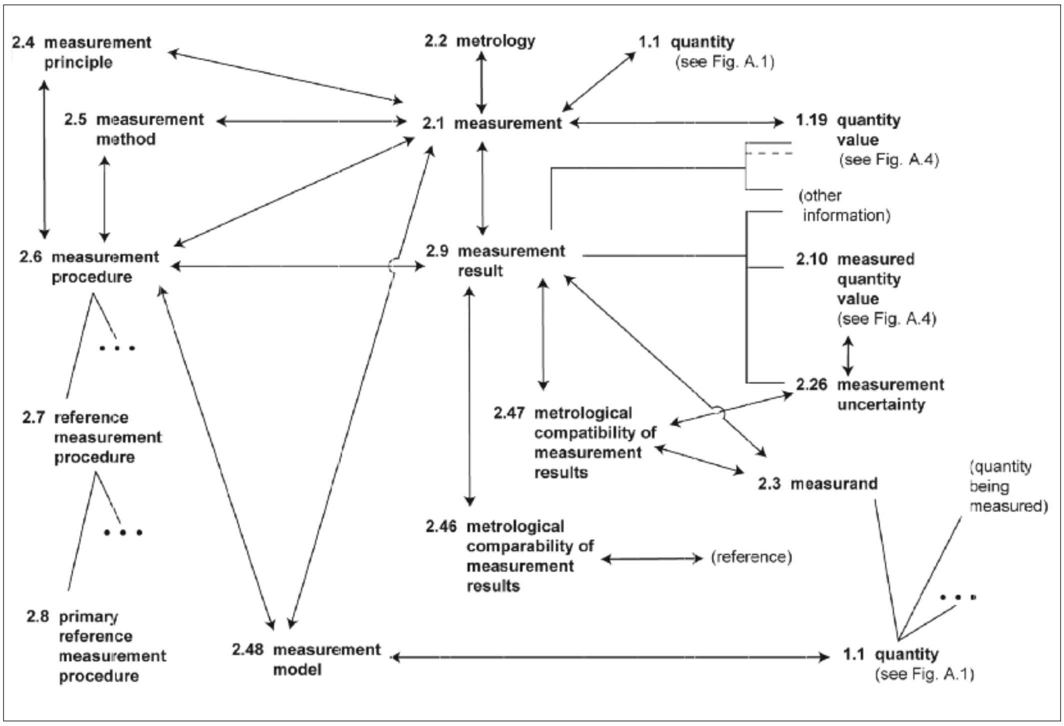
OIML BULLETIN

VOLUME LIII • NUMBER 2
APRIL 2012

Quarterly Journal

Organisation Internationale de Métrologie Légale



ISSN 0473-2812

Theme: Evolving Concepts in Metrology

BULLETIN

Volume LIII • Number 2

April 2012

THE OIML BULLETIN IS THE QUARTERLY JOURNAL OF THE ORGANISATION INTERNATIONALE DE MÉTROLOGIE LÉGALE

The Organisation Internationale de Métrologie Légale (OIML), established 12 October 1955, is an intergovernmental organization whose principal aim is to harmonize the regulations and metrological controls applied by the national metrology services of its Members.

Editor-in-Chief: Stephen Patoray
Editor: Chris Pulham

2012 Subscription Rate
60 €

ISSN 0473-2812

PRINTED IN FRANCE

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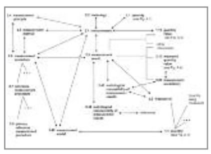

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Editorial

Willem Kool
BIML Assistant Director

Evolving Concepts in Metrology

Most of us who are involved in legal metrology are aware of the existence of the *International Vocabulary in Metrology* (VIM) and the *Guide to the Expression of Uncertainty in Measurement* (GUM), two fundamental metrological guidance documents.

Many people may have seen them, browsed through them or even studied them to comprehend their contents. On the other hand, not many of us have actually used them extensively, or even consulted them on a regular basis. Nevertheless, they are very important guides for our activities.

The VIM contains "basic and general concepts and associated terms". Terms are what we use in our publications and communications to convey the concepts they represent. Our thinking about these concepts evolves and therefore their definitions are subject to change. Sometimes these changes are subtle, but sometimes they seem to have enormous consequences, such as the evolution of the concept of 'measurement uncertainty' or the new definition of 'calibration'.

All these changes affect our work and we need to take them into account when developing new, or when revising existing Recommendations and other publications. Most of that work is the responsibility of OIML Project Groups and their members; in particular, their conveners have to be aware of these developments.

The theme for this issue of the Bulletin is "Evolving concepts in metrology". The main papers focus on issues that are currently "hot" discussion topics in the Working Groups of the Joint Committee for Guides in Metrology.

The JCGM, of which the OIML is a Member Organization, is responsible for maintaining the VIM and the GUM.

Currently, the JCGM is conducting two surveys, one to obtain views on how to revise the GUM and the other to learn about the experiences and opinions that users of the latest edition of the VIM have concerning the changes compared to the previous edition and the application of the new and revised concepts in the VIM. You will find an announcement and information about the surveys in this issue of the Bulletin. I invite all of you who have any experience at all with the VIM and the GUM to take part in the surveys; by doing so you will contribute to the work of the JCGM that is so important for all of us in (legal) metrology. ■

CONCEPTS IN METROLOGY

Joint Committee for Guides in Metrology

Online surveys seeking the views of VIM and GUM users

Willem Kool, BIML Assistant Director

The tasks of the Joint Committee for Guides in Metrology (JCGM), of which the OIML is a member Organization, are to maintain and promote the use of two basic guidance documents in the field of metrology:

- the *Guide to the Expression of Uncertainty in Measurement* (known as the GUM), and
- the *International Vocabulary of Metrology* (known as the VIM).

The current versions of these guidance documents have been published by the OIML as OIML G 1-100:2008 and OIML V 2-200:2012 respectively and may be downloaded free of charge from the OIML web site (www.oiml.org/publications).

The first and second editions of the VIM were published in 1984 and 1993, respectively. The current, third edition was first published in 2007. With this third edition an attempt was made to broaden the scope for the application of the VIM to, in particular, laboratory medicine and chemistry. The latest developments in metrology, for instance with respect to metrological traceability and measurement uncertainty, led to many new or revised concepts in the VIM, while some others were deleted because they were no longer considered "basic" concepts.

The GUM was first published in 1993 and was republished in 1995 and again in 2008, both times with only minor corrections. Its approach to the evaluation of uncertainty in measurement has gradually gained acceptance in many different scientific fields, although not universally. Some of the limitations of the GUM have been overcome by the development of two supplements:

- Supplement 1 on the propagation of distributions using a Monte Carlo method, published in 2008, and
- Supplement 2 on the extension of the GUM method to any number of output quantities, published in 2011.

Currently, the GUM and its Supplements are not fully consistent with each other and also not with the terminology in the latest edition of the VIM. The JCGM therefore decided to start a revision of the GUM.

At their annual meeting in December 2011 the eight Member Organizations of the JCGM agreed to organize two enquiries among the users of the VIM and the GUM:

- An enquiry among the users of the GUM to obtain feedback on a "rational paper on the revision of the GUM" that has been prepared by JCGM Working Group 1. The rational paper reflects the consensus views of the members of JCGM/WG1 on the direction that the revision of the GUM should take. The rational paper has been converted into an online survey that may be accessed via the joint BIPM/OIML web portal www.metrologyinfo.org.
- An enquiry in the form of a questionnaire addressed to the users of the VIM to obtain feedback from users of the VIM about their experience in applying the third edition in general and their views on some of the changes and new concepts compared to the previous edition. Users are also encouraged to propose "frequently asked questions", which the JCGM will publish on the internet. The questionnaire has also been converted into an online survey that may be accessed via the joint BIPM/OIML web portal www.metrologyinfo.org.

The closing date for both surveys is 15 June 2012. Participants may respond anonymously, but those that leave their e-mail address will receive a summary of the responses.

Anyone who uses, or has used the GUM and/or the third edition of the VIM, or who wishes to express their views relevant to these basic guidance documents in metrology, is invited to take part in the surveys. Please note that because of limited resources, only submissions via the web site are taken into consideration; due to the expected large number of responses, it will not be possible to process them manually.

Visit www.metrologyinfo.org

Joint Committee for Guides in Metrology

CONCEPTS IN METROLOGY

Evolution of the concept of measurement uncertainty

From errors to probability density functions

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Measurement, properties and quantities

The latest edition of the *International Vocabulary of Metrology* (VIM) [1] defines 'measurement' as the "process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity" and 'measurand' as the "quantity intended to be measured". The definition of 'quantity' is: "property of a phenomenon, body or substance, where the property has a magnitude that can be expressed as a number and a reference". The concepts 'property' and 'reference' have not been defined, although 'reference' is discussed in a note to the definition of 'quantity'. This note reads: "A reference can be a measurement unit, a measurement procedure, a reference material, or a combination of such".

Most (legal) metrologists will think of 'quantity' as something for which a measurement unit exists. A 'measurement unit' according to the VIM is a "real scalar quantity, defined and adopted by convention, with which any other quantity of the same kind can be compared to express the ratio of the two quantities as a number". This does not work for properties such as hardness or color. However, hardness and many other properties are also considered "measurable" in the sense that it is possible to establish a total ordering relation (by magnitude) following a conventional procedure (the reference). Such quantities are named 'ordinal quantities'. Differences and ratios of ordinal quantities have no physical meaning.

This feature does not prevent National Metrology Institutes (NMIs) from carrying out comparisons on hardness measurement capabilities. A comparison implies the determination of a reference value, typically some kind of mean, and of the deviation, i.e. the difference of each participant's result with respect to the reference value. In addition, standard deviations are routinely calculated by each individual NMI and by the pilot laboratory to evaluate the uncertainty associated with each individual result and with the reference value, respectively.

It should be noted here that these algebraic operations are applied to the results of measurements of the same measurand. While it is understandable that the results of two measurements of the hardness of the same object may differ by, say, 2 HRC, claiming that a knife blade is 2 HRC harder than another does not have a similarly unambiguous quantitative meaning.

A warning about the meaning of means and standard deviations had already been formulated in 1946 by the psychologist S.S. Stevens in his pioneering study [2], in which he established a classification of "scales of measurement" still widely adopted.

In modern language (and in the VIM) 'property' is a superordinate concept, of which 'quantity' is a subordinate. Quantities constitute the subset of properties having a magnitude, which can be "measured" by using ratio, interval or ordinal scales, according to Stevens' classification. Stevens' "absolute scale" may be considered as a special case of the ratio scale, where the "unit" is "1" (counting). Stevens' classification is completed by the "nominal scale" where the order of the classes (numbers or names, e.g. "Alan", "John", "Pierre") does not relate to any intrinsic characteristic of the property itself (in this example "name of a person"). Although the individual names of a group of people may be presented in alphabetical order, this order does not represent any kind of "magnitude", or relative importance. The property "name of a person" is thus a 'nominal property'.

The definition of 'measurement' in the VIM has a note that reads: "Measurement does not apply to nominal properties", to stress that, in order to perform a measurement, it is necessary that the measurand be a quantity, i.e. a property with a magnitude.

Quantity values and true value

In classical physics a quantity involved in a physical system is traditionally believed to have a unique value. To characterize this value, the qualifier "true" is usually

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This paper is based on "From errors to probability density functions - Evolution of the concept of measurement uncertainty" by Walter Bich, which will be published in a forthcoming issue of IEEE Transactions on Instrumentation and Measurement.

adopted. There is a long debate about the use of this qualifier.

In the second edition of the VIM, the idea already existed that more than one true value might be possible for a quantity depending on how well the quantity is defined. This idea is put forward more explicitly in the current, third edition of the VIM, according to which, in general, there exists a whole set of true values for a measurand. The set should account for the so-called 'definitional uncertainty', defined as: "component of measurement uncertainty resulting from the finite amount of detail in the definition of a measurand". The concept of definitional uncertainty has its merits, but it represents a difficulty, not only for the conceptual scheme of uncertainty evaluation, but also for practical measurements. Fortunately, a note to the definition of 'true quantity value' in the VIM reads: "When the definitional uncertainty associated with the measurand is considered to be negligible compared to the other components of measurement uncertainty, the measurand may be considered to have an "essentially unique" true quantity value. This is the approach taken by the *Guide to the expression of uncertainty in measurement* (GUM) [3] and associated documents, where the word "true" is considered to be redundant.

One can think of many examples where the measurand is not very well defined. For instance: the measurand "atomic weight of carbon" will vary according to the isotopic composition of the sample and "distance between Paris and Rome" depends on which representative points are chosen in both cities for the measurement.

The GUM states: "This guide is primarily concerned with the expression of uncertainty in the measurement of a well-defined physical quantity – the measurand – that can be characterized by an essentially unique value. If the phenomenon of interest can be represented only as a distribution of values, or is dependent on one or more parameters, such as time, then the measurands required for its description are the set of quantities describing that distribution or that dependence". In other words: the GUM recognizes "definitional uncertainty", but does not provide explicit guidance on its evaluation, nor a specific example. The application of the GUM requires a well-defined measurand.

Error and uncertainty

Historically, performing a measurement has been viewed as the task of trying to find a numerical value as close as possible to the (unknown) "true" value of a measurand. The difference between the two values is the 'measurement error'. However, since the "true" value is unknown, in the definition of 'measurement error', the concept of 'reference quantity value' is used instead of 'true quantity value'.

The next step was to try to quantify the closeness of the measurement result to the "true" value. A problem in that respect is that, if the measurement error were known, even approximately, it could be combined with the measurement result to obtain a better value. This is an apparently naïve concept, but it is one of the pivotal ideas in the modern views on uncertainty, and will be discussed to a deeper extent. In any case, since the true error is unknown, the only possible measure for the closeness of the measurement result to the true value of the measurand is of probabilistic nature.

According to the currently leading views, a measurement aims to improve the state of knowledge about the measurand. Uncertainty can be viewed as the logical reciprocal of that state of knowledge. The better we know the measurand, the smaller is the uncertainty. As the state of knowledge on a quantity value improves, the interval within which the quantity value is believed to lay narrows.

Indirect measurement

Most measurements are indirect, which means that the measurand is not observed directly but is a function of other quantities which are measured or observed. The measurement error then becomes a function of the errors of the quantities actually measured/observed. The approach adopted in the GUM, for instance, is to assign a probabilistic measure (standard deviation) to each component of uncertainty and combine the standard deviations of the components to arrive at a standard deviation for the uncertainty of the measurement result.

Random and systematic errors

The approach adopted in the GUM works well for random errors and there is no novelty in using it. The problem arises with systematic errors, for which no specific propagation rule is known. Should such a rule exist, a further problem is how to combine the two types of errors. The solution to this problem provided in the GUM is based on a simple consideration. If a systematic error is identified, it must be possible to estimate its value. This is known as "bias".

The common procedure was (and sometimes still is) to include bias in the uncertainty budget. However, bias is not an uncertainty component, but a contribution to the measurement estimate and should be included in the measurement evaluation model, with the appropriate sign, as a correction. However, biases, sometimes in the form of an "educated guess", themselves typically have associated uncertainties that should be treated in the same way as uncertainties for random errors. According to the GUM, "objective" estimates and those based on educated guess have the same dignity, the only measure about their value being the uncertainty.

Because random errors are viewed as a population (typically Gaussian), statistical tools may be used to assign an uncertainty measure. This will not work for bias uncertainty because there is no population behind a systematic error. If statistics does not work with systematic errors, probability does or, at least, one of its many interpretations. This interpretation goes under the generic term "Bayesian"[1], in contrast with the "frequentist" attitude.

In the Bayesian interpretation, random is whatever cannot be known exactly and the state of knowledge on a quantity, whether coming from experiment or from other sources, including subjective judgment, is modeled by a probability density function, or PDF[2]. Almost everything is random, according to this view. For example: although we can write the value of π with an enormous number of digits, our knowledge on it is incomplete. This incomplete knowledge is expressed by a (very narrow) PDF, so that π is considered as a random variable.

The advantage of the Bayesian interpretation over the frequentist viewpoint is that all uncertainty components can be treated in the same way, because they have the same probabilistic nature. As a consequence, whereas it is meaningful to distinguish between random and systematic error, the same distinction does not apply to uncertainties.

Incompatible concepts

At the time when Bayesian concepts of probability were introduced in measurement, the concept of 'true value' became the subject of severe criticism. The approach based on 'true value' and 'error' was questioned as being based on unknowable quantities, i.e. idealized concepts. The very terms were almost banned from the literature and whoever dared to use them was considered suspiciously as a supporter of old ideas. At that time (and often still today) the statistical education that physicists and, in particular, metrologists received was essentially frequentist, so that, for them, it was not easy to accept the "novel" and sometimes counterintuitive Bayesian interpretation.

Apparently, the concept of 'true value' seems to be incompatible with that of 'random quantity' from a philosophical or logical point of view. However, from a practical point of view these concepts are not incompatible at all. In practice, we can consider π to be a random variable, because our knowledge about its value is incomplete. Nevertheless, there is no doubt that its value is a real (as yet unknowable) number.

Therefore, the question of whether 'true value' and 'error' are logically valid concepts or not, is immaterial to the development of a formally correct uncertainty theory. Deciding whether π is a random quantity or has a true value with an associated PDF describing the state of knowledge on it, may be a crucial philosophical problem, but for a practitioner who needs sound uncertainty evaluations, it is little more than a matter of taste.

An uncertain uncertainty

When PDFs are used to model the state of knowledge on a quantity, their variances (more precisely, their positive square roots, or standard deviations) can be used as the measure of uncertainty. This is the method prescribed by the GUM and allows using the same laws of propagation for all input errors, thus arriving at a unique statement of uncertainty for the measurand. The GUM gives some guidance on the assignment of PDFs and on the calculation of the corresponding variances in a number of common situations.

The variance obtained from a sample of indications and that of a PDF assigned to an input quantity, however, differ in an important feature. The former is an estimate of the true population variance and has an "uncertainty" depending on the sample size, measured by its "degrees of freedom"[3]. This means that the variance of the measurand (i.e. the measurement uncertainty) itself becomes uncertain.

