

The Expression of Uncertainty in Quantitative Testing

PURPOSE

To provide guidance to member bodies with the aim of harmonising the approach to the interpretation and implementation of accreditation requirements for expressing uncertainty in quantitative testing. To provide information of the approach to be taken by member bodies to the assessment of the expression of uncertainty in quantitative testing.

EAL-G23 * THE EXPRESSION OF UNCERTAINTY IN QUANTITATIVE TESTING

Authorship

This publication has been finally revised by EAL Committee 2 (Calibration and Testing Activities), based on the draft produced by the EAL Task Force on the Expression of Uncertainty in Testing.

Official Language

The text may be translated into other languages as required. The English version remains the definitive version.

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Guidance publications

This document represents a consensus of EAL member opinion and preferred practice on how the relevant clauses of the accreditation standards might be applied in the context of the subject matter of this document. The approaches taken are not mandatory and are for the guidance of accreditation bodies and their client laboratories. Nevertheless, the document has been produced as a means of promoting a consistent approach to laboratory accreditation amongst EAL member bodies, particularly those participating in the EAL Multilateral Agreement.

Further information

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0 Introduction

- 0.1 Quantitative testing is defined, using the terms of the *International Vocabulary of Basic and General Terms in Metrology* (VIM) [ref 1], as:

A set of operations having the object of determining the magnitude of a particular attribute of a phenomenon, body or substance that may be distinguished qualitatively and determined quantitatively, generally expressed as a unit of measurement multiplied by a number.

1 Background

- 1.1 The European standard EN 45001 Clause 5.4.3 requires that test reports include:

a statement on measurement uncertainty (where relevant)

and also states that:

quantitative results shall be given together with calculated or estimated uncertainty.

The use of the words 'where relevant' raises the possibility of different interpretations and inconsistency in the approach of laboratories and accreditation bodies.

- 1.2 It is noted that ISO/IEC Guide 25 Clause 13.2, requires:

a statement of the estimated uncertainty of the calibration or test result (where relevant)

and states in Clause 10.2:

The laboratory shall use appropriate methods and procedures for all calibrations and tests...(including.....estimation of uncertainty of measurement ...).

- 1.3 Accreditation bodies have the responsibility of ensuring that the requirements are met by the laboratories they accredit. However, the prevailing state of development and application of the subject of uncertainty in testing within EAL must be recognised and taken into account when implementing accreditation policy in this area.

- 1.4 Guidance for the evaluation of uncertainty is given in the ISO publication, *Guide to the Expression of Uncertainty in Measurement (The Guide)* [ref 2]. It is recognised that complementary guidance documents have been, and are being, developed by other organisations, eg by organisations representing laboratories, such as EURACHEM and EUROLAB, and by accreditation bodies.

- 1.5 In the case of calibration, as distinct from testing, further guidance is given in EAL-R2, *Expression of the Uncertainty of Measurement in Calibration* [ref 3].

- 1.6 Comprehensive guidance for evaluating uncertainty in chemical analysis is given in the EURACHEM publication, *Quantifying Uncertainty in Analytical Measurement* [ref 4].
- 1.7 Guidelines are proposed in this document with the aim of moving towards a consistent and harmonised position between accreditation bodies, both in the development and the implementation of policy for expressing uncertainty in quantitative testing.
- 1.8 This document is not a detailed guide for laboratories, although it may assist them by drawing attention to the main points of policy and procedure relevant to the treatment of uncertainty in testing.

2 Reasons for evaluating uncertainty

- 2.1 The uncertainty of a result is a quantitative indication of its quality.
- 2.2 The expression of the uncertainty of a result allows comparison of results from different laboratories, or within a laboratory or with reference values given in specifications or standards. This information can often prevent unnecessary repetition of tests.
- 2.3 The uncertainty of the result of a test may need to be taken into account by a customer when interpreting data. For example, comparison of results from different batches of material will not confirm real differences in properties or performance if the observed differences could simply be accounted for by the uncertainty of the results.
- 2.4 An evaluation (or at least a full consideration) of the components, including random effects from human operators, that contribute to the overall uncertainty of a measurement or test result provides a means of establishing that the test procedure, including the metrological characteristics of the equipment used, will allow valid measurements and results to be obtained.
- 2.5 A consideration of uncertainty components also indicates aspects of a test to which attention should be directed to improve procedures.

3 EAL policy for member bodies

- 3.1 Member bodies should adopt the following common approach to the evaluation and reporting of uncertainty in testing in accordance with the requirements of EN 45001.
- 3.2 Member bodies should ensure that the methodology and terminology used by a laboratory performing quantitative tests when evaluating and reporting uncertainty comply with the international recommendations expressed in *The Guide*.

