
- the Guide shall be used as an international written standard of direct validity;
- it is advisable to appeal to the world scientific circles with the initiative to continue discussions on proposals of the Working Group of the CIPM and to publish a new revised version of the Guide.

The first approach contradicts to a tendency toward integration of Russia into the world community and to harmonization of home NDs with those applied internationally. This approach "falls out" of the context connected with developing the conception of applying the Guide in Russia and in what follows, this will not, therefore be considered.

With allowance made for a wide "spectrum" of opinions advanced by specialists, it is possible to consider several versions of application fields of the Guide in Russia.

When developing the Recommendation [5], its authors used a second, moderate conception that allowed application of the Guide in international comparisons of measurement standards carried out under the aegis of the CIPM and its CCs as well as in issuing certificates of compliance on the basis of results of testing of foreign measuring instruments and in their calibration; and also in preparing publications for them to be published abroad.

According to the results obtained after circulating the Guide in its first version, the report containing opinions of eight responding organizations was prepared. Among these organizations we can mention the following: VNIIMS, Rostest-Moskow, VNIIFTRI, UNIIM, GNIII of the Ministry of Defence of Russia, Electronstandart, Tekhnomash, and International Professorial Association. As a whole, all the opinions were positive. They have confirmed actuality of the developed document.

A specific nature of the document had an influence on its structure and content, i.e. in addition to the recommendations on application of the Guide, as such, the document contains a brief statement of the concept "*uncertainty*", a comparisons of two approaches to evaluation of accuracy based on the concepts "*uncertainty*" and "*errors*" of measurements, as well as some examples of calculating the *uncertainty* and evaluating the *error*.

The following considerations were used as the justification of this document structure:

- for the present, not everybody can get acquainted with the full text of the Guide (among other things, this is a laborious and time consuming work);
- the ND being developed is intended for a wide circle of specialists and is small in size;
- it is advisable to provide a correspondence with the existing tendency, observed throughout the world, i.e. publishing small sized guides by some national metrology institutes, as well as the manual on special kinds of measurements and concrete measurement tasks.

The content of the document includes four sections: "Application fields and normative references"; "Definitions and designations"; "Recommendations on application of the Guide"; "Correspondence between presentation forms of measurement results used in home normative documents on metrology and the form used in the Guide".

Besides, this document also has four Appendixes and bibliographical references.

Appendix A deals with a comparative analysis of two approaches to expression of accuracy of measurement results.

Appendix B gives an example of evaluating the characteristics of *error* and of calculating *uncertainty* of measurements in the fields of measurement of current strength by means of a voltmeter and a current shunt.

Appendix C gives an example of evaluating the characteristics of *error* and of calculating *uncertainty* in the field of length measurement of a line scale.

And, lastly, Appendix D gives (for simplicity sake of using the Recommendation) values of the Student coefficient with v degrees of freedom.

It is important to notice that the discussion on the concept "*uncertainty*" and on its application fields has been continuing up to the present time both in Russia and abroad. Within the developed normative document [5], it is impossible to reconcile all the existing opinions and viewpoints, what was not, by the way, the aim of its development.

It seems likely that the Recommendation is a document of a transient time period, which just now allows home metrologists to calculate *uncertainties* of measurements without a cardinal change of its notions about evaluation of *errors* of measurements.

The next stage in introducing the Guide into home metrology practice was a consideration of this topic at the meeting of the Scientific-and-Technical Commission on Metrology and Measurement Techniques of the Russia's Gosstandard, held in February 1, 2000. The Commission has come to the decision which, in particular, states: "To consider it expedient, in development of new normative documents as well as in revision of the NDs on metrology, standardization and certification, now in force, to include in these documents the requirements for expression of measurement results with the use, of an *uncertainty* when needed along with the characteristics of an *error*.

At the 10^{th} meeting of the COOMET Committee held in May 25-26, 2001, it was decided to include into the program of this international organization the following topic: "About the Procedure for Application of the" Guide to the Expression of Uncertainty in Measurement "in the Member-Countries of the COOMET".

We would like to express our hope in that the introduction of the concept "*uncertainty*" in Russia will run parallel to the work on improvement and revision of the Guide itself.

Here, it should be noted that much has been gained in this direction in Russia.

In particular, prof. I.F. Shishkin, a President of the International Professorial Association, when he yet was with the VNIIM, has carried out a great work on this problem and published a textbook on metrology for institutions of higher education, in which the concept "*error*" of a result of measurements was not used whatsoever. He is now ready to continue this work within the frames of the new Working Group being either an initiative (in Russia) or an international one.

Prof. A.N. Golovin, who is with Byelorussian State Institute for Metrology, has formulated the GANK' discrete-continuous law that was a generalization of the Puasson law and

the normal law of errors which made it possible in particular to calculate to a high accuracy, the *expanded uncertainty* at different distributions of its components.

Many interesting works on this subject have been carried out by the specialists of the VNIIM, as well as by those of Rostest-Moskow, VNIIFTRI, VNIIMS and other state research metrology centres of Russia.

References

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5. IR 2552-99 Recommendation (GSI) Application of the "Guide to the Expression of Uncertainty in Measurement", VNIIM, St. Petersburg, 1999, 31 pp. (in Russian).