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[1] See: http://en.wikipedia.org/wiki/Bayesian_probability

[2] A probability density function (PDF) is a function that describes the relative likelihood for a random variable to take on a given value. The probability for the random variable to fall within a particular region is given by the integral of this variable's density over the region. The probability density function is nonnegative everywhere, and its integral over the entire space is equal to one. [source: Wikipedia]

[3] A common way to think of degrees of freedom is as the number of independent pieces of information available to estimate another piece of information. More concretely, the number of degrees of freedom is the number of independent observations in a sample of data that are available to estimate a parameter of the population from which that sample is drawn. For example, if we have two observations, when calculating the mean we have two independent observations; however, when calculating the variance, we have only one independent observation, since the two observations are equally distant from the mean. [source: Wikipedia]

To mitigate the inconsistency implied in mixing sample variances and PDF variances, in the GUM, the latter are artificially reduced to estimates by attaching a degrees of freedom to them. This is not done in the main body of the GUM, but in its annex G, where the *expanded uncertainty*, an uncertainty measure based on standard uncertainty but different from it (and more useful to end users) is discussed. The argument adopted is that the assigned PDF may not be totally reliable, hence the need to attach degrees of freedom to its variance. In this way, the two existing views in the GUM are reconciled by steering the Bayesian view toward the frequentist. It will be seen in a moment that the opposite steering is now preferred.

A certain uncertainty

An uncertainty affected itself by uncertainty implies the idea of a true, unknowable uncertainty. The uncertainty of the measurand would be just an estimate of this true uncertainty. This viewpoint is certainly respectable, but in recent years has been more and more criticized. In addition, the attachment of degrees of freedom to PDF variances looks unconvincing.

The Bayesian paradigm provides a rigorous framework in which uncertainties have no uncertainty. In it, PDFs are assigned to all input quantities to represent the state of knowledge on them, whether this knowledge comes from a sample of data or not. Let us concentrate on the former category. When knowledge comes from a sample of data m with standard deviation s, in the present GUM approach the corresponding variance is a sample variance (s^2/m, called in the GUM "an experimental variance of the mean") with a degrees of freedom one less than the number of data in the sample ($v = m - 1$), which estimates the variance V of the hypothetical infinite population of possible data, assumed to have, in most cases, a Gaussian distribution. In a Bayesian context, such as that adopted in Supplements 1 and 2 to the GUM [4, 5], the appropriate variance is that of a scaled and shifted Student's t-distribution, thus avoiding the need to attach questionable degrees of freedom to PDF variances.

The Student's t-distribution does not have a defined variance for $m = 2$, or $m = 3$. This is in agreement with common sense. Who would rely on an experimental standard deviation calculated from 2 or three observations only? In such cases, it is preferable to use some prior knowledge, as recommended in the present GUM.

The advantages of the Bayesian paradigm are evident; the most striking being that the uncertainty associated with the measurand no longer has uncertainty. This point deserves a deeper discussion. The idea of a "true" uncertainty, of which that associated with a measurand would be an estimate, is not compatible with that of a single-valued measurand. However, what is in this framework the meaning of the uncertainty associated with the measurand? For example, in measurement comparisons, in which different experimenters give for the same measurand not only different estimates, but also different uncertainties, which interpretation has to be given to them? In the authors' opinion, the answer lies in the subjectivity of the concept. Each experimenter declares through the uncertainty his personal state of knowledge on the measurand, gathered by means of the specific experiment he carried out. Alternatively, one might use the expression "degree of belief" in the interval of possible values for the measurand. Both concepts, "state of knowledge" and "degree of belief", imply a degree of subjectivity. So, the uncertainty calculated in a Bayesian framework is certain, but to some extent subjective. These are considered desirable properties.

Better measures

Standard deviation is a good measure of the state of knowledge on a quantity. However, it is not sufficient in many applications, in which the user needs to establish an interval of values within which the measurand lies with a stipulated probability. This interval is known as 'confidence interval' in a frequentist framework ('interval' in the GUM) or 'coverage interval' in Supplements 1 and 2 to the GUM. There are subtle differences between those concepts, so that, following the recent trend, the last of them will be discussed.

A coverage interval is a fraction of the domain on which the PDF for the quantity is defined, the coverage probability being the area encompassed by the PDF and the coverage interval, the total area under the PDF being equal to one. Therefore, to specify a coverage interval at a given coverage probability, it is necessary to know the PDF. Given that the PDFs for the input quantities are assigned, the problem remains to build the PDF for the measurand from those of the input quantities.

This problem, in mathematical statistics, has a straightforward solution which, however, is almost impossible to implement analytically except in the simplest and less interesting cases. In Supplement 1 to the GUM a numerical simulation method (Monte Carlo) is adopted, which gives efficiently and consistently the PDF for the measurand, as well as the tools to build the requested coverage interval. The GUM, in annex G, also proposes a solution which, however, yields correct results under a number of conditions that limit its applicability. An important further feature of Supplement 1 is that, in it, the list of recipes for assigning PDFs to input quantities is much richer than in the

GUM, and based on two methods: the Bayes' rule for knowledge based on data samples and the principle of maximum entropy[4] for the other cases.

The next GUM

From what has been discussed above, it might seem that the GUM is obsolete. This is not the case, as its approach works well in many cases and is so widespread that it would not be wise to abandon it. Rather, the GUM is not consistent with its Supplements, in which a Bayesian framework is adopted. Therefore, it is necessary to revise the GUM. This process is underway in the JCGM (Joint Committee for Guides in Metrology), WG 1, and will last some years. For sure the next GUM will be clearly recognizable as an evolution, rather than a revolution.

Bayes' rule

Bayes' rule[5] is a mechanism that allows building fresh knowledge on prior knowledge, thus improving the state of knowledge. This is accomplished by suitably combining the prior PDF, representing the prior knowledge about the measurand and typically broad, with experimental data to obtain a posterior PDF, representing the improved state of knowledge, typically narrower. Very solid experimental data will make the prior PDF negligible, whereas meager experimental data will add little to the existing knowledge, so that the posterior PDF will not significantly differ from the prior PDF.

As an example, consider a 1 kg mass standard to be calibrated on a high accuracy balance. The manufacturer of the standard claims that it belongs to OIML class E_2, for which the maximum permissible error is ± 1.6 mg. The natural choice to encapsulate this knowledge in a suitable prior PDF is a uniform PDF, centered at 1 kg and of width 3.2 mg. If the calibration yields an estimate with an uncertainty of, say, 10 µg, it is intuitive that prior knowledge will have virtually no effect, so that the use of Bayes' rule will almost coincide with a traditional procedure in which prior knowledge is ignored. The situation changes in the case of a re-calibration of a standard, for which a prior estimate is available with an uncertainty much better than that provided by current calibration. In that case, the fresh information is negligible compared to prior knowledge, and the calibration can at most be viewed as a stability check for the standard.

The implementation of Bayes' rule was discouraged in practical measurements until some ten years ago due to computational difficulties. Then, a numerical simulation technique, known as Markov Chain Monte Carlo (or MCMC) came to solve magically computational issues. With it, prior knowledge of any of the involved quantities, including the measurand, can be incorporated in the mathematical model in a straightforward and elegant way. This fully Bayesian inference is already adopted in many fields, from geology to meteorology, but is comparatively little known in metrology.

Conclusion

In this paper we considered some of the basic concepts in metrology ('measurement', 'quantities', 'quantity value', 'true value', ...) and looked at how the concept of 'measurement uncertainty' has evolved from the concept of 'error' (as the difference between an observed quantity value and a "true" quantity value) to that of a measure based on probability. Currently we appear to be in a transition from a frequentist to a Bayesian attitude in which we describe our "state of knowledge", or "degree of belief" by a probability density function (PDF). The revision of the GUM, currently underway in JCGM/WG 1, will be a further milestone in this process.

Rather than a new concept which is incompatible with that based on 'error' and 'true value', an uncertainty evaluation based on PDFs describing our state of knowledge about a quantity, should be seen as a natural evolution from those concepts. ■

Acknowledgment

This article is an adaptation of "From errors to probability density functions- Evolution of the concept of measurement uncertainty" by Walter Bich, which will be published in a forthcoming issue of IEEE Transactions on Instrumentation and Measurement. The authors thank IEEE for allowing publication in the OIML Bulletin. The authors are the convener (WB) and

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[4] In Bayesian probability theory, the principle of maximum entropy is an axiom. It states that, subject to precisely stated prior data, which must be a proposition that expresses testable information, the probability distribution which best represents the current state of knowledge is the one with largest information content [source: Wikipedia].

[5] See: http://en.wikipedia.org/wiki/Bayes_rule.

a member (WK) of the Joint Committee for Guides in Metrology (JCGM) Working Group 1 (GUM). The opinions expressed in this paper do not necessarily represent the views of this Working Group.

The authors gratefully acknowledge the colleagues of JCGM/WG 1 for fruitful general discussion, which contributed to form their views on the subject.

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CONCEPTS IN METROLOGY

Uncertainty of error: The error dilemma

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Abstract

'Measurement error'[2] has historically been defined in the metrology community as a difference of 'values', usually as a difference between a 'measured value' and a 'reference value.' The reference value is sometimes considered to be a 'true value', which is unknowable, and so the 'measurement error' is then unknowable. However, in some cases the reference value is considered to be a value assigned to a measurement standard (e.g., a 'conventional value'), which can be known. In this case, 'measurement error' is regarded as being knowable and measurable (for example, the 'error of indication of a measuring system'). The characteristic of being "measurable" requires that there be a corresponding 'quantity' that can be measured. When measurement error is considered to be measurable, it must then be regarded as a 'quantity' (and not as a 'quantity value'). Although the concepts of 'quantity' and 'quantity value' are related, they are distinct concepts, and from a terminological perspective the same term ("error") cannot be used for both concepts. This paper addresses the dilemma of how best to regard 'measurement error' and associated concepts: as quantity values or as quantities. This distinction has important implications when considering the concept of 'uncertainty of error', which arises when error is considered to be measurable.

1 Introduction

The concepts of 'quantity', of 'measurement error' and of 'error analysis' have long histories in metrology [1-6]. Relatively recently, the concept of 'measurement uncertainty' [7] has been developed in order to try to overcome some of the well-known difficulties associated with 'error'. One such difficulty is that [7: Section 3.2.1] "error is an idealized concept and errors cannot be known exactly". Another difficulty is how to combine components of 'measurement error' ('systematic error' and 'random error') in a meaningful way. Despite such difficulties, 'measurement error' continues to be used.

This paper examines the ways that 'measurement error' is perceived and why it continues to be a useful concept (at least in some contexts), how 'measurement uncertainty' and 'measurement error' are related and yet are fundamentally different from each other, and the dilemma of deciding whether/how measurement error should be defined, either as a 'quantity' or as a 'quantity value'. The latter distinction is important because if measurement error continues to be defined as a quantity value, then use of the concept of 'uncertainty of error', widely used in some metrology disciplines such as conformity assessment (see. e.g., [8]), becomes questionable, since quantity values are not themselves measured (only quantities are measured).

A quantity can be described as a "property having a magnitude that is expressed by a quantity value", where the quantity value is a "number and reference together expressing magnitude of a quantity" [6]. In the present text, the reference is a measurement unit. It is important to note that 'quantity' and 'quantity value' are different concepts. For example, a quantity typically has a spatiotemporal address and can be measured, while a quantity value does not have a spatiotemporal address and so cannot be measured. While the concepts of quantity and quantity value both use the concept of 'comparison', the concept of quantity value requires that a comparison has actually taken place (usually with a measurement unit), whereas the concept of quantity does not require that a comparison has taken place. As a further example of the difference between 'quantity' and 'quantity value', a quantity such as "length of that specific object" is the unique spatial separation between two specified points at either end of the object, whereas there are multiple possible quantity values (e.g., 1.00 inches or 2.54 cm) that can be used to express the magnitude (number and reference) of the length of the object.

1 The authors are members of the Joint Committee on Guides in Metrology (JCGM) Working Group 2 (VIM). The opinions expressed in this paper do not necessarily represent the views of this Working Group.

2 In this paper, single quotes ('…') are used to denote concepts, whereas double quotes ("…") are used to highlight words, phrases or definitions when useful.

2 What is 'measurement error'?

All three editions of the *International Vocabulary of Metrology* [4, 5, 6] (VIM), as well as the *Guide to the Expression of Uncertainty in Measurement* [7] (here referred to as the GUM), have defined 'measurement error' as a difference between a 'measured value' and a 'reference value'. The 'reference value' is usually considered to be a 'true value' but is sometimes taken to be a value assigned to a measurement standard (e.g., a 'conventional value'). Depending upon which type of reference value is used, measurement error may be considered to be "unknowable" (meaning that it is not possible to assign a value to it) or "knowable" (meaning that it is possible to assign a value to it).

When 'measurement error' is considered to be unknowable, there is little advantage in distinguishing whether it should be treated as a quantity or as a quantity value. Probably the most important aspect of the concept of 'measurement error' in this case is that its quantity value is assumed to be equal to zero, which means that the measured value of the quantity intended to be measured (the measurand) is assumed to be equal to the true value of the measurand, although there is still a measurement uncertainty that associates a degree of belief with that assumption. This will be elaborated below in Section 2.1.

When 'measurement error' is considered to be knowable, an advantage becomes apparent in treating it as a quantity instead of as a quantity value. Since a quantity can be measured, whereas a quantity value is not regarded as being measurable, a measurement uncertainty can be associated with a measured value of the measurement error, which can be used in making various types of decisions (e.g., in conformity assessment), as will also be elaborated below in Section 2.2.

2.1 'Unknowable' measurement error

If measurement error is taken to be the difference between a measured value and a corresponding true value of a measurand, the measurement error is considered to be unknowable since a true value is unknowable (except in those rare instances when it is defined). A true value can be thought of as a measured value that would be obtained as a result of a "perfect" measurement (that is, a measurement where all influence quantities are known and accounted for in the measurement model, where there are no random fluctuations and where no mistakes are made in performing the measurement). Since such a perfect measurement is not possible, it is not possible to know a true value of a measurand. Note that the expression "a true value" and not "the true value" is used, since there is usually a small but finite definitional uncertainty that accompanies the definition of any measurand, which results in there being a narrow set of true values that satisfy the definition of the measurand.

However, even though a true value is not knowable, that does not mean that the concept of 'true value' is not useful. The concept of true value is essential for a proper understanding of the concept of 'measurement uncertainty', which can be described as a measure of how well a true value of the measurand is believed to be known. The notion of belief is important since it is, in effect, what distinguishes measurement uncertainty from measurement error concerning what can be said about a true value of a measurand.

That the concept of true value is useful is sometimes lost, misunderstood or forgotten, since the GUM discourages use of the term "true" (considering it to be redundant [7: 3.1.1 & Note]). The GUM refers to 'true value' as just 'value', which fosters the erroneous assumption that the GUM discourages the concept of true value. To avoid confusion, the VIM [6] and this paper encourage use of the full term "true value".

Note that, historically, in some metrology disciplines the term "true value" is used to mean a value assigned to a calibrated measurement standard. That is not the meaning of the term in this paper, and therefore the term "conventional value" is used for that concept.

The concepts of "unknowable" measurement error, true value and measurement uncertainty are illustrated in Figure 1, in the context of characterizing a calibrated standard weight, shown schematically at the top right of the figure.

In Fig. 1 it is assumed that the weight is calibrated using a high quality measuring system that is not otherwise mentioned or shown. The calibration certificate of the standard weight contains the measured mass value ($m_{\text{calibrated}}$) of the standard weight, along with the associated standard measurement uncertainty ($u_{\text{calibrated}}$). The standard measurement uncertainty is obtained during the calibration of the standard weight, through a calibration hierarchy providing metrological traceability via a traceability chain, back to the measurement unit shown on the horizontal axis of the figure. For illustrative purposes only, a 'true value' of the mass of the standard weight is shown in the figure on the horizontal axis, where it is indicated that it exists, but is in principle unknowable (unless it is defined).

Also shown in Fig. 1 is a probability density function (PDF_1) that provides a probability density for a true value of mass, where probability is taken as an expression of the degree of belief. In particular, the integral of this density between a and b is the probability that a true value is between a and b. As an example, a

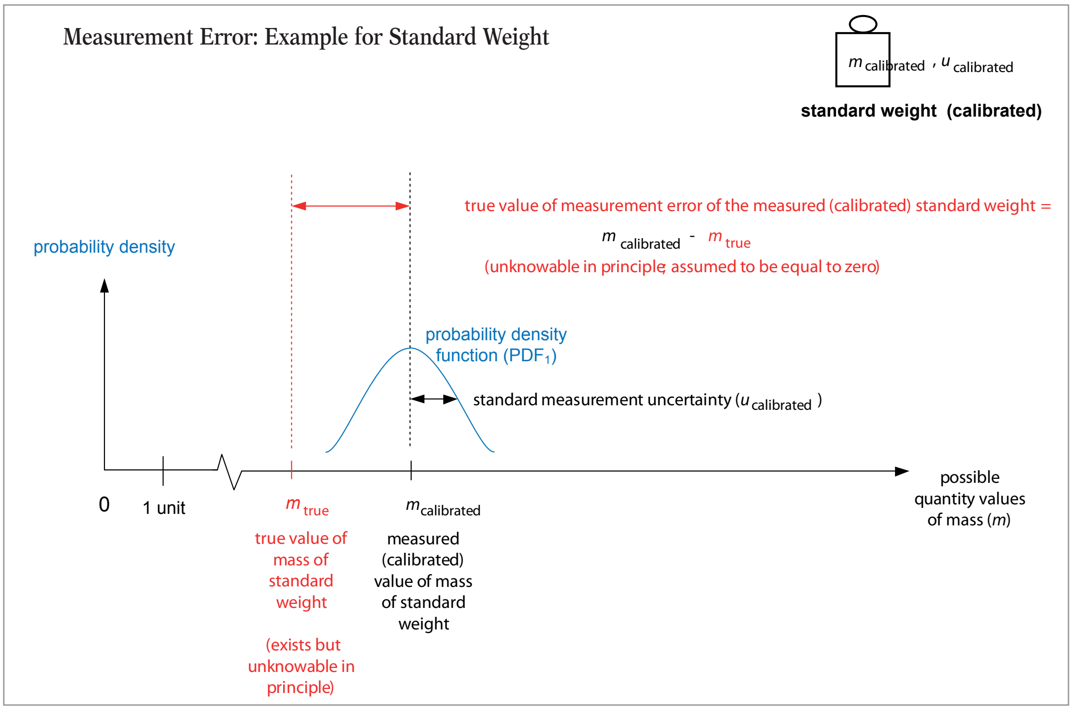

Figure 1. Demonstration of "unknowable" 'measurement error' and of 'measurement uncertainty' for a calibrated weight that will subsequently be used as a measurement standard. While unknowable measurement error is typically assumed to be zero, here it is shown, for illustrative purposes only, that it might actually be significantly different from zero.

could be $m_{calibrated} - u_{calibrated}$, and b could be $m_{calibrated} + u_{calibrated}$, in which case the integrated probability is 67 %. $u_{calibrated}$ is obtained from PDF_1, usually as the standard deviation of the (assumed) Gaussian curve, as indicated.