- 3.3 In practice, they must take account of the prevailing problems for evaluating and reporting uncertainty in various fields of testing and the different perceptions of the significance of uncertainty between the various parties involved in testing and in the use of test results.
- 3.4 The implementation of the policy of member bodies regarding the expression of uncertainty in testing should take place at an appropriate pace. This may be different from one field of testing to another.
- 3.5 Member bodies should cooperate with each other and with organisations representing laboratories in the initiation, development and harmonisation of guidance documents on the expression of uncertainty in specific testing fields, with the objectives of achieving consistency and reducing duplication of effort and thereby reducing costs.
- 3.6 Member bodies should jointly consider sector-specific guidance documents produced by authoritative bodies, endorse those that they conclude are suitable and agree a time-scale for implementation by laboratories.
- 3.7 The standard EN 45001 calls for uncertainty to be reported for all quantitative results. Laboratories should be required to have a documented policy for the reporting of uncertainty for accredited quantitative tests. As a preliminary stage, member bodies should regard the inclusion of uncertainty statements on test reports to be a priority under the following circumstances:
- (a) when required by the specification;
 - (b) when the customers instructions call for it; or
 - (c) when the uncertainty affects compliance with a stated specification or limit.
- 3.8 Laboratories should be required to have a documented policy for the evaluation of uncertainty for accredited quantitative tests and should be encouraged to document their methods, based on *The Guide*, for evaluation of uncertainty for such tests.
- 3.9 Where methods for the evaluation of uncertainty for specific tests or testing fields have been endorsed by EAL, they should be followed by laboratories.
- 3.10 Member bodies should assess the consistency and correctness of uncertainty evaluations and statements made in accredited laboratories. The laboratory should be able to demonstrate to the assessor that the uncertainty is correctly evaluated. This could be achieved by retaining full records of the evaluation of uncertainty components, details of calculations and any assumptions made. This evidence should be supported, where possible, by comparison with the results of tests on international or national certified reference materials, or of proficiency tests, or of repeated tests.

4 Summary of procedure for evaluating and reporting uncertainty

- 4.1 The guidance for the evaluation and reporting of uncertainty is that set out in *The Guide*. (Other documents are available, or are being developed, for guidance for specific testing fields.) The following paragraphs give a general summary.
- 4.2 The uncertainty of a result is a combination of a number of uncertainty components. Even a single instrument reading may be influenced by several factors. Careful consideration of each step involved in the test is required to identify and list all the factors that contribute to the uncertainty. This is the most crucial stage and requires a good understanding of the measurement equipment, the principles and practice of the test and the influence of environment.
- 4.3 The next step is to quantify uncertainty components by appropriate means. An initial approximate quantification may be valuable in enabling some components to be shown to be negligible and not worthy of more rigorous evaluation. In most cases a practical definition of negligible would be a component that is not more than a fifth of the size of the largest component. Some components may be quantified by calculation of the standard deviation from a set of repeated measurements. Quantification of others will require the exercise of judgement using all relevant information on the possible variability of each factor, including:
- (a) previous measurement data;
 - (b) manufacturer's specifications;
 - (c) data provided in calibration certificates;
 - (d) uncertainty assigned to reference data taken from handbooks;
 - (e) experience with or general knowledge of the behaviour and properties of relevant materials and instruments; evaluations made under this heading are quite common in many fields of testing, but must be made with care and by suitably experienced personnel;
 - (f) results of an interlaboratory comparison test programme;
- 4.4 A realistic evaluation of the uncertainty of a quantitative result should give due consideration to all factors influencing the result, including the results from quality control samples, the capability of the equipment used, the adequacy of any standards used and the consistency of performance of laboratory staff. An understatement of uncertainty might cause too much reliance to be placed in the result with potentially damaging consequences. An overestimate of uncertainty could cause use of more expensive equipment than is needed or the unnecessary rejection of products, services or materials.

- 4.5 It should be kept in mind during the evaluation that undue effort is not usually justifiable in attempting to quantify exactly every minor component.
- 4.6 The standard uncertainty is expressed as the standard deviation. The standard uncertainty components have to be combined to produce the combined standard uncertainty of the result using the approach set out in *The Guide*.
- 4.7 It is usually necessary to quote an 'expanded uncertainty', and the combined standard uncertainty therefore needs to be multiplied by the appropriate 'coverage factor'. This must reflect the level of confidence required. In general, a value of 2 for the coverage factor can be taken to define an interval having a level of confidence of approximately 95%.
- 4.8 The information given when reporting the result of a test and its uncertainty shall relate to the requirements of the client or of the standard, or both. The following information should be available either in a report or in the records of the test:
- (a) methods used to calculate the result and its assigned uncertainty;
 - (b) list of uncertainty components and documentation to show how they were evaluated, eg a record of any assumptions made and the sources of data used in the evaluation of the components;
 - (c) sufficient documentation of the steps and calculations in the data analysis to enable repeat of the calculation if necessary;
 - (d) all corrections and constants used in the analysis and their sources.
- 4.9 Any uncertainty that results from the test sample not being fully representative of the whole, should normally be identified separately in the evaluation of uncertainty. However, there may be insufficient information to enable this to be done and, in that case, this must be stated in the report of uncertainty.
- 4.10 Unless otherwise specified, the result of the measurement should be reported together with the assigned expanded uncertainty appropriate to the 95% level of confidence in the following manner:
- Measured value 100,1 (units)
- Uncertainty of measurement $\pm 0,1$ (units)
- The reported uncertainty is an expanded uncertainty based on a standard uncertainty of 0,05 (units) multiplied by a coverage factor of $k = 2$, which provides a level of confidence of approximately 95%.
- 4.11 When a statement of compliance with a specification is made, which omits the measurement results and associated uncertainty, the laboratory should record those results and uncertainty and maintain them for possible future reference.

- 4.12 If the measurement value, extended by the uncertainty, exceeds the specified tolerance or limit while the measurement value itself falls within the tolerance or limit the measurement results and the associated uncertainty should be given in the report.

5 References

1. *International Vocabulary of Basic and General Terms in Metrology (VIM)*. International Organization for Standardization, 1993.
2. *Guide to the Expression of Uncertainty in Measurement*. BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML. International Organization for Standardization, Printed in Switzerland, ISBN 92-67-10188-9, First Edition, 1993. Corrected and reprinted 1995
3. EAL-R2 : 1996. *Expression of the Uncertainty of Measurement in Calibration*.
4. *Quantifying Uncertainty in Analytical Measurement*, EURACHEM, 1995.