Figure 1 explicitly illustrates the measurement error of the mass of the standard weight. If measurement error is considered to be the calculated difference between the measured (calibrated) value of the mass of the standard weight and an unknowable true value of the mass of the standard weight, then it is a quantity value. If the measurement error is considered to be a quantity, it has an unknowable quantity value (which is its true value). In either case, the quantity value of the measurement error is unknowable, but is assumed to be equal to zero. For illustrative purposes, however, a non-zero quantity value of the measurement error is shown in Fig. 1, and is labeled there as an unknowable true value of the measurement error.

Note that the GUM discourages use of the concept of 'measurement error' because it is "unknowable", and instead promotes 'measurement uncertainty', since measurement uncertainty can be calculated, and gives a measure of the belief in a true value of the mass of the standard weight. It is important to keep in mind that, in the context of measurement, despite the possible reality depicted in Fig. 1, where a true value of the mass of the standard weight is significantly outside of the interval defined by the standard measurement uncertainty, the measurement error is typically assumed to be zero, based on all of the available information from the measurement (calibration), since 'corrections' should have been made for all known components of (systematic) error.

The measurement uncertainty depicted in Fig. 1 is that associated with the measured (calibrated) value of mass of the standard weight. While it is not depicted as an uncertainty of the measurement error, it could in fact also be considered as such if measurement error is considered to be a quantity.

Note that, despite measurement error being "unknowable" (for example, since it is impossible to know whether a mistake has occurred during any part of the measurement), the idea of estimating measurement error, and techniques to do so, have a long history. Foremost among these techniques is 'cross-validation' [9], which is a technique for estimating the performance of a predictive model.

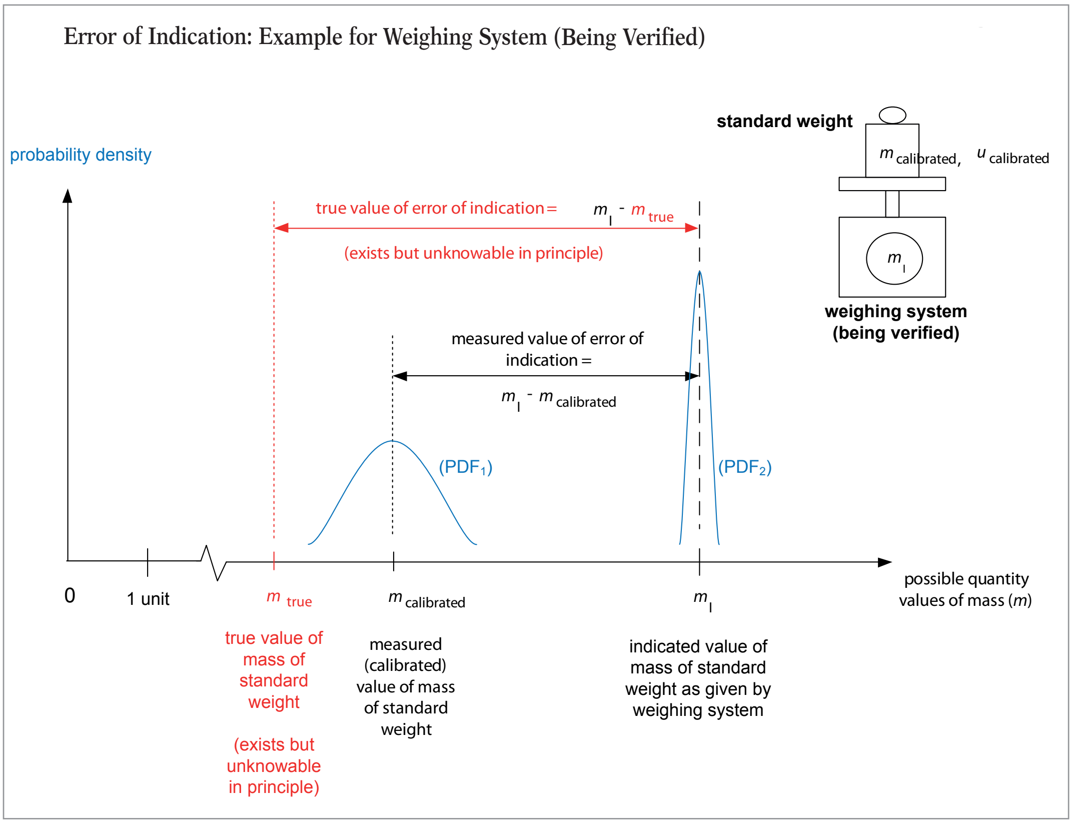

Figure 2. Demonstration of "knowable" error for a calibrated weight that is used as a measurement standard. 'Error of indication' can be considered here to be a difference of two knowable quantity values, or as a difference of two knowable quantities.

2.2 "Knowable" measurement error

While 'measurement error' treated above in Section 2.1 is "unknowable", there are important areas of metrology where measurement error, or at least 'error', is treated as "knowable" (that is, a measured value can be obtained for it). Such an 'error' could be termed "measured error", to distinguish from 'measurement error'. Important examples include the verification of measuring systems ('error of indication') and the manufacture of machined parts ('manufacturing error').

2.2.1 Verification of a measuring system (error of indication)

Figure 2 illustrates the situation for verification of a measuring system, where a weighing system is being verified to evaluate whether the 'error of indication' is within stated requirements. Error of indication could be defined here as a quantity value, the calculated difference between the indicated value of mass and the calibrated value of mass assigned to the mass standard that is now sitting on the pan of the weighing instrument. 'Error of indication' could also reasonably be defined as a quantity, which means that it must have both a measured value and (an unknowable) true value. Consideration of the quantity corresponding to 'error of indication' will be left for another paper.

Figure 2 contains much of the same information as Fig. 1, but in addition shows the value (m_I) of the indication of the mass of the standard weight as obtained from the weighing system being verified. The two 'errors of indication' are also shown, the one with respect to a 'true value' of the mass of the standard weight (which is still unknowable), and the other with respect to the measured (calibrated) value of the mass of the standard weight (which is knowable and, in fact, known). The measured value of the error of indication is taken as the 'best-estimate' of a "true" value of the error of indication since, as discussed above, the error value of the measured (calibrated) mass of the measurement standard (standard weight) is typically assumed to be zero.

In a verification scenario, whether in a "laboratory" or a "field" environment, the objective is not to "correct" or "adjust" the indicated value to the measured (calibrated) value of the mass standard, but rather to assess whether the measured difference (error of indication value) between the indicated value and the

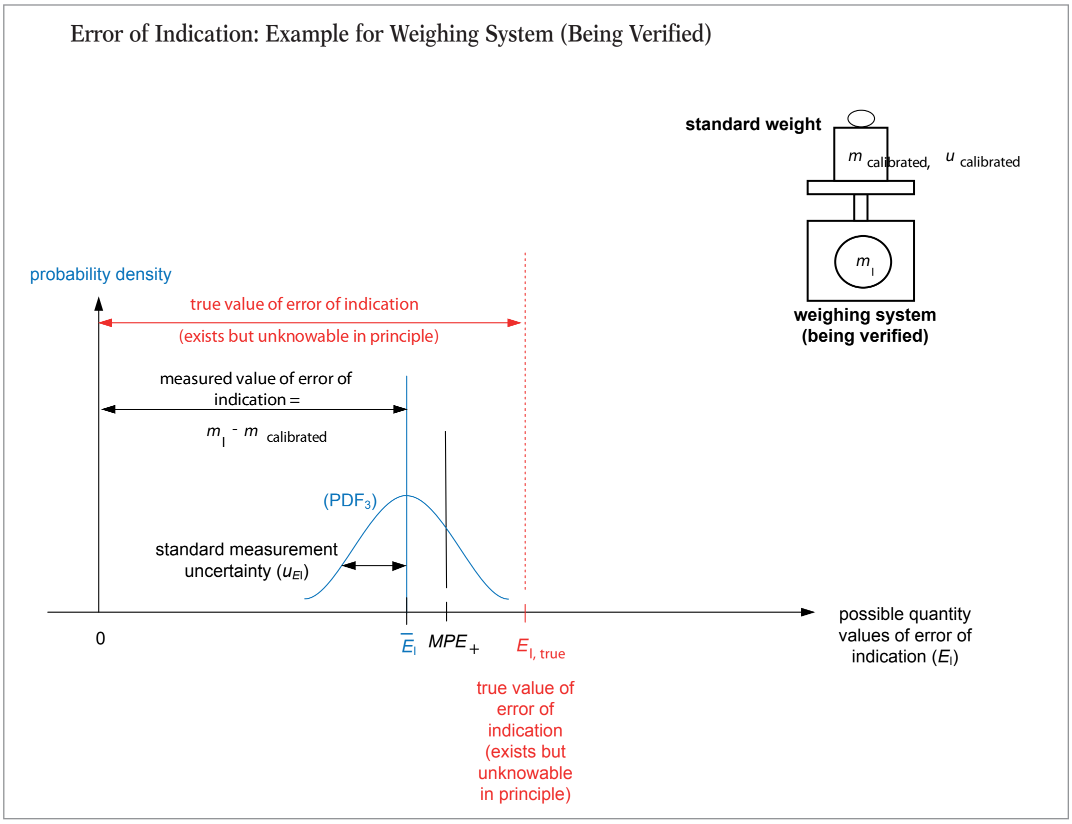

Figure 3. Demonstration of "knowable" error for the same information as in Fig. 2, only plotted as a function of error (and not mass). The PDF_3 here is a convolution of the two PDFs in Fig. 2. MPE_+ denotes the positive maximum permissible error (of indication) according to some specification.

calibrated value of the mass standard is within acceptable limits of the "maximum permissible errors" (MPEs), as stated in regulation (e.g., in an OIML Recommendation). While it is highly desirable that the error of indication value be small (and even zero), this is typically not found to be the case in verification.

Also shown in Fig. 2 are two PDFs, one (PDF_1) for the measured (calibrated) value of mass of the standard weight (this is the same PDF as shown in Fig. 1), and the other (PDF_2) for the indicated value of the mass of the standard weight. Sources of uncertainty of the indicated value could come from lack of reproducibility of repeated measurements, instability (jitter) of the indicated value, and finite resolution of the indicator. The information in these two PDFs is used to make a statement about how well a 'true value' of the error of indication is believed to be known. This is illustrated in Fig. 3.

Note that the horizontal axis in Fig. 3 is now changed from that in Figs. 1 and 2, and is labeled "possible quantity values of error of indication." The measured value of the error of indication is the same as is given in Fig. 2 and, as discussed earlier, is the best estimate of a 'true value' of the error of indication. As for any measurand, a PDF can be constructed giving the probability density that a 'true value of the error of indication' (the measurand in this case) lies within an infinitesimal region around a particular possible 'true value of the error of indication'. Such a PDF is illustrated in Fig. 3, along with the associated standard measurement uncertainty (u_{EI}). This PDF (PDF_3) is obtained by combining (sometimes called convoluting) the two PDFs in Fig. 2 [10]. Note that u_{EI} is the 'measurement uncertainty' of the 'error of indication', which explicitly demonstrates the interdependence of the concepts 'measurement uncertainty' and 'error' in a verification scenario. Most notably, when error is treated in this way as a quantity, it makes sense to talk about both its measured value and the measurement uncertainty associated with that measured value.

When a measuring instrument is being verified, the 'error of indication' is a known 'measured error'. When this measuring instrument is subsequently used to perform a measurement, the resulting 'error' is an unknown 'measurement error'. This demonstrates the complexity of use of the term "error".

2.2.2 Manufacture of machined parts (manufacturing error)

Another example of "knowable" 'error', while clearly not an example of "knowable" 'measurement error' (in the sense of a measurement error being the result of an imperfect measurement), found in metrology is the 'manufacturing error' associated with a machined part (say, a spacer), which has a thickness that differs from the intended manufactured thickness. In this example, both the thickness of the spacer and the target thickness of the spacer can be envisioned as quantities (having associated quantity values). The 'difference' between these two quantities can also be envisioned as a quantity (having an associated quantity value).

If the target thickness value for a manufactured spacer is specified as ℓ_T, and the measured thickness value of the same spacer is specified as ℓ_M, then the measured value of the manufacturing error can be calculated as $E_{manufacturing} = \ell_M - \ell_T$. In such a case, since both ℓ_M and ℓ_T are "known", $E_{manufacturing}$ is also "known". Also, since there is a measurement uncertainty associated with ℓ_M, there is a measurement uncertainty associated with $E_{manufacturing}$.

In the usage of the term "error" as a quantity in this case, it again makes sense to think of an 'uncertainty of error', since the manufacturer will likely want to have some idea of the likelihood that various manufactured parts "fit" with each other, and the measurement uncertainty associated with the measured manufacturing error value will aid in assessing such likelihood. Whether 'uncertainty of error' should be considered as a quantity will be left for discussion in another paper.

3 Conclusions

The Error Dilemma can be posed as follows:

- Even though, historically, measurement error has been defined as a difference of values, and not as a difference of quantities, should it now rather be (re-) defined as a difference of quantities?
- **What are the advantages?** All types of 'error' would be treated on the same footing, as being (sometimes "knowable") quantities, avoiding dual usage of a term for different concepts. In the case of "unknowable" error, while the quantity value of the error cannot be "measured" (and is assumed to be zero), the measurement uncertainty associated with the measured value of the measurand is also that associated with the measurement error value.
- **What problems might defining measurement error as a quantity cause?** Many texts that describe/discuss/use measurement error would need to be changed, along with corresponding educational efforts. This is probably the biggest part of the dilemma.

4 Acknowledgements

The authors appreciate the kind inputs from Paul De Bièvre, Carol Hockert, Leslie Pendrill, Antonio Possolo, Marc Priel and Wolfgang Wöger. ■

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CONCEPTS IN METROLOGY

Considerations on the evolution of metrological concepts

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Summary: *This paper presents the main developments over recent years in measurement concepts and aspects regarding the way of transposing some of these concepts into Romanian. One of the significant developments refers to the 'measurement result'. This is analyzed together with other concepts that are related to it: 'metrological traceability', 'measurement uncertainty' and 'calibration'. The development of activities related to 'nominal property' has sometimes led to the situation that the meanings of specific concepts have evolved faster than the practices related to their use. The analysis of these developments is completed with issues arising from the Romanian transposition of the concepts in the latest edition of the International Vocabulary of Metrology (VIM3), such as 'devices for measurement', 'uncertainty' and 'calibration' and some related concepts.*

Keywords: *Common perception of the metrological concepts, non-correlations of Romanian transposition*

1 Introduction

Measurements and their results play an increasingly important role in society [1]. In order for them to satisfy the need to correlate human activities beyond professional geographical boundaries, it is necessary to build and then consolidate confidence in measurements.

One of the important elements on which this confidence is based is the common perception of measurement concepts and terms that describe the measurement. The main tool developed up to 1993 by the international metrology community for this purpose is the *International Vocabulary of Metrology* - VIM2 [2]. In conjunction with this, the *Guide to the expression of uncertainty in measurement* - GUM1 [3] was also developed as a necessary instrument in understanding and implementing the approach based on uncertainty that tends to replace the traditional approach in metrology based on errors and error analysis.

The need for coverage of measurements and examinations in new fields such as chemistry and medicine, and for the improvement of certain concepts such as 'metrological traceability' and 'measurement uncertainty', that are related to the concept of 'measurement result' on the one hand and those related to 'qualitative property examination' on the other hand, have led to a new edition of the *International Vocabulary of Metrology* - VIM3 [4]. This document was translated into Romanian and published as a Romanian standard in 2010 - VIM3ro [5].

The considerations in section 2 cover some developments on measurement concepts, from VIM2 and GUM1 to VIM3, and those in section 3 cover issues related to the Romanian transposition of some of these concepts.

2 Developments in measurement concepts

2.1 Concepts regarding 'measurement' and 'measurement results' with a focus on 'metrological traceability', 'measurement uncertainty' and 'calibration'

In VIM2 and in the GUM [3],[6],[7], the definition in section 3.1, respectively B.2.11, of 'measurement result' (the value attributed to a measurand, obtained by measurement) does not explicitly "contain" the measurement uncertainty even if Note 2 of the definition states: "A full expression of the result of a measurement includes information about the measurement uncertainty". The interpretation of this last provision is that when reported, the measurement result must be accompanied by information on the measurement uncertainty (U) and not that the result of measurement "includes" U. This interpretation is supported even by the definition in VIM2 - 3.9 of 'measurement uncertainty' ("parameter, associated with the measurement result that characterizes the spread of values ..."), which shows that this is "associated with" and not "included in" the measurement result.

As stated in GUM - 2.2.3, Notes 3 and 3.3.1, the result of a measurement is a (the best) estimation of the true value of the measurand, i.e. its singular value.

This fact is actually considered inconvenient because the singular value mentioned above and all the other values whose dispersion is characterized by uncertainty are values that have a common characteristic: i.e. that with different probabilities they can reasonably be attributed to the measurand.

This inconvenience was eliminated by:

1) the introduction in VIM3 of a new concept, 'measured value', which is equivalent to the concepts of 'measurement result' and 'estimation of the measurand value' from VIM2 and the GUM;

2) redefining the concept 'measurement result': VIM3 - 2.9 defines 'measurement result' ("set of quantity values being attributed to a measurand together with any other available relevant information"), so that it "includes" now, beside the measured (individual) value, the other values which are believed, with a different probability, to be reasonably attributed to the true value of the measurand.

For the purpose of this paper, the measurand is considered to have an "essentially unique" true value (VIM3, 2.11, Note 3).

The common element of 'measurement uncertainty' and 'measurement result' is the **set of values** attributed to the measurand. 'Measurement uncertainty' is a non-negative parameter that expresses the dispersion of values assigned to a measurand, based on the information used (VIM3, 2.26) and 'measurement result' is a set of values attributed to the measurand supplemented with any other relevant information available (VIM3, 2.9). The probability density function (pdf) is relevant information for both the measurement result and the measurement uncertainty. Therefore, the measurement result is usually expressed by a **single value** ('measured value' - VIM3, 2.10) and a measurement uncertainty. If the measurement uncertainty is considered negligible for certain purposes, then the measurement result is expressed only by the measured value. But otherwise, if the measurement uncertainty is not available, then the measurement result contains only the measured value but may not be satisfactory for some applications where confidence in measurement results and decisions taken on the basis of these results is required.

Both in the older descriptions from VIM2 [2],[8] and in one from VIM3 [4],[5], 'metrological traceability' is a property of 'measurement result'. The consequence of developments in describing the concept of 'measurement result' is the fact that the description of the metrological traceability from VIM3 is adapted to the measurement result seen as a set of values ("property of the measurement result that can be compared to a reference through a documented unbroken chain of calibrations and each contributing to the uncertainty of measurement") instead of a singular value.

The uninterrupted chain of comparisons of **individual values** with determined uncertainties (i.e. comparisons / calibrations that do not "contain" the determination of the measurement uncertainty) from the old description of metrological traceability contained in VIM2 was replaced by a documented unbroken chain of calibrations that, in the new description, refers to establishing a relationship between **sets of values** characterized by measurement uncertainty ("operation that, under specified conditions, in a first step establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication"). The unbroken and documented chain of calibrations is a "calibration hierarchy" and each calibration contributes to increasing the measurement uncertainty along the succession of calibrations.

VIM3 provides new meanings for the mentioned **reference** in the description of metrological traceability. Thus, in addition to the **measurement standard**, there is also the **definition of a measurement unit** under the form of its practical realization. This is redundant when the stated reference value corresponds to a measurement unit, because the meaning of the term *measurement standard* is just "realization of the definition of a given quantity, with stated quantity value and associated measurement uncertainty, used as a reference" (VIM3, 5.1).

In the case of the quantity thermodynamic temperature, the reference is usually the measurement standard made up of the realization of the quantity "International Temperature Kelvin" which is obtained through the materialization of the ITS-90 [9] (e.g.: the SIT 90 realization [10] at BRML-INM).

The concept of 'measurement' has evolved and, along with it, the result of this operation (i.e. 'measurement result') has acquired new meanings. Thus, the definition "set of operations having as purpose determination of **a value** of a quantity" in the old VIM2 has evolved into "process of experimentally obtaining **one or more** quantity values that can reasonably be attributed to a quantity" (VIM3, 2.1); the measurement process is not applicable to qualitative properties (VIM3, 1.30).

In VIM3, the measurand is considered as the quantity "intended to be measured" instead of the quantity "subject of measurement" as in VIM2 and the GUM. It was therefore clarified that the measurand change effects generated by the interaction between the measuring instrument and the object of the measurement are different sources of uncertainty and they cannot be included in the definition of uncertainty.

VIM2 also defines other concepts that are directly related to the concept of 'measurement result'. Some of these concepts are: 'accuracy of measurement', 'repeatability' (of a measuring instrument or of results of measurements) and 'reproducibility' (of results of measurement), 'error' (of measurement), 'random error', 'systematic error', 'correction', 'correction factor'. All these concepts have been restated in accordance with the new context given by VIM3, referred to above.

2.2 Concepts related to 'nominal property'

VIM3 makes an explicit distinction between 'quantity' ("property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed as a number and a reference" - VIM3, 1.1) and 'nominal property' ("property of a phenomenon, body, or substance, where the property has no magnitude" - VIM3, 1.30), stating that the measurement "does not apply to **nominal properties**". In conclusion, all the metrological concepts mentioned in section 2.1 refer only to quantities that are measured and do not refer to nominal properties.

The definition of 'metrology' covers "the science of measurement and its applications" (VIM3, 2.2). The immediate interpretation is that metrology refers only to quantities because they are measured and that it does not refer to nominal properties. However, 'nominal property' and some related concepts were also included in VIM3 because they have similarities with the concepts related to quantity, as shown in Table 1.

It becomes obvious that the concept of 'material measure' (VIM3, 3.6) contains only a part of the reference materials (VIM3, 5.13, 5.14); RMs and CRMs providing nominal property values are not covered.

These aspects can be used by testing laboratories, medical laboratories and by those involved in their accreditation as an argument to improve the practice according to which, sometimes, "qualitative measurements are made", "qualitative quantities are measured", "the uncertainty cannot be determined because the measurement is qualitative".

3 Aspects related to the Romanian transposition of some of the advanced concepts of VIM3

3.1 Some non-correlations in the transposition of the International Vocabulary of Metrology (VIM3) into a Romanian standard (VIM3ro)

Using in VIM3ro [5] the same name "mijloc de măsurare" both for a group of technical means described in Chapter 3 of the Vocabulary used to make measurements (which are called "devices for measurement" in the original VIM3) and also for one of the technical means called "measuring instrument" of this group (VIM3, 3.1), i.e. the use of the same name for the two notions which are not identical, and also the inclusion, in addition to the definition in 3.1 of the two notes specific to the Romanian version (notes 3[1] and 4[1]) in which there are statements that could be considered as inaccurate or unnecessary, could be interpreted as an inaccurate transposition of the original version of VIM3 into Romanian. This creates the basis for confusing or erroneous interpretations of the meaning of the original terms.

In VIM3ro the national note 3[1], including the so-called "subcategories" of the defined object, was added

Table 1 Terms associated with the term *nominal property* together with similar terms applicable to the term *quantity*

Nominal property	Quantity	Comments
Examination of a nominal property (VIM3 - 5.13)	Measurement (VIM3 - 2.1)	Examples of nominal properties: sex of human beings, material color, ISO country code
Nominal property value, Value (VIM3 - 1.30, 5.13, 5.14; [13] - A.2.2)	Quantity value, Value (VIM3 - 1.19)	The nominal property value can be expressed in words, phrases or names, alphanumeric codes unrelated to a quantitative expression
Examination uncertainty, Uncertainty associated with nominal property value, Uncertainty (VIM3 - 5.13, 5.14; [13] - A.2.2)	Measurement uncertainty, Uncertainty (VIM3 – 2.26)	The term uncertainty may designate a *measurement uncertainty* or an *uncertainty associated with a nominal property*
Traceability of a nominal property value, Traceability (VIM3 - 5.14; [13] - A.2.2)	Metrological traceability, Traceability (VIM3 – 2.41, 5.14)	The term *traceability* may designate the *metrological traceability* of a quantity value or *traceability* of a nominal property value

to the definition in 3.1 of the original term "measuring instrument". It is not clear from the text of the note whether the authors of the Romanian transposition intended to give the significance of parts of a "measuring instrument" or of its constructive-functional types to subcategories. Some of these subcategories ("dispozitiv de măsurare", "traductor de măsurare", "lanț de măsurare") already have other meanings than those given in definition 3.1, being used/defined separately in VIM3, in the title of chapter 3, as well as in clauses 3.7 and 3.10 respectively.

Other subcategories may have the meaning given by definition 3.1 but this becomes clear in other parts of the standard, a national special note no longer being necessary. They are "material de referință" (VIM3, 3.1 - Note 2, 3.6 - example, 5.13, 5.14), "măsură" (VIM3, 3.1 - Note 2, 3.6), "instrument de măsurare" and "aparat de măsurare" (VIM3, 3.1). The other subcategories are not relevant to strengthen the significance of definition 3.1. For example, the subcategory "echipament de măsurare" ("measuring equipment") often has a wider significance than that of "measuring instrument", surpassing the status of "subcategory".

Definition 3.1 of the original term "measuring instrument" was added in VIM3ro national note 4[1], in which there are statements that could be considered as inaccurate and which introduce a classification of the complexity criteria for "measuring instrument" which is not in the original version and which seems to contradict other parts of the standard.

Claims that the terms "instrument de măsurare" and "aparat de măsurare" are not defined in the original version of VIM3 are refuted by the very definition 3.1; the term defined by this is "measuring instrument" in English or "instrument de mesure"/"appareil de mesure" in French. Starting from this wrong premise, the authors of the transposition of VIM3 into Romanian have redefined the two terms and introduced a classification which excludes many materialized measures from the significance of definition 3.1. This contradicts the definition of materialized measure (VIM3, 3.6) and the definition of the measuring instrument (VIM3, 3.1 - including note 2). The confusion generated by this national classification is also strengthened by the fact that for one of the two terms of classification the name "instrument de măsurare" is used; even the translation of the term "measuring instrument" that is classified and in the original version has another meaning. This classification does not seem to be necessary in the context of the general concept regarding the devices for measurement in the new VIM3 because it does not provide any additional useful information about the "measuring instrument" or any further understanding of its relationship with other types of devices for measurement.

3.2 Some non-correlations in the Romanian version of the international standard regarding medical laboratories

The international standard containing requirements for medical laboratories [11] was correlated with the VIM3 provisions, including those on nominal properties which are subject to examinations (see Section 2.3).

However, the transposition into Romanian [12] of this international standard does not exactly take into account the meaning of all the concepts used even though they are defined in VIM3. An example is the transposition into Romanian of art. 5.6.2. In the original version it states: "The laboratory shall determine the **uncertainty** of results, where relevant and possible...". Correlating this requirement with the provisions on reference materials (VIM3, 5.13 and 5.14 - Note 3), we can see that the term "uncertainty" covers both the concept of "uncertainty of measurement" specific for quantities and measurement processes and also the concept of "uncertainty associated with a nominal property value". The transposed version of Art.5.6.2 above is: "Where possible and relevant, the laboratory must determine the **measurement uncertainty**...". Thus, medical laboratories in Romania may consider that the requirements of Article 5.6.2 of [11] do not apply to nominal properties and to processes of examining these properties because the Romanian transposition [12] provides the interpretation that the requirements related to uncertainty refer only to quantities and not to nominal properties.

ISO 15189:2007 contains requirements relating to the calibration of certain measuring devices used by medical laboratories ([11], 5.3.2, 5.3.7, 5.3.9, 5.3.13, 5.6.3). Traditionally, in the Romanian language the term "etalonare" is used for the operation of comparing a measuring instrument with a measurement standard or standards and for establishing the link between information about the measurand supplied by these ([8], 6.11; [5], 2.39). This operation is called "calibration" in English and "étalonnage" in French.

The traditional character of using the term "etalonare" stems from the fact that the two Romanian vocabularies of metrology [8], [5] have included this term and its general significance for nearly 20 years, that the term was used in metrology long before the VIM2ro, and also that almost unanimously in Romania, laboratories speak about "certificate de etalonare" and not about "certificate de calibrare".

However, the Romanian version of ISO 15189:2007 [12] uses a different term from the specified one, namely "calibrare" instead of "etalonare" ([12], 5.3.2, 5.3.7, 5.3.9, 5.3.13). This transposition, which is not in compliance with certain long-standing and unchallenged national rules, allows both laboratories and the accreditation infrastructure to assign different meanings to the term "etalonare" and implicitly therefore to the original term "calibration". This can happen because in VIM3ro the term "calibrare" does not exist and in VIM2ro - 4.29, the term "calibrare" has a different meaning from the term "etalonare" and therefore a different meaning from the original term "calibration".

Not abiding by certain international rules (the intention of which is to ensure consistency in the use of certain well-known terms which are already defined and globally well accepted) when transposing standards into Romanian can lead to the incorrect application of those international rules in Romania. Thus, there are some interpretations in the laboratory and accreditation community whereby in certain cases "calibration" is seen as an "adjustment" (VIM3, 3.11), although the "adjustment of a measuring system should not be confused with calibration, which is a prerequisite for adjustment".

4 Conclusions

The evolution of concepts related to 'nominal property' has been analyzed. VIM3 makes an explicit distinction between 'quantity' and 'nominal property', stating that "the measurements are not applied to nominal properties". The authors have presented the results of a comparative study between terms such as examination of a nominal property, nominal property value, examination uncertainty and traceability of a nominal property value, and similar terms specific for the measurement. Thus, a tool has been built for laboratories and accreditation bodies in order to improve certain practices according to which "qualitative measurements are sometimes made", "qualitative quantities are measured", "the measurement uncertainty is not determined because the measurement is qualitative".

Studies have revealed non-correlations in the transposition of the VIM3 into the Romanian standard VIM3ro.

The use in VIM3ro of the same term "mijloc de măsurare" both for a group of technical means described in Chapter 3 of the Vocabulary used in making measurements (which is called "device for measurement" in the original document (VIM3)), and also for one of the technical means called "measuring instrument" in this group (VIM3, 3.1), i.e. the use of the same name for the two non-identical notions, and the inclusion, in addition to the definition in 3.1 of notes 3[1] and 4[1] which are specific to the Romanian version (in which statements are made that could be considered inaccurate or unnecessary) can be interpreted as resulting in an inaccurate transposition of the original version of VIM3 into Romanian. The possibility therefore exists of confusing or incorrect interpretations of the meaning of the original terms.

Some non-correlations have been found in the Romanian version [12] of the international competence requirements for medical laboratories [11]. In connection with one of these non-correlations, the concept of 'uncertainty' covers both the concept of 'uncertainty of measurement' specific for quantities and measurement processes and also the concept of "uncertainty associated with a nominal property value" (VIM3, 5.13 and 5.14 - Note 3). Some of the requirements listed above refer to the term uncertainty but they were taken in the Romanian version as only referring to the term uncertainty of measurement, thus minimizing their area of action. Thus, the medical laboratories in Romania may consider that these requirements ([11], 5.6.2) shall not apply to nominal properties and examination processes of these properties. Another non-correlation concerns the use in the Romanian version [12] of the term "calibrare" instead of "etalonare" imposed by tradition and the most specialized documents. This has led to misinterpretation concerning the term "calibration" = "etalonare" in accordance with, for example, its meaning of "adjustment" (VIM3, 3.11) although "adjustment of a measuring system should not be confused with calibration, which is prerequisite for adjustment".

Therefore, some requirements concerning calibration ([14], 5.4.6.1) are sometimes no longer applied, which might leads to wrong decisions of competence. A revision of the Romanian standards [12], [5] is therefore recommended in order to eliminate the above-mentioned non-compliances. ■

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UNCERTAINTY

Uncertainty analysis of custody transfer operations with upright cylindrical tanks

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1 Abstract

Tank gauging is one of the methods used to determine the quantity of a hydrocarbon contained in a storage tank. Many tank gauging operations are performed daily around the world, often involving large amounts of money in custody transfer operations. In each transaction there is a risk of money loss for the buyer or seller and this risk may be quantified by the uncertainty analysis of the transferred volume. The uncertainty analysis will show for the buyer and seller the necessity to accept the risk for each transaction. It can also show a possible need for change in the measurement process, e.g., in-line measurement. This paper discusses a number of issues associated with the uncertainty of volume measurement in upright cylindrical tanks with floating roofs. It includes the analysis and discussion of the process of determining tank volumes and the overall uncertainty of the transferred volume with upright cylindrical tanks. It also includes a discussion of the influence and relevance of each measurement variable on the overall uncertainty of the transferred volume, to provide the tank operators with insight in determining the most important variables in the process of transferring volume by a tank. Finally, the uncertainty analysis is validated by the Monte Carlo method since there are many correlated uncertainties in the process of transferring volume by a tank. The results show that, when the correlated uncertainties are considered in the modeling, the final uncertainty of the transferred volume is reduced drastically. A value of ±0.10 % (k = 2) can be achieved. Therefore, a tank can also be used as a standard to verify metering systems of OIML R 117 accuracy class 0.3 and 0.5.

2 Introduction

The use of upright cylindrical tanks for storing liquid petroleum products is a very common practice among petroleum companies around the world. To determine the volume of liquid in these tanks, these companies have installed many different types of tank volume measurement systems. The volume can be determined either by manually gauging the tank or by using an automatic gauging system installed on the tank. These different approaches have driven the industry to establish standard volume measurement calculation methodologies for petroleum products, for example, API MPMS 12.1.1, [1]. This standard describes the procedures and standardizes the volumetric and mass calculation of crude oil, petroleum products, and petrochemical products that are stored in tanks.

The methodologies for measurement of the transferred volumes are based on complex calculations with numerous variables that many times are correlated through the use of the same instrument during the opening and closing measurements. These include, for example: the height measurement, the tank's volumetric table, the temperature measurement, the use of the same correlation to calculate the effect of liquid temperature, and so on. The resulting transferred volume measurement is a function of all these variables, and the associated uncertainty of the measurement is a function of the uncertainty of each variable associated with their correlations.

3 Methodology

3.1 Calculation procedures to determine the net standard volume (NSV)

The methodologies to determine the tank volume are typically based on the American Petroleum Institute (API) standards, more specifically here, the "API MPMS Chapter 12 – Calculation of petroleum quantities – Section 1: Calculation of static petroleum quantities – Part 1: Upright cylindrical tanks and marine vessels" [1]. In the field, the desired volumetric quantity to be determined is the net standard volume (NSV) of liquid in a tank. Its determination is based on data from online tank instrumentation or manual measurements, along with data from tank strapping tables. The base temperature to be utilized in the calculations may be 60 °F, 15 °C or 20 °C.

The process of determining the NSV is outlined:

1. Determination of gross observed volume (GOV):
   a. Determination of total observed volume (TOV).
   b. Determination of free water (FW) and sediments.

c. Determination of the correction factor for the effect of temperature on the shell of the tank (CTSh).
d. Determination of the floating roof adjustment (FRA).
2. Determination of volume correction factor (VCF or CTL).
3. Determination of gross standard volume (GSV).
4. Determination of the correction for sediment and water (CSW).
5. Determination of NSV.

3.1.1 Gross observed volume (GOV)

The API equation for GOV (in liters) is given by eq. (1):

$$\mathrm{GOV} = [(\mathrm{TOV} - \mathrm{FW}) \times \mathrm{CTSh}] - \mathrm{FRA} \tag{1}$$

where:

a) TOV is the observed volume that is derived with the level instrument measurement, using linear interpolation of the strapping table level and volume values from the tank table (strapping table). TOV (in liters) is given by eq. (2):

$$\mathrm{TOV} = V_{\mathrm{TTB}} + \frac{(V_{\mathrm{TTA}} - V_{\mathrm{TTB}})}{(L_{\mathrm{TTA}} - L_{\mathrm{TTB}})} \times (L_{\mathrm{M}} - L_{\mathrm{TTB}}) \tag{2}$$

where:

L_{M} = the measured level (actual level in meters).
V_{TTB} = volume value from tank table below measured level (in liters).
V_{TTA} = volume value from tank table above measured level (in liters).
L_{TTA} = level value from tank table above measured level (in meters).
L_{TTB} = level value from tank table below measured level (in meters).

b) FW (in liters) is the adjustment for the presence of free water and tank bottom sediment. It is determined by performing a free water level measurement, and utilizing the TOV equation and tank strapping table to determine FW volume. In this paper this adjustment will be considered zero assuming the tank has been drained before the official transfer.

c) CTSh is the correction factor for the effect of temperature on the shell of the tank. The tank steel temperature is approximated by using both the temperature of the liquid inside the tank and the outside ambient air temperature. The resulting tank steel temperature is compared to the tank steel reference temperature (from the strapping table) and a correction factor is determined to account for the volumetric effects of tank steel expansion or contraction due to temperature. CTSh can be calculated by eq. (3):

$$\mathrm{CTSh} = 1 + 2\alpha\Delta T + \alpha^2\Delta T^2 \tag{3}$$

where:

α = linear coefficient of expansion per °C of tank shell material. = 0.000 011 2 for mild carbon steel (Table 4 in API MPMS Chapter 12.1.1) or may be obtained from the strapping table.

ΔT may be calculated by eq. (4):

$$\Delta T = T_{Sh} - T_{\mathrm{b}} \tag{4}$$

T_{Sh}, may be determined by eq. (5):

$$T_{sh} = [(7 \times T_{\mathrm{L}}) + T_a] / 8 \tag{5}$$

where:

T_{L} = tank liquid average temperature (in °C), determined by measurement.
T_{a} = ambient air temperature around tank (in °C), determined by measurement.
T_{b} = tank base temperature (in °C), from the strapping table = 15 °C.

d) FRA (in liters) is the floating roof adjustment. This is the volumetric adjustment made to the GOV based on the displacement of liquid due to roof weight. FRA may be determined by eq. (6). Floating roof correction will be less accurate if the liquid level falls inside the floating roof's critical zone. So, operation in this zone is avoided. Roof corrections are not applicable for volumes below the critical zone.

$$\mathrm{FRA} = \frac{M_{\mathrm{ROOF}}}{\rho_{15} \times \mathrm{CTL}} \tag{6}$$

where:

M_{ROOF} = the mass of the roof in kg, from the strapping table or tank vendor data.
ρ_{15} = the density of the product at 15 °C. In this paper the density is considered constant during the opening and closing readings of the tank.
CTL = correction for temperature of the liquid. It corrects for a volume at an observed temperature to a standard temperature. This is the same as VCF. The equation can be found in API MPMS 11.1, [2].

3.1.2 Volume correction factor (VCF or CTL)

The API method of determining the VCF or CTL is by using tables published in the API MPMS Chapter 11.1:

Determination of volume correction factors. Table 54B contains volume correction factors for the product analyzed with densities in kg/m^3 and tank liquid temperature in °C. The volume correction factor in the table that corresponds to these two values is used as the CTL in the calculation of the floating roof adjustment and gross standard volume. The CTL can also be calculated by eq. (7):

$$CTL = e^{[-\alpha_T \times (T_L-15) \times (1+0.8 \times \alpha_T \times (T_L-15))]} \tag{7}$$

where:

α_T = thermal expansion coefficient of the liquid (1/°C). It can be determined by eq. (8):

$$\alpha_T = \frac{K_0}{\rho_{15}^2} + \frac{K_1}{\rho_{15}} + K_2 \tag{8}$$

where:

K_0, K_1, K_2 = constants, depending on the type of product. In this paper the following values are used: K_0 = 186.969 6, K_1 = 0.486 2, K_2 = 0.

3.1.3 Gross standard volume (GSV)

The GSV (in liters) can be calculated by eq. (9):

$$GSV = GOV \times CTL \tag{9}$$

3.1.4 Correction for sediment and water (CSW)

The CSW can be calculated by eq. (10):

$$CSW = \frac{(100 - S\&W\ \%)}{100} \tag{10}$$

where:

S&W % = percentage of sediment and water in the liquid.

3.1.5 Net standard volume (NSV)

The NSV (in liters) can be calculated by eq. (11):

$$NSV = GSV \times CSW \tag{11}$$

The NSV represents the total volume of all liquid, excluding sediment and water and free water, corrected by the appropriate volume correction factor (CTL) for the observed temperature to a standard temperature of 15 °C. In this paper, CSW is assumed to be one based on the type of product analyzed. Therefore, NSV is equal to GSV.

3.2 Calculation procedures to determine the transferred volume (TV)

The quantity to be determined is the transferred volume (TV) of the tank. This transferred volume (in liters) or the displacement volume can be calculated by eq. (12) or eq. (13):

$$TV = NSV_{CL} - NSV_{OP} \tag{12}$$

$$TV = GSV_{CL} - GSV_{OP} \tag{13}$$

where:

CL = closing reading.
OP = opening reading.

The values of NSV and GSV may be calculated through equations eq. (9) or eq. (11) applied to closing or opening reading.

3.3 Uncertainty analysis techniques

Whenever a measurement of volume (or displaced volume) is made, the value obtained is simply the best estimate that can be obtained of the volume or quantity. In practice, the volume or quantity could be slightly greater or less than this value and the uncertainty characterizes the range of values within which the volume or quantity is expected to lie with a specified confidence level.

The *Guide to the Expression of Uncertainty in Measurement* (GUM) [3], is the authoritative document on all aspects the evaluation of uncertainty and should be referred to in any situation where other international standards do not provide enough depth or detail. In particular, Annex F to the GUM gives guidance on evaluating uncertainty components.

The implementation of the GUM starts with the analysis of the mathematical model of measurement (the measurement equation itself) that includes all contributions relevant to the test or calibration. The overall uncertainty is then estimated by the law of uncertainty propagation, following the identification and quantification of individual uncertainty of influence factors.

The Joint Committee for Guides in Metrology (JCGM) recently published a supplement to the GUM presenting a Monte Carlo method for uncertainty analysis [4]. This is an alternative method that was not covered when the GUM was first launched in 1993. With the computing power available nowadays, even in personal computers, it has become feasible to perform an uncertainty analysis directly by a Monte Carlo simulation for a result that is a function of multiple variables. This method is not limited to simple expressions but can also be used for highly complicated experimental data reduction equations or for numerical solutions of advanced simulation equations. Another important utility of the Monte Carlo simulation is the ability to validate the calculations performed by the method of the GUM. The law of uncertainty propagation proposed by the GUM can operate fully in most cases. However, it is complex to quantify the effects of the approaches involved, such as non-linearity of the mathematical model, inapplicability of the Welch-Satterthwaite formula and the non-normal distribution of the output quantity.

The concept of propagation of distributions used by the Monte Carlo simulation consists primarily of assigning appropriate probability distributions (as uniform, normal, triangular, etc.) for uncertainty sources of the test or calibration. These distributions are then propagated through the measurement equation and the mean and standard deviation of the results are estimated. The uncertainty of the test or calibration is calculated according to a certain desired level of confidence (typically 95.45 %), after a large number of repetitions performed [4].

3.4 Procedure for evaluating and expressing uncertainty

The procedure used here for evaluating and expressing uncertainty is the procedure recommended in the GUM.

1. The assumptions inherent in uncertainty analysis include that the spurious errors have been eliminated. Errors of this type should not be included as part of the uncertainty of the measurement. Spurious errors can reveal that the measurement process is not under control. An example of a spurious error is a valve that should be closed and is leaking during the transferred volume of the tank.
2. Establishing the mathematical function (the relationship) expressed between the measurand, y, and the input quantities, x_i, on which y depends: $y = f(x_1, x_2, \ldots, x_M)$, where M is the number of input quantities. The function, f, shall contain all input quantities, including all corrections and correction factors, that can contribute significantly to the uncertainty of the measurement result.
3. Determining the input quantities x_i.
4. Estimating the standard uncertainty $u(x_i)$ of each input estimate x_i. This can be done either as a Type A evaluation of standard uncertainty (for an input estimate obtained from a statistical analysis of observations), or as a Type B evaluation of standard uncertainty (for an input estimate obtained by other means), in accordance with the GUM. If the uncertainty of the input quantity x_i is given as an expand uncertainty, $U(x_i)$, this expanded uncertainty may be converted to a standard uncertainty by dividing with the coverage factor, k, eq. (14):

$$u(x_i) = \frac{U(x_i)}{k} \tag{14}$$

For example, if $U(x_i)$ is given at a 95.45 % confidence level, and a normal probability distribution is used, $k = 2$. If the confidence level is 100 %, and a rectangular probability distribution is used, $k = 1.73$.

5. Evaluating the covariance in association with input estimates that are correlated, in accordance with the GUM. For two input quantities x_i and x_j, the covariance is given, by eq. (15), as:

$$u(x_i, x_j) = u(x_i) \times u(x_j) \times r(x_i, x_j) \text{ with } (i \neq j) \tag{15}$$

where the degree of correlation is characterized by $r(x_i,x_j)$, the correlation coefficient between x_i and x_j (with $i \neq j$ and abs$(r(x_i,x_j)) \leq 1$.
The value of $r(x_i,x_j)$ may be determined by engineering judgment or based on simulations or experiments. The value is a number between –1 and +1,where $r(x_i,x_j) = 0$ represents uncorrelated quantities, and abs$(r(x_i,x_j)) = 1$ represents fully correlated quantities. In this paper it is assumed that $r(x_i,x_j) = 1$ for all correlated input quantities.

6. The result of the measurement is to be calculated in accordance with the GUM, i.e. the estimate y is to be calculated from the functional relationship, f, using for the input quantities the estimates x_i obtained in step 3.
7. The combined standard uncertainty, $u_c(y)$, of the measurement result (output estimate), y, is evaluated from the standard uncertainties and the covariances associated with the input estimates, in accordance with the GUM. $u_c(y)$ is given as the positive square root of the combined variance u_c^2, given by eq. (16):

$$u_c^2(y) = \sum_{i=1}^{N} \left(\frac{\partial f}{\partial x_i}\right)^2 u^2(x_i) + 2\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \frac{\partial f}{\partial x_i}\frac{\partial f}{\partial x_j} u(x_i x_j) \tag{16}$$

where N is the number of input estimates x_i, $i = 1, \ldots, N$.

8. The expanded uncertainty U is determined by multiplying the combined standard uncertainty, $u_c(y)$, by the coverage factor, k, according eq. (17):

$$U = k \times u_c(y) \tag{17}$$

on the basis of the level of confidence required for the uncertainty. Normally, the confidence level adopted is 95.45 % with $k = 2$ for a normal distribution and for effective degrees of freedom of $u_c(y)$ that has a significant size.

9. Finally, the result of the measurement (the output estimate), y, is to be reported, together with its expanded uncertainty, U and its confidence level.

4 Modeling of the transferred volume

As shown above, the calculation process for determining the transferred volume from the measured values and the strapping table information is quite demanding, and requires the use of multiple variables. Many of the variables used in the calculations have uncertainties associated with them. For example, each measuring instrument has an uncertainty. Determining the uncertainty of the transferred volume requires an in-depth analysis of the mathematical model for tank volume measurement. Based on the equations in Section 3, a model can be built for the transferred volume, according eq. (12) or eq. (13). These equations may be built into a spreadsheet to calculate the uncertainty of transferred volume. The partial derivatives of eq. (16) may be calculated numerically by calculating the effect of a small change in the input variable, x_i, on the output value, y.

The construction of the model includes:

- Choosing an existing representative tank to be a base example for the uncertainty analysis. The tank's data can be found in Table 1.

Table 1: Tank strapping data

Tank name	AAA
Tank type	Upright cylindrical with floating roof
Storage product	Diesel
Tank diameter (nominal)	44 m
Capacity (nominal)	25 000 000 L
Tank height (nominal)	16.5 m
Reference gauge height	18.561 m
Tank strapping/reference density	840 kg/m³
Safe fill height	14.830 m
Tank critical zone range	0.93 to 2.18 m
Tank strapping/reference steel temperature	15 °C
Roof's mass	97 200 kg

Table 2: Strapping table parameters used to calculate the transferred volumes and their uncertainties

Tank level (L_M) - MOH		Tank level (L_M) - MLT		Tank level (L_M) - LOL	
Parameter	Value	Parameter	Value	Parameter	Value
L_M (m)	14.702	L_M (m)	7.354	L_M (m)	2.306
V_{TTB} (L)	22 139 304	V_{TTB} (L)	11 012 302	V_{TTB} (L)	3 375 432
V_{TTA} (L)	22 154 456	V_{TTA} (L)	11 027 430	V_{TTA} (L)	3 390 543
L_{TTA} (m)	14.710	L_{TTA} (m)	7.360	L_{TTA} (m)	2.310
L_{TTB} (m)	14.700	L_{TTB} (m)	7.350	L_{TTB} (m)	2.300

- Developing the tank's and uncertainty's equations. The equations can be found in Section 3.
- Determining the strapping table information and modeling constants. The strapping table information can be found in the Table 2. The constants were described in this text.
- Determining the values of the input quantities and the associated uncertainty values for each input quantity. This can be found in Table 3.

For the purposes of this paper, an existing representative tank (Tank AAA) has been chosen as the base example for the uncertainty analysis process. Tank "AAA" has the following construction characteristics:

- Tank type: upright cylindrical tank.
- Roof type: floating roof.
- Level measurement: automatic gauging.
- Temperature measurement: automatic multiple spot average thermometers.
- Strapping reference temperature: 15 °C.

Table 1 outlines some tank strapping data obtained from its strapping table.

Table 2 outlines the specific levels and volumes from the strapping table to be used in the calculation process. With this information, the transferred volumes and their uncertainties are calculated for two base cases, as described below.

- Case 1: Transferred volume from the maximum operation fill height (MOH) to the mid-level of the tank (MLT).
- Case 2: Transferred volume from the MOH to the lowest operation level (LOL) of the tank.

Table 3 outlines the values of the variables to be used in the calculation of the transferred volumes and their associated uncertainties. All the uncertainties presented in this table are expanded uncertainties, $U(x_i)$, evaluated as Type B, and are given with their coverage factor k.

The level measurement uncertainty was estimated based on [5]. The strapping table volume measurement uncertainty was estimated based on [6]. The tank liquid temperature uncertainty was estimated to be $U = \pm 1.0$ °C (rectangular distribution) considering that there is a temperature gradient in the tank, which was not measured by the multiple point thermometers. This value is the double of the value presented [7], when verifying as a system (in the field) the multiple point thermometers against the portable thermometer ($U = \pm 0.5$ °C). This verification is realized when the tank is nearly full, with all temperature elements submerged. The ambient (air) temperature uncertainty was obtained [1], and the tank liquid average density uncertainty was obtained [8].The roof's mass uncertainty was estimated to be $U = \pm 1.0$ % of its mass considering a rectangular distribution. The uncertainty of the correlation utilized

Table 3: Input quantities

Quantity	Value	Estimated uncertainty $U(x_i)$	Probability distribution	Coverage factor (k)	Measurands correlated
L_M - MOH	14.702 m	±4 mm	Rectangular	1.73	C
L_M - MLT	7.354 m	±4 mm	Rectangular	1.73	C
L_M - LOL	2.306 m	±4 mm	Rectangular	1.73	C
V_{TTB} - MOH	22 139 304 L	±0.06 %	Normal	2	C
V_{TTA} - MOH	22 154 456 L	±0.06 %	Normal	2	C
V_{TTB} - MLT	11 012 302 L	±0.08 %	Normal	2	C
V_{TTA} - MLT	11 027 430 L	±0.08 %	Normal	2	C
V_{TTB} - LOL	3 375 432 L	±0.11 %	Normal	2	C
V_{TTA} - LOL	3 390 543 L	±0.11 %	Normal	2	C
T_L - MOH	40.0 °C	±1.0 °C	Rectangular	1.73	C*
T_L - MLT	38.0 °C	±1.0 °C	Rectangular	1.73	C*
T_L - LOL	38.0 °C	±1.0 °C	Rectangular	1.73	C*
Ta - MOH	45 °C	±2.5 °C	Rectangular	1.73	C
Ta - MLT	35 °C	±2.5 °C	Rectangular	1.73	C
Ta - LOL	35 °C	±2.5 °C	Rectangular	1.73	C
ρ_{15}	840.0 kg/m³	±1.5 kg/m³	Rectangular	1.73	N/A
M_{ROOF}	97 200 kg	±1 %	Rectangular	1.73	N/A
CTL - MOH	0.978 8	±0.05 %	Normal	2	C
CTL - MLT	0.980 5	±0.05 %	Normal	2	C
CTL - LOL	0.980 5	±0.05 %	Normal	2	C
α	0.000 011 2 (1/°C)	±10 %	Rectangular	1.73	N/A

*Just the uncertainty of the instrument is considered correlated.

to calculate the CTL was obtained [2]. Finally, the uncertainty of the linear coefficient of expansion of the tank shell was estimated to be U = ±10 % of the value reported considering a rectangular distribution. The last column of Table 3 presents with the index "C" the quantities that are considered correlated.

5 Results

The primary results of the transferred volumes and their uncertainties are presented in Table 4 characterizing the "base cases" for the two cases. The input data and uncertainty values of each variable are those shown in Tables 2 and 3.

The two base cases considered here for analysis in this paper are:

a) Case 1: Transferred volume from the MOH to the MLT.

b) Case 2: Transferred volume from the MOH to the LOL of the tank.

As can be seen in Table 4, case 2 presents the lowest uncertainty, U = ±0.13 %. This means that we shall transfer as great a quantity of liquid as possible from the tank, which is, from highest level (MOH) to the lowest level (LOL). Also, the range of uncertainty is from ±0.13 % to ±0.21 %. Most of this range is inside the acceptable limit for custody transfer [9], which is the metering regulation of the United Kingdom. This regulation establishes a typical uncertainty in mass flow rate measurement of ±0.25 % for custody transfer systems. The range of uncertainty from ±0.13 % to ±0.21 % was achieved due to the addition of correlated terms in the uncertainty analysis model. Otherwise,

Table 4: Transferred volumes and associated uncertainties

Base cases	Transferred volume (TV)	Uncertainty (U) (k = 2)	Uncertainty (U) (k = 2)
Case 1	10 876 065 L	±22 496 L	±0.21 %
Case 2	18 364 735 L	±24 684 L	±0.13 %

Table 5: Comparison between the GUM and Monte Carlo methods

Base cases	Transferred volume (TV)	GUM uncertainty (U) (k = 2)	Monte Carlo uncertainty (U) (k = 2)
Case 1	10 876 065 L	±0.21 %	±0.21 %
Case 2	18 364 735 L	±0.13 %	±0.13 %

using just the first term of eq. (16), a value of ±0.16 % or ±0.30 % is achieved for cases 1 and 2, respectively. This shows the importance of considering correlated terms during the volume transfer processes.

The major parameter that contributes to the final uncertainty of the transferred volumes of cases 1 and 2 is the uncertainty of the temperature of the liquid. If we assume that the uncertainty of the temperature of the liquid is now reduced to the uncertainty of the thermometers, ±0.5 °C, the uncertainty of the transferred volumes (U) will be around ±0.10 % for both cases. The reduction in the final uncertainty of case 1 is due to two factors: (a) the reduction of total uncertainty of the liquid temperature from ±1.0 °C to ±0.5 °C, thereby reducing the first term of eq. (16) and, (b) a higher percentage contribution of the second term of eq. (16) over the final uncertainty of the transferred volume when compared with case 2. This higher contribution is due to the higher quantity of liquid remaining in the tank (MLT) after the transfer. This contribution is almost 1.5 times higher than case 2. For case 2, the principal factor for the reduction of the uncertainty is due to the reduction of the first term of eq. (16) as previously discussed.

These results show us that if we decrease the uncertainty of the liquid temperature to the level of the uncertainty of the temperature probe, the uncertainty of the transferred volume will decrease and will be constant and not a function of the transferred volume. This sensitivity analysis is presented in the next section where the temperature uncertainty is reduced to ±0.5 °C. The uncertainty reduction can be achieved through the installation of more probes around the tank, and therefore decreasing its temperature gradient. So, special attention shall be given to the liquid temperature measurement, mainly in an attempt to reduce the influence of the temperature gradient in the liquid inside the tank.

Table 5 presents the comparison results of the uncertainties for the base cases between the GUM method and the Monte Carlo method [4]. As can be seen both methods present the same results, which permits us to validate the GUM method used in this paper. Also, [10] presents an experimental comparison between the transferred volume that has passed through a turbine meter and the volume obtained using an upright cylindrical tank for a given batch. The difference between turbine meter and tank gauge readings has been 0.05 %, considering the tank as the "true value". This difference is smaller than the smallest uncertainty of Table 4, or in order words, the normalized error is smaller than 1. So, this comparison may also be used to validate the uncertainty calculations presented here.

Table 6: Sensitivity analysis of case 1

Quantity	Value	Estimated uncertainty ($U(x_i)$)	Transferred volume (TV)	Uncertainty (U) (k = 2)
L_M - MOH	14.702 m	±2 mm	10 876 065 L	±0.21 %
L_M - MLT	7.354 m	±2 mm		
V_{TTB} - MOH	22 139 304 L	±0.03 %	10 876 065 L	±0.20 %
V_{TTA} - MOH	22 154 456 L	±0.03 %		
V_{TTB} - MLT	11 012 302 L	±0.04 %		
V_{TTA} - MLT	11 027 430 L	±0.04 %		
T_L - MOH	40.0 °C	±0.5 °C	10 876 065 L	±0.08 %
T_L - MLT	38.0 °C	±0.5 °C		
Ta - MOH	45 °C	±1.25 °C	10 876 065 L	±0.21 %
Ta - MLT	35 °C	±1.25 °C		
ρ_{15}	840.0 kg/m³	±0.75 kg/m³	10 876 065 L	±0.21 %
M_{ROOF}	97,200 kg	±0.5 %	10 876 065 L	±0.21 %
CTL - MOH	0.978 8	±0.025 %	10 876 065 L	±0.20 %
CTL - MLT	0.980 5	±0.025 %		
α	0.000 011 2 (1/°C)	±5 %	10 876 065 L	±0.21 %

Table 7: Sensitivity analysis of case 2

Quantity	Value	Estimated uncertainty ($U(x_i)$)	Transferred volume (TV)	Uncertainty (U) (k = 2)
L_M - MOH	14.702 m	±2 mm	18 364 735 L	±0.13 %
L_M - LOL	2.306 m	±2 mm		
V_{TTB} - MOH	22 139 304 L	±0.03 %	18 364 735 L	±0.13 %
V_{TTA} - MOH	22 154 456 L	±0.03 %		
V_{TTB} - LOL	3 375 432 L	±0.06 %		
V_{TTA} - LOL	3 390 543 L	±0.06 %		
T_L - MOH	40.0 °C	±0.5 °C	18 364 735 L	±0.09 %
T_L - LOL	38.0 °C	±0.5 °C		
Ta - MOH	45 °C	±1.25 °C	18 364 735 L	±0.13 %
Ta - LOL	35 °C	±1.25 °C		
ρ_{15}	840.0 kg/m^3	±0.75 kg/m^3	18 364 735 L	±0.13 %
M_{ROOF}	97,200 kg	±0.5 %	18 364 735 L	±0.13 %
CTL - MOH	0.978 8	±0.025 %	18 364 735 L	±0.13 %
CTL - LOL	0.980 5	±0.025 %		
α	0.000 011 2 (1/°C)	±5 %	18 364 735 L	±0.13 %

5.1 Sensitivity analysis of the uncertainty of the transferred volume

Presented here are the results of a sensitivity analysis of the uncertainty of the transferred volumes for cases 1 and 2. For each case, the uncertainty of each quantity of Table 3 will be halved while keeping constant the other quantities, and therefore, analyzing the final result of the uncertainty of transferred volume.

This analysis will show the influence and relevance of each measurement variable on the overall uncertainty of the transferred volume, to provide to the tank operators some insight in determining the most important variables in the process of transferring volume by a tank.

Table 6 presents the results of the sensitivity analysis for case 1. Each line of Table 6 presents the quantity at which the uncertainty was halved with the others kept constant. As can be seen, the only quantity that impacted the final uncertainty of transferred volume was the liquid temperature. The other quantities did not impact the final result of the uncertainty of transferred volume.

Table 7 presents the results of the sensitivity analysis for case 2. Each line of Table 7 presents the quantity at which the uncertainty was halved with the others kept constant. As can be seen again, the only quantity that impacted the final uncertainty of transferred volume was the liquid temperature. The others did not impact the final result of the uncertainty of transferred volume.

So, with the results of Tables 6 and 7, we can conclude that the uncertainty values presented in Table 3 are more than sufficient to meet the uncertainty levels required for custody transfer measurements.

6 Conclusions and recommendations

This paper has discussed a number of issues associated with the uncertainty of the transferred volume in upright cylindrical tanks with floating roofs. It included the analysis and discussion of the process of determining tank volumes and the overall uncertainty of the transferred volume of one particular tank used to measure diesel fuel. It also included a discussion of the influence and relevance of each measurement variable on the overall uncertainty of the transferred volume, to provide the tank operators with some insight in determining the most important variables in the process of transferring volume by a tank.

Table 3 outlines the typical input quantities of the variables to be used in the calculation of the transferred volumes and their typical associated uncertainties. For the liquid temperature it has been assumed that there is gradient that was not measured by the multiple point thermometers. So, an uncertainty of U = ±1.0 °C was estimated for liquid temperature measurement. This uncertainty is two times larger than the accuracy specified in [7] to calibrate the multiple point thermometers. With the typical values of Table 3, it is expected to have an uncertainty range of the transferred volumes from ±0.13 % to ±0.21 % for the tank levels analyzed in this paper. The smallest uncertainty was obtained for case 2, where there was the most quantity of liquid transferred. So, it is recommended to transfer the greatest quantity of liquid possible from the tank to have the smallest uncertainty of transferred volume, here, ±0.13 %. This recommendation is only valid if there is suspicion that the liquid temperature gradient cannot be corrected by temperature probes.

Tables 6 and 7 outline the results of the sensitivity analysis of each measurement variable on the overall uncertainty of the transferred volume. The uncertainty of each variable has been reduced by half to see the variation of the final uncertainty of the transferred volume. For both cases analyzed, the only variable that has impacted the final uncertainty of the transferred volume was the liquid temperature. These results show that if we decrease the uncertainty of liquid temperature to the level of the uncertainty of the temperature probe, the uncertainty of transferred volume will decrease more than the base cases analyzed. In both cases the uncertainties were the same and were not a function of the transferred volume. A value of around ±0.10 % was obtained; so, special attention must be given to the liquid temperature measurement, mainly in an attempt to reduce the temperature gradient of the liquid inside the tank. For each tank it is recommended to evaluate this temperature gradient to plan the necessity of the installation of more probes around the tank, and therefore reduce this temperature gradient. It is useful to remember that if there is a temperature gradient larger than that mentioned in this paper, a larger uncertainty than calculated here will be achieved.

Additional calculations were made with a smaller tank used to measure kerosene. With the uncertainty values of Table 3, values of ±0.17 % and ±0.30 % were achieved for the uncertainty of the transferred volume of cases 1 and 2, respectively. With the reduction of the uncertainty of the liquid temperature to the level of the uncertainty of the temperature probe, an uncertainty of ±0.10 % was also achieved for both cases. The same methodology of section 3 above has been applied to these calculations.

Finally, with the uncertainty levels achieved in this paper, the use of a tank gauge may be proposed to the legal metrology authorities as a field standard to verify dynamic metering systems of accuracy class 0.3, 0.5 and so on, on periodic verification in the field. It is well known that there are many dynamic metering systems in the field, operating without a prover beside them [10]. Normally, these dynamic metering systems are linked together with existing tanks in the field that are already calibrated, according to the frequency required by international standards. ■

7 References

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CONFIDENCE IN MEASUREMENTS

A way to stimulate public awareness

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Introduction

In the framework of ensuring adequate consumer protection, legal metrology plays a role in facilitating both domestic and international trade by providing assurance of correct measurements for the trade of goods and services.

In domestic trade facilitation, the consumer needs to have confidence in measurements and in the use of the measuring instruments that produce the measurements which are subsequently used to determine the quantity of goods and services, and their cost.

In international trade facilitation, every economy needs assurance of the accuracy of measurement results for its exported and imported goods, as well as ensuring that no losses are encountered as a result of inaccurate or non-conforming measurement results.

Legal metrology activities in Indonesia are governed by the *Act on Legal Metrology*, aimed at protecting public interest by ensuring the truthfulness of measurement processes and legal confidence in the use of units, standards, methods of measurement, and measuring instruments.

As a part of trade development, one element noted in the national policy on long-term and mid-term national development is that economic growth must be accompanied by strong domestic trade in order to maintain the stability of prices and domestic logistics, the competitiveness of domestic products, market trust, and fair trade.

It was considered that legal metrology is an effective tool for market surveillance, and should be used as a focus for strategies aimed at establishing fair trade, both for consumers and suppliers as market players, with the objective of boosting the growth of the domestic economy.

This target cannot be met unless both consumers and suppliers have the necessary level of awareness in creating trust through legal metrological control.

The development of legal metrology and the growth of national measurements

Economic growth and global measurements paved the way for the development of both national trade and an appropriate national legal metrology system during the period 2005–2009. Increasing oil prices, the global crisis, and the rapid growth of science and technology (in particular in the field of measurement) had much influence on national metrological performance in providing consumer protection and trade facilitation.

In an effort to make the most of every potential opportunity, the future Indonesian national legal metrology system will be as follows:

1 Legal metrology in the trade sector will play a valuable role, by enhancing a creative economy as a booster for innovation in metrology, standardization, and conformance in “one standard – one test – accepted everywhere”. In this way, legal metrology will significantly contribute to enhancing the Gross National Product (GNP) by: 1) the integration of legal metrology with standardization and conformity assessment into a national metrology infrastructure; 2) establishing a strong mutual partnership and good communication between metrology, standardization, and conformity assessment in particular supporting the trade sector; 3) encouraging the use and export of domestic produced measuring instruments from small and medium-sized enterprises (SMEs) and manufacturers; 4) establishing good coordination between central and local government in improving legal metrology, supervising SMEs, and enhancing public awareness; and 5) increasing the application of management and technology of measurement, in particular in a networked system.

2 Technology based on information technology is more commonly used in boosting the efficiency of economic activities for individuals and groups such as online public services in the metrological field.

3 Legislation in metrology and an increase in law enforcement are in line with the rapid economic growth in supporting business existence, business climate, and enhancing the credibility of economic policies.

4 Businesses in the domestic market are more comfortable in facing the free trade area as a consequence of the global market.

5 The rapid developments in measuring instrument technology (in particular instruments used for trade) serve to improve the accuracy of and confidence in measurement results.

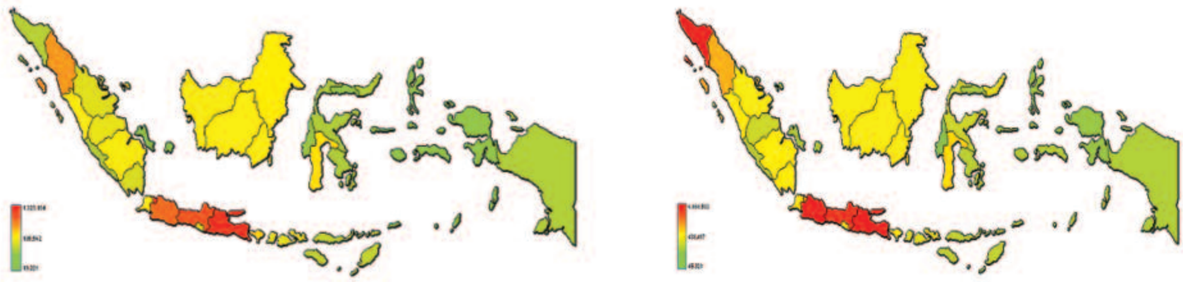


Fig. 1 Map of electrical energy meter dispersion (left) and water meter dispersion (right). Source: National Center of Statistics

6 Legal metrology provides a positive contribution by creating employment, and enhances a country's environment, culture and stability.

Metrological assurance in using measuring instruments (in particular in trade) has become important in supporting the growth of the economy in general. Indirectly, the economic impact of measurement processes, in particular related to trade activities, has significantly affected the GDP of each region in Indonesia, both in the provinces and in urban areas.

A study[1] in Australia estimated that the total volume of measurement-related trade transactions in the period 1990–1991 was about AUD 322 billion or 60 % of GNP. A study in the USA in 1996 had estimated that the total volume of measurement-related trade transactions was about USD 4 130 billion or 54.5 % of GNP. In Indonesia, a rough estimation of the same figure amounted to ± 52.6 % of GNP[2].

As can be seen from the national data provided, the total number of measuring instruments used for trade throughout Indonesia in 2011 was approximately 68.6 million units, consisting of:

- ± 44.7 million electrical energy meters (see Fig. 1, left),
- ± 11.5 million water meters (see Fig. 1, right), and
- ± 12.4 million other instruments such as non-automatic weighing instruments, taximeters, gas meters, fuel dispensers, etc.

[1] Benefit of Legal Metrology for the Economy and Society, John Birch A.M, CIML Honorary Member

[2] Source form National Center of Statistics

However, the resources available to local governments to carry out metrological activities are limited. A survey conducted by the Japan International Cooperation Agency (JICA) in 2006 shows that there is a change in the function of the regions as a result of regional autonomy, resource constraints, and equipment limitations.

A review of the legal metrology system by the Center for Domestic Trade, Research and Development Board of the Ministry of Trade in 2007 found that one obstacle is the discrepancy in local government and institutional resources between the area of Java Island (e.g. Jakarta, East Java, West Java) and the rest of Indonesia, both in terms of human resources and technical infrastructure. A comparison of performance shows that on average, each regional legal metrology authority has approximately 18 inspectors serving 9.13 Districts or City Districts, with around 1200 villages and a population of more than 4 million. In the whole country, some 230 million people must be protected.

The scope of consumer protection activities, especially in the field of legal metrology, is widely associated with the large number of consumers who must be protected, the broad range of legal metrology activities, and the broad variety of supervised prepackaged products and measuring instruments.

Meanwhile, activities relating to consumer protection in the field of legal metrology consist of verification of measuring instruments, surveillance of measuring instruments in use, of prepackaged products and of the use of SI units, law enforcement, and also the handling of consumer complaints.

Considering this very broad scope and the increased importance of consumer protection in the field of legal metrology, there must be coordination between legal metrology stakeholders so that the implementation of consumer protection can proceed more dynamically and more efficiently.

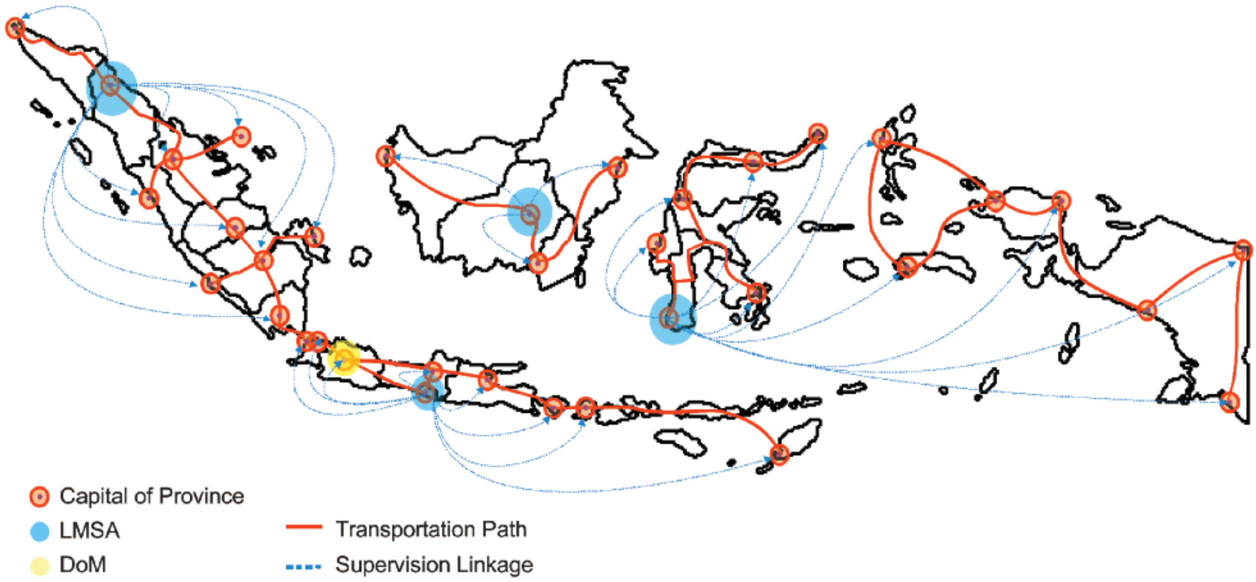


Fig. 2 Network of the Regional Legal Metrology Standardization Agencies

Strategy to increase public confidence in measurements

Public confidence in measurements must be increased so that the impact of legal metrology developments can be directly felt by the whole community. The way to achieve this is by formulating strategic steps, which requires a change of mindset based on the spirit of transformation.

The most fundamental change of mindset is in understanding that the development of legal metrology as a tool to increase public confidence in measurements requires a joint collaboration between central government, local government, private enterprise and the community (in the spirit of mutual recognition and acceptance). It should also be understood that ultimately, development will depend on the role of the public/community and the private sector.

This understanding should be reflected in government policy so that existing regulations are used to actively engage the public and private sectors to promote the establishment of maximum confidence in measurements. The role of government is to develop policies to build regulations that stimulate the community, users, and those engaged in trade. This stimulus may take the form of metrological service policy, fees for verification services, competitiveness of domestic products, import-export of measuring instruments, etc. The objective of law enforcement is to ensure the smooth operation of these policies by reducing law-breaking practices. Furthermore, central and local government should establish, to the greatest extent possible, their legal metrology activities within the framework of a national traceability system.

To facilitate local government efforts to increase confidence in measurements, Legal Metrology Standardization Agencies (LMSAs) were formed in 2005 for four regions, thus facilitating the technical assistance offered by local government which can now be provided directly, effectively and efficiently.

The LMSAs are the central government facilitators in accelerating the improvement of metrological services in the regions by making available human resources for metrological activities, testing equipment, and technical assistance to the Regional Verification Offices. The LMSAs also play a role in maintaining the traceability of the measurement standards used in legal metrology so that the accuracy of the measurement results is maintained throughout the country. Thus, the regions are coordinated and are able to work efficiently by means of an infrastructure which is maintained and supervised by central government.

The fundamental principle of ensuring confidence in measurements has led to the use of regulated measuring instruments (in particular those used for trade), net content of pre-packed products, and to the use of SI units in accordance with statutory regulations.

The successful way to provide confidence in measurements is determined as follows:

1 The use of measuring instruments is analyzed from the aspect of:

 a Ownership of the type approval certificate,
 b Conformity to type,
 c Suitability and correct use,
 d Accuracy,
 e Validity of the measuring instrument (marking and sealing).

2 The circulation of pre-packed products on the market is gauged by labeling the quantity of product and by checking the actual quantity.

3 The use of SI units is achieved by indicating the unit symbols in accordance with statutory regulations.

However, these measures are insufficient to describe the overall and holistic measures. A number of more institutional measures are needed, as indicated below:

1 Governments should ensure that all the implementing agencies responsible in the field of legal metrology act in accordance with statutory regulations.

2 Governments should ensure that the inspectors or verification officers have the necessary competence in accordance with specified requirements.

3 Governments should ensure that all standards and equipment used for metrological services are traceable nationally.

4 Government shall adopt appropriate legislation to provide legal assurance.

5 Government encourages the creation of public awareness so that members of the public understand their rights and obligations in areas covered by legal metrology.

The role of the government is to provide the necessary tools to ensure confidence in measurement results. This requires that the government implements the necessary strategies to promote metrology issues, to develop adequate metrological infrastructures, and to support research in the field of metrology in order to protect the public and businesses against measurement-related fraud. Metrological activities for socio-economic development require a comprehensive and coherent metrology policy which takes into account issues related to consumers, trade, public safety and security. In the development of its national metrology system, the government should ensure transparency for all stakeholders.

Fig. 3 Fundamental principle of confidence in measurements

Metrological award as a National Flagship

The National Flagship is designed to build public awareness, notably concerning the importance of the integrity of the measurement results. The Flagship is intended to aid fair measurement as an added value that supports a stronger economy, improves the image of the Indonesian people, and improves national metrological performance, one of the indicators for which is the use of measuring instruments in accordance with applicable regulations.

The Flagship consists of launching the Fair Market award, the Fair City award and the Metrological Prime Award, in order to increase confidence in measurements and to protect against the impact of inaccurate measurements and trade activities that are against the interests of consumers.

The objectives of the Flagship are as follows:

1 To create fair markets by promoting interest in legal metrology.

2 To enhance the image of traditional markets for the public, especially in providing a basis for the accuracy of measurement results in trade transactions.

3 To increase the understanding and awareness of users of measuring instruments for trade concerning the importance of using correct and valid measuring instruments in building consumer and market trust.

4 To enhance the image of local government in attracting prospective investment through providing confidence in measurements, fair trade, and transparency.

5 To strengthen supervision and law enforcement, which includes the public as a subject of supervision.

6 To enhance the role and performance of local governments in conducting legal metrology in the region.

7 To perform public communication about the meaning, objective and importance of legal metrology.

The expected benefits of the Flagship are:

- to boost regional economic growth as a result of increased trade transactions,
- to increase the regional added value and image,
- to increase public confidence in market transactions, and
- to ensure adequate legal metrological protection.

The expected outcomes of the implementation of the Flagship are as follows:

1 To minimize losses incurred as a result of inaccurate measurements in trade transactions both for consumers and sellers.

2 To reduce losses incurred in both domestic and international trade transactions (exports and imports).

3 To enhance the image and competitiveness of traditional markets for the community so that SME businesses may benefit from better market opportunities.

4 To increase national metrological performance in order to provide confidence in measurements.

Overview of the Fair Traditional Market

The launching of the Fair Traditional Market is an attempt to improve the image of traditional markets, particularly in urban areas that cannot compete with modern markets. In addition, the lack of understanding of traditional marketing managers and users of measuring instruments as to the importance of legal metrology forms the background to this activity. Fraud often occurs in trade transactions in the traditional markets; ultimately, therefore, consumers will naturally turn to modern markets.

However, this is not necessarily beneficial for small communities, whose regional economic growth may suffer as a consequence. This is because the number of traditional markets in Indonesia is estimated at more than 13 450, which sustain approximately 12 or 13 million trading companies each with the capacity to hire 2–3 sales people (APKASI, 2003). From a regional point of view, this is an advantage and adds value to economic growth.

There are several activities in support of the Fair Traditional Market Award:

1 To gather data and information on measuring instruments in each traditional market to ensure they are all correctly identified (in particular nonautomatic weighing instruments).
2 To increase verification and re-verification service activities.
3 To provide technical assistance to users of measuring instruments and to supervisors of traditional markets, thus providing an understanding of the importance of ensuring reliable measurement results in trade transactions.

Overview of the Fair City Award

The Fair City Award was launched in an effort to improve the image of cities or regions and to prepare them for the era of global trade, notably the free flow of goods, services and investments. Accurate measurement results create fair competition and foster a sense of mutual recognition and acceptance in trade.

There are several activities in support of the Fair City Award, as follows:

- Gathering data and information on measuring instruments in each traditional market to ensure that 100 % of measuring instruments are correctly identified (in particular electrical energy meters, water meters, nonautomatic weighing instruments, fuel dispensers and taximeters).
- Performing verification and re-verification.
- Offering technical assistance to users of measuring instruments to provide an understanding of the importance of providing guarantees as to the correctness of measurement results in trade transactions.

Prime Metrological Award

The Prime Metrological Award is awarded to individuals, to a community, or to institutions who work in the field of legal metrology in recognition of their performance, ideas and participation in developing legal metrology. It is comprised as follows:

1 The award for the best Regional Verification Offices which have demonstrated a sense of responsibility in conducting legal metrology activities in their region.
2 The award for the best inspectors/verification officers who have demonstrated performance, competence and dedication in conducting legal metrology activities.
3 The award for the best traditional markets which have continuously and consistently shown proficiency in ensuring that all measuring instruments in their market fulfill the regulations.

Closing remarks

This Flagship is a strategic way to accelerate providing confidence in measurement results as part of the objective of legal metrology.

In addition, the challenges faced in organizing both domestic and international legal metrology activities often require quick, focused action, with benchmarks and a clear pattern of management.

Every level of government should accelerate the process of providing confidence in measurement results nationally, provincially and in the districts, especially in providing added value to the communities and regions. The Flagship could also be implemented with the direct participation of the community and the expected benefits of these activities will also be directly felt by the community. ■

Rifan Ardianto, Head of Section of Cooperation
Directorate of Metrology, Indonesia

Our Organization:

Directorate of Metrology
Directorate General of Standardization
and Consumer Protection
Ministry of Trade, Jalan Pasteur No.27,
Bandung 40171, Indonesia
Phone: +62 22 420 3597 – Fax: +62 22 420 7035
http://ditjenspk.kemendag.go.id

PROJECT GROUP MEETING

OIML Project Group: TC 17/SC 7/p1 *Revision of R 126 Evidential breath analysers*

14 February 2012

LNE, Paris, France

Luis Mussio, BIML

Introduction

A meeting of OIML Project Group TC 17/SC 7/p1 was held in Paris on 14 February 2012, attended by a small number of P-members. The main purpose was to explain to those SC members that had voted "no" to the most recent draft of OIML R 126 *Evidential breath analyzers* why their comments could not be taken into account, and the procedure to be followed in this case. Those attending were France, Ireland, Netherlands and Poland. Although unable to be present in Paris, NMI Australia participated in the meeting through videoconference.

Agenda

- Welcome addresses
- Introduction of participants
- General information
- Adoption of the agenda
- Introductory remarks by the BIML
- Discussion and conclusions

Background

The revision of R 126 has been ongoing since 2003. The timeline for this revision and the different actions taken are as below:

2003-10..........New project - Revision of OIML R 126 further to the periodic review conducted five years after the Recommendation was published
2004-11..........1 CD circulated
2005-05..........TC 17/SC 7 meeting
2006-04..........2 CD circulated
2007-04..........3 CD circulated
2008-05..........4 CD circulated
2008-06..........TC 17/SC 7 meeting
2008-12..........5 CD circulated
2009-09..........TC 17/SC 7 meeting
2010-06..........6 CD circulated
2011-04..........7 CD circulated
2011-08..........CIML Preliminary online ballot held
2012-02..........TC 17/SC 7/p1 meeting

In April 2011, the 7 CD was approved by TC 17/SC 7 and was submitted for CIML preliminary online ballot; it passed the ballot stage with 29 votes in favor, 5 against and 2 abstentions. However, a number of proposals or objections requiring substantial amendments of the text were made during the ballot, and for that reason the BIML sent the document back to TC 17/SC 7. These comments formed the main topic of the February Paris Project Group meeting.

Following the presentation by the convener of the history of the DR showing the different positions of the various SC members as well as an overview of the decisions from previous meetings, additional information was requested by the participants in support of the convener's technical conclusions. This information has been circulated among the participants.

After this fruitful discussion, the final conclusions are:

- The convener strongly believes that the present draft of R 126 represents an improvement compared to the current Recommendation because:
  - it introduces the possibility to implement tests with dry gases as well as with wet gases;
  - it is less technology specific; and
  - it introduces software requirements.
- The convener believes that R 126 has been exhaustively discussed at the TC 17/SC 7/p1 level; discussions notably covered those topics that gave rise to objections during the CIML ballot. Unfortunately, the convener does not envisage being able to make further modifications to the draft.

With this final conclusion in mind, and as the CIML preliminary online ballot was successful, the convener requested that the 7 CD (i.e. the DR that was submitted to CIML preliminary ballot) be put to the CIML for approval in its 47th Meeting in October 2012.

In turn, the BIML requested the CIML President to consider this possible outcome, and if accepted, to submit the DR of R 126 for approval by the CIML. This request was considered during the Presidential Council Meeting in March 2012. R 126 will therefore be submitted to the CIML in Bucharest in October this year. ■

MEETING

Presidential Council

Paris, 5–6 March 2012

Left to right:

- Mr. Stephen Patoray, BIML Director
- Dr. Philippe Richard, Switzerland
- Dr. Yukinobu Miki, Japan
- Mrs. Kong Xiaokang, P.R. China (representing Mr. Pu Changcheng)
- Pr. Roman Schwartz, Germany, CIML Second Vice-President
- Mrs. Corinne Lagauterie, France
- Mr. Cees van Mullem, The Netherlands
- Mr. Peter Mason, UK, CIML President
- Mr. Stuart Carstens, South Africa
- Dr. Grahame Harvey, Australia, CIML First Vice-President
- Mr. Alan Johnston, Canada
- Dr. Charles Ehrlich, USA

During the Presidential Council meeting, members had the opportunity to review and discuss the following key items:

- Review of the schedule and agendas for the 14th OIML Conference and 47th CIML Meeting
- Review of the 2011 accounts and discussion of the draft 2013–2016 budget
- Review of plans for infrastructure upgrades at the BIML
- Review of the BIML work program for 2012
- Review of the revision of the BIML Staff Regulations and also the Financial Regulations
- Update on liaison activities
- Consideration of possible activities for developing countries
- Review of OIML technical work and of the work of the Ad hoc Work Group on the Technical Directives

Press release

www.bipm.org

WORLD METROLOGY DAY 2012

Metrology for Safety

www.oiml.org

World Metrology Day has now become an established annual event during which more than 80 countries celebrate the impact of measurement on our daily lives, no part of which is untouched by this essential (but largely hidden) aspect of modern society.

This day was chosen in recognition of the signing of the Metre Convention in 1875, the beginning of formal international collaboration in metrology. Each year World Metrology Day is organized and celebrated jointly by the International Bureau of Weights and Measures (BIPM) and the International Organization of Legal Metrology (OIML).

The international community which ensures that measurements can be made correctly across the world endeavors to raise awareness each World Metrology Day (20 May) through a poster campaign and web site. Previous themes have included topics such as measurements for innovation, and measurements in sport, the environment, medicine and trade.

This year the chosen theme is ***Metrology for safety***, reflecting the importance of correct measurements to ensure our safety whether at work or in our leisure activities. Just like "metrology", the term "safety" covers a very wide area of topics but many people are unaware of the vital role the worldwide metrology community plays.

Our safety is crucially dependent on good metrology, for example helping ensure the reliability of the planes we fly in, the impact resistance of the cars we drive, or the correct values of the radiation dose used in therapy we might one day need.

National and regional metrological regulations based on internationally agreed technical requirements help avoid or eliminate technical barriers to trade, ensure fair trade practice, care for the environment, maintain a satisfactory healthcare system, and (last but not least) ensure our safety – a concern for all of us. Some examples where OIML International Recommendations are adopted as a basis of national legislation are tire pressure gauges, speedometers, radar equipment for the measurement of the speed of vehicles, evidential breath analyzers and automatic instruments for weighing road vehicles.

Our safety depends on the metrology community doing its job, and doing it well. Indeed accurate, reliable and internationally accepted measurements are essential in the modern world as we deal with today's grand challenges. So join us in celebrating World Metrology Day, and recognize the contribution of the intergovernmental and national organizations that work throughout the year on behalf of all the players involved in metrology for safety. ■

About the BIPM

The signing of the Metre Convention in 1875 created the BIPM and for the first time formalized international cooperation in metrology. The Metre Convention is one of the oldest and most enduring intergovernmental treaties and remains as relevant today as it did 137 years ago. The Convention established the International Bureau of Weights and Measures and laid the foundations for worldwide uniformity of measurement in all aspects of our endeavors, historically focusing on and assisting industry and trade, but today just as vital as we tackle the grand challenges of the 21st Century such as climate change, health, and energy. The BIPM undertakes scientific work at the highest level on a selected set of physical and chemical quantities. The BIPM is the hub of a worldwide network of national metrology institutes (NMIs) which continue to realize and disseminate the chain of traceability to the SI into national accredited laboratories and industry.

About the OIML

In 1955 the International Organization of Legal Metrology (OIML) was established as an Intergovernmental Treaty Organization in order to promote the global harmonization of legal metrology procedures with the Bureau International de Métrologie Légale (BIML) as the Secretariat and Headquarters of the OIML. Since that time, the OIML has developed a worldwide technical structure that provides its Members with metrological guidelines for the elaboration of national and regional requirements concerning the manufacture and use of measuring instruments for legal applications.

www.worldmetrologyday.org

OIML Systems

Basic and MAA Certificates registered 2012.01–2012.03

Information: www.oiml.org section "OIML Systems"

The OIML Basic Certificate System

The *OIML Basic Certificate System for Measuring Instruments* was introduced in 1991 to facilitate administrative procedures and lower the costs associated with the international trade of measuring instruments subject to legal requirements. The System, which was initially called "OIML Certificate System", is now called the "OIML Basic Certificate System". The aim is for "OIML Basic Certificates of Conformity" to be clearly distinguished from "OIML MAA Certificates".

The System provides the possibility for manufacturers to obtain an OIML Basic Certificate and an OIML Basic Evaluation Report (called "Test Report" in the appropriate OIML Recommendations) indicating that a given instrument type complies with the requirements of the relevant OIML International Recommendation.

An OIML Recommendation can automatically be included within the System as soon as all the parts - including the Evaluation Report Format - have been published. Consequently, OIML Issuing Authorities may issue OIML Certificates for the relevant category from the date on which the Evaluation Report Format was published; this date is now given in the column entitled "Uploaded" on the Publications Page.

Other information on the System, particularly concerning the rules and conditions for the application, issue, and use of OIML Certificates, may be found in OIML Publication B 3 *OIML Basic Certificate System for OIML Type Evaluation of Measuring Instruments* (Edition 2011) which may be downloaded from the Publications page of the OIML web site. ■

The OIML MAA

In addition to the Basic System, the OIML has developed a *Mutual Acceptance Arrangement* (MAA) which is related to OIML Type Evaluations. This Arrangement - and its framework - are defined in OIML B 10 (Edition 2011) *Framework for a Mutual Acceptance Arrangement on OIML Type Evaluations*.

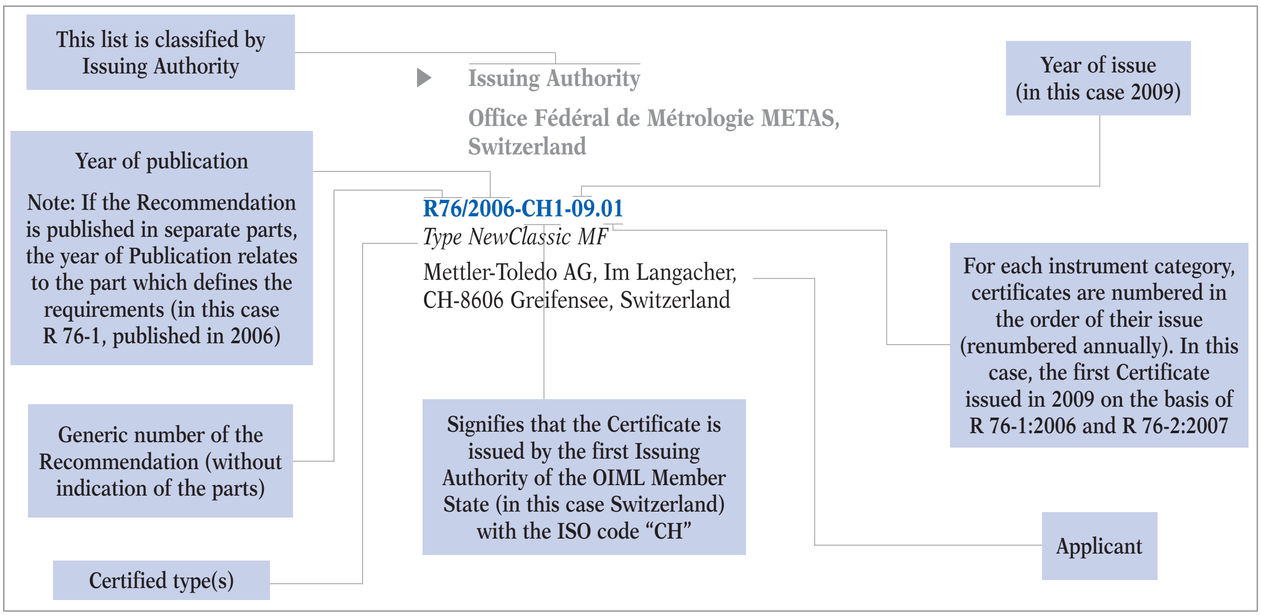
The OIML MAA is an additional tool to the OIML Basic Certificate System in particular to increase the existing mutual confidence through the System. It is still a voluntary system but with the following specific aspects:

- Increase in confidence by setting up an evaluation of the Testing Laboratories involved in type testing;
- Assistance to Member States who do not have their own test facilities;
- Possibility to take into account (in a Declaration of Mutual Confidence, or DoMC) additional national requirements (to those of the relevant OIML Recommendation).

The aim of the MAA is for the participants to accept and utilize MAA Evaluation Reports validated by an OIML MAA Certificate of Conformity. To this end, participants in the MAA are either Issuing Participants or Utilizing Participants.

For manufacturers, it avoids duplication of tests for type approval in different countries.

Participants (Issuing and Utilizing) declare their participation by signing a Declaration of Mutual Confidence (Signed DoMCs). ■



INSTRUMENT CATEGORY: R 49 (2006)

Water meters intended for the metering of cold potable water

▶ Issuing Authority / *Autorité de délivrance*

Czech Metrology Institute (CMI), Czech Republic

R049/2006-CZ1-2011.01 Rev. 1
Magnetic Flow Meter - Type: Transmitter type 8732 and Flow Sensor types 8705 and 8711

Emerson Process Management/ Rosemount Flow Division, 12001 Technology Drive, 553 44 MN Eden Prairie, United States

▶ Issuing Authority / *Autorité de délivrance*

Laboratoire National de Métrologie et d'Essais, Certification Instruments de Mesure, France

R049/2006-FR2-2012.01
Water meter ITRON type P290+

Itron France, 11 Boulevard Pasteur, FR-67500 Haguenau, France

▶ Issuing Authority / *Autorité de délivrance*

Physikalisch-Technische Bundesanstalt (PTB), Germany

R049/2006-DE1-2008.02 Rev. 3
Water meter for cold potable water. Type SM100, SM100E, SM100P or SM001, SM001E, SM001P - SM150, SM150E, SM150P - SM250, SM250E, SM250P - SM700, SM700E, SM700P

Elster Metering Ltd., 130 Camford Way, Sundon Park, Luton LU3 3AN, Bedfordshire, United Kingdom

R049/2006-DE1-2008.03 Rev. 1
Electromagnetic flow meter with electronical register. Type: Promag 51 P/W

Endress + Hauser Flowtec AG, Kagenstrasse 7, CH-4153 Reinach BL 1, Switzerland

R049/2006-DE1-2010.03 Rev. 1
Water meter for cold potable water. Combination meter and mechanical register. Type: C4000

Elster messtechnik GmbH, Otto-Hahn Strasse 25, DE-68623 Lampertheim, Germany

R049/2006-DE1-2012.02
Water meter for cold potable water. Type: MTK, MTK-S

Zenner International GmbH & Co KG, Römerstadt 4, DE-66121 Saarbrücken, Germany

R049/2006-DE1-2012.03
Ultrasonic water meter for cold potable water and hot water. Type: AFLOWT UF

SEVLAND GmbH, Hauptstraße 27, DE-90547 Stain, Germany

R049/2006-DE1-2012.03 Rev. 1
Ultrasonic water meter for cold potable water and hot water. Type: AFLOWT UF (external power supply), AFLOWT BUF (battery powered)

SEVLAND GmbH, Hauptstraße 27, DE-90547 Stain, Germany

INSTRUMENT CATEGORY: R 51 (2006)

Automatic catchweighing instruments

▶ Issuing Authority / *Autorité de délivrance*

National Measurement Office (NMO), United Kingdom

R051/2006-GB1-2008.01 Rev. 4
CW3 Checkweigher

Loma Systems Group and ITW Group, Southwood, Farnborough, Hampshire GU14 0NY, United Kingdom

R051/2006-GB1-2008.01 Rev. 5
CW3 Checkweigher

Loma Systems Group and ITW Group, Southwood, Farnborough, Hampshire GU14 0NY, United Kingdom

▶ Issuing Authority / *Autorité de délivrance*

Physikalisch-Technische Bundesanstalt (PTB), Germany

R051/2006-DE1-2008.01 Rev. 1
Automatic catchweighing instrument

Leich und Mehl und Co. GmbH, Porschestrasse 7, DE-71394 Kernen in Remstal, Germany

INSTRUMENT CATEGORY: R 60 (2000)

Metrological regulation for load cells (applicable to analog and/or digital load cells)

▶ Issuing Authority / *Autorité de délivrance*

Laboratoire National de Métrologie et d'Essais, Certification Instruments de Mesure, France

R060/2000-FR2-2011.01 Rev. 1 (MAA)
Single point load cell type AX

Scaime S.A.S, Z.I. de Juvigny, B.P. 501, FR-74105 Annemasse Cedex, France

▶▶

Issuing Authority / *Autorité de délivrance*

International Metrology Cooperation Office, National Metrology Institute of Japan (NMIJ) National Institute of Advanced Industrial Science and Technology (AIST), Japan

R060/2000-JP1-2011.01 Rev. 1 (MAA)
Compression load cell - Type: DCC1-20T, DCC1-24T, DCC1-36T
Yamato Scale Co., Ltd., 5-22 Saenba-cho, JP-673-8688 Akashi, Hyogo, Japan

R060/2000-JP1-2011.09 (MAA)
Compression load cell - Type: HR II-20, HR II-30, HR II-50, HR II-100, HR III-50, HR III-80, IR-20, IR-30
JFE Advantech Co., Ltd, 3-48 Takahata-cho, Nishinomiya, JP-663-8202 Hyogo, Japan

R060/2000-JP1-2011.10 (MAA)
Compression load cell - Type: CS002-200K, CS002-500K, CS002-1T, CS002-2T, CS002-3T, CS002-5T
Minebea Co., Ltd, 1-1-1 Katase Fujisawa-shi, JP-251-8531 Kanagawa-ken, Japan

R060/2000-JP1-2011.10 Rev. 1 (MAA)
Compression load cell - Type: CS002-200K, CS002-500K, CS002-1T, CS002-2T, CS002-3T, CS002-5T
Minebea Co., Ltd, 1-1-1 Katase Fujisawa-shi, JP-251-8531 Kanagawa-ken, Japan

R060/2000-JP1-2012.01 (MAA)
Tension Load Cell - LC1205-K100,LC1205-K200, LC1205-K500
A&D Company Ltd., 3-23-14 Higashi-Ikebukuro, Toshima-Ku, JP-170-0013 Tokyo, Japan

Issuing Authority / *Autorité de délivrance*

NMi Certin B.V., The Netherlands

R060/2000-NL1-2011.16 (MAA)
Compression Load Cell - Type: QCC21-20T, QCC21-24T, QCC21-36T
Yamato Scale Co., Ltd., 5-22 Saenba-cho, JP-673-8688 Akashi, Hyogo, Japan

R060/2000-NL1-2011.36 (MAA)
Load Cell - Type: S40A
Hottinger Baldwin Measurement (Suzhou) Co. Ltd., 106 Hengshan Road, CN-215009 Suzhou, P.R. China

R060/2000-NL1-2011.40 (MAA)
Load Cell - Type: CB069
Minebea Co., Ltd, 1-1-1 Katase Fujisawa-shi, JP-251-8531 Kanagawa-ken, Japan

Issuing Authority / *Autorité de délivrance*

National Measurement Office (NMO), United Kingdom

R060/2000-GB1-2011.05
T301x Digital compression alloy steel load cell
Avery Weigh-Tronix, Foundry Lane, Smethwick, West Midlands B66 2LP, United Kingdom

Issuing Authority / *Autorité de délivrance*

Physikalisch-Technische Bundesanstalt (PTB), Germany

R060/2000-DE1-2006.02 Rev. 2
Strain gauge bending beam load cell - Type: PW15xH
Hottinger Baldwin Messtechnik GmbH, Im Tiefen See 45, DE-64293 Darmstadt, Germany

INSTRUMENT CATEGORY: R 61 (2004)

Automatic gravimetric filling instruments

Issuing Authority / *Autorité de délivrance*

NMi Certin B.V., The Netherlands

R061/2004-NL1-2011.01
Automatic gravimetric filling instrument. Type: VentoDigit IV
FLSmidth Ventomatic SpA, Via G. Marconi, I-24030 Valbrembo (BG), Italy

INSTRUMENT CATEGORY: R 76-1 (1992), R 76-2 (1993)

Nonautomatic weighing instruments

Issuing Authority / *Autorité de délivrance*

National Measurement Office (NMO), United Kingdom

R076/1992-GB1-2012.01 (MAA)
CT100 Series
CAS Corporation, #19, Ganap-Ri, Gwangjuk-Myoun, Yangju-Si, KR-482-841 Kyunggi-Do, Korea (R.)

R076/1992-GB1-2012.01 Rev. 1 (MAA)
CT100 Series - Non automatic weighing instrument
CAS Corporation, #19, Ganap-Ri, Gwangjuk-Myoun, Yangju-Si, KR-482-841 Kyunggi-Do, Korea (R.)

INSTRUMENT CATEGORY: R 76-1 (2006), R 76-2 (2007)

Non-automatic weighing instruments

Issuing Authority / *Autorité de délivrance*

NMi Certin B.V.,
The Netherlands

R076/2006-NL1-2011.30
Non automatic weighing instrument. 752KG, 753KG, 599KG, 500KG, 752KGWA, 753KGWA, 599KGWA, 597KGWA ...
Transcell Technology Inc., 975 Deerfield Park Way, 60089 Buffalo Grove, Illinois, United States

R076/2006-NL1-2011.33
Non automatic weighing instrument. 752KG, 753KG, 599KG, 500KG, 752KGWA, 753KGWA, 599KGWA, 597KGWA ...
Pelstar LLC, 11800 South Austin Avenue, Unit B, 60803 Alsip, Ilinois, United States

R076/2006-NL1-2011.35 (MAA)
Non automatic weighing instrument. Type: 82alpha
Rhewa Waagenfabrik August Freudewald GmbH & Co. KG, Feldstrasse 17, D-40822 Mettmann, Germany

R076/2006-NL1-2011.36 (MAA)
Non automatic weighing instrument. Type: HX and HS
Mettler-Toledo GmbH, Im Langacher, CH-8606 Greifensee, Switzerland

R076/2006-NL1-2011.37 (MAA)
Weighing module type PDB655
Mettler-Toledo (Changzhou) Measurement Technology Ltd, No. 111, West HaiHu Road, ChangZhou XinBei District, CN-213125 Jiangsu, P.R. China

Issuing Authority / *Autorité de délivrance*

National Measurement Office (NMO),
United Kingdom

R076/2006-GB1-2012.01 (MAA)
RW-5000 Series: RW-5002PL Model
CAS Corporation, #19, Ganap-Ri, Gwangjuk-Myoun, Yangju-Si, KR-482-841 Kyunggi-Do, Korea (R.)

R076/2006-GB1-2012.02 (MAA)
Indicating device: DD1050, DD1050i,DD2050
Societa Cooperativa Bilanciai Campogalliano a.r.l, Via S. Ferrari, 16, IT-41011 Campogalliano (Modena), Italy

R076/2006-GB1-2012.03
IP100 P, IPE100 SS, IPE90 P, IPE90 SS
Scaime S.A.S, Z.I. de Juvigny, B.P. 501, FR-74105 Annemasse Cedex, France

INSTRUMENT CATEGORY: R 117 (1995) + R 118 (1995)

Fuel dispensers for motor vehicles

Issuing Authority / *Autorité de délivrance*

SP Technical Research Institute of Sweden, Sweden

R117/1995-SE1-2005.01 Rev. 4
One or two sided fuel pump/dispensers for motor vehicles (see certificate for models)
Dresser Wayne Inc., 3814 Jarrett Way, Austin TX 78728, United States

OIML CERTIFICATE SYSTEM

List of OIML Issuing Authorities

The list of OIML Issuing Authorities is published in each issue of the OIML Bulletin. For more details, please refer to our web site: www.oiml.org/certificates. Changes since the last issue of the Bulletin are marked in red.

		R 16	R 21	R 31	R 49	R 50	R 51	R 58	R 60	R 61	R 75	R 76	R 81	R 85	R 88	R 93	R 97	R 98	R 99	R 102	R 104	R 105	R 106	R 107	R 110	R 112	R 113	R 114	R 115	R 117/118	R 122	R 126	R 128	R 129	R 133	R 134	R 136
AT1	Bundesamt für Eich- und Vermessungswesen (BEV)					■	■	■		■		■		■	■		■	■		■	■		■	■	■			■	■	■							
AU1	National Measurement Institute (NMI)				■	■	■		■			■		■									■	■						■		■		■			
BE1	SPF Economie, PME, Classes Moyennes et Energie											■					■	■																			
BG1	State Agency for Metrology and Technical Surveillance (SAMTS)											■						■																			
BR1	Instituto Nacional de Metrologia, Normalização e Qualidade Industrial (INMETRO)											■																									
CH1	Office Fédéral de Métrologie (METAS)	■		■	■	■	■		■	■		■					■	■				■	■	■						■						■	
CN1	General Administration of Quality Supervision, Inspection and Quarantine of P. R. China (AQSIQ)								■			■					■	■																			
CZ1	Czech Metrology Institute (CMI)				■							■	■	■								■								■						■	
DE1	Physikalisch-Technische Bundesanstalt (PTB)	■		■	■	■	■	■	■	■		■		■	■		■	■	■	■	■	■	■	■	■			■	■	■		■	■	■	■		■
DK1	The Danish Accreditation and Metrology Fund (DANAK)					■	■		■	■		■						■				■	■	■						■				■		■	
DK2	FORCE Certification A/S				■																																
DK3	Dansk Elektronik, Lys & Akustik (DELTA)					■	■		■	■		■											■	■										■		■	
ES1	Centro Español de Metrología (CEM)				■		■		■	■		■					■	■														■					
FI1	Inspecta Oy					■	■		■	■		■		■									■	■						■							
FR1	Ministère de l'Economie, de l'Industrie et de l'Emploi (MEIE)	*All activities and responsibilities were transferred to FR2 in 2003*																																			
FR2	Laboratoire National de Métrologie et d'Essais (LNE)		■	■	■	■	■	■	■	■		■	■	■	■		■	■	■	■		■	■	■	■			■	■	■		■		■		■	
GB1	National Measurement Office (NMO) - Formerly NWML		■		■	■	■		■	■	■	■		■				■				■	■	■						■				■		■	
GB2	National Physical Laboratory (NPL)																■																				
HU1	Hungarian Trade Licensing Office (MKEH)											■																									
JP1	National Metrology Institute of Japan / National Institute of Advanced Industrial Science and Technology (NMIJ / AIST)								■			■																	■	■							
KR1	Metrology and Measurement Division (KATS)											■																									
NL1	NMi Certin B.V.		■	■	■	■	■		■	■		■	■	■			■		■			■	■	■						■		■	■	■		■	
NL2	KIWA Nederland B.V.				■																																
NO1	Norwegian Metrology Service (Justervesenet)					■	■			■		■										■	■	■						■				■			
NZ1	Measurement and Product Safety Service (MAPSS Wellington)											■																									
PL1	Central Office of Measures (GUM)											■						■		■																	
RO1	Bureau Roumain de Métrologie Légale (B.R.M.L.)																■	■							■			■	■								
RU1	Russian Research Institute for Metrological Service (VNIIMS)			■	■	■	■	■	■	■		■		■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
SE1	Swedish National Testing and Research Institute AB (S.P.)					■	■		■	■		■		■				■					■	■						■							
SI1	Metrology Institute of the Republic of Slovenia (MIRS)											■																									
SK1	Slovak Legal Metrology				■							■																		■							
US1	NCWM, Inc.								■			■																									
VN1	Directorate for Standards and Quality (STAMEQ)											■																									

DEVELOPING COUNTRIES

Announcing the

Fourth OIML Award for Excellent contributions from Developing Countries to legal metrology

Background

Many developing countries suffer from a lack of resources for the operation of a sound Legal Metrology System. Although these resources cannot be provided by the OIML, the Organization supports initiatives for the development of legal metrology. To highlight the importance of metrology activities in developing countries, and to provide an incentive for their improvement, in 2009 the OIML established an Award for "*Excellent contributions from developing countries to legal metrology*".

This Award is intended to raise the awareness of, and create a more favorable environment for legal metrology and to promote the work of the OIML. The Award intends: "*to acknowledge and honor new and outstanding activities achieved by individuals, national services or regional legal metrology organizations contributing significantly to legal metrology objectives on national or regional levels.*"

How can candidates be proposed?

Nominations may be made by any individuals or organizations concerned with legal metrology, including the individual or organization seeking the Award.

Nominations should be sent to Ian Dunmill at the BIML and must contain facts, documents and arguments explaining why the candidate deserves the Award. The closing date is 1 July 2012.

Selection procedure

The BIML will prepare a list of candidates highlighting the importance of the achievements, and will rank the applications. The Award winner will be selected by the CIML President and announced at the 47th CIML Meeting in October 2012.

Selection criteria

The criteria which will be used to assess the candidates' contribution or achievement will include:

- its significance and importance;
- its novelty;
- its attractiveness and adaptability for other legal metrology services.

The OIML Award

The Award will consist of:

- a Certificate of Appreciation signed by the CIML President;
- a token of appreciation, such as an invitation to make a presentation of the Award-winning achievement at the next CIML Meeting or OIML Conference at the OIML's expense;
- an engraved glass award trophy.

Further information

For more details, please contact:

Ian Dunmill
BIML Assistant Director
ian.dunmill@oiml.org

Past Awards

2011 - José Antonio Dajes (Peru) and Juan Carlos Castillo (Bolivia)

2010 - Thai Legal Metrology Service

2009 - Mr. Osama Melhem (Jordan)

The OIML is pleased to welcome the following new

CIML Members

- **Ireland**
  Ms. Mairead Buckley
- **Republic of Croatia**
  Mr. Ismar Avdagic
- **Serbia**
  Mrs. Vida Zivkovic

OIML Meetings

47th CIML Meeting, 14th Conference & Associated Events
1–5 October (Bucharest, Romania)

TC 6 (Prepackaged products)
22–26 October (Tokyo, Japan)

Committee Drafts

Received by the BIML, 2012.01 – 2012.03

Amendment (201x) to OIML B 10:2011: Framework for a Mutual Acceptance Arrangement on OIML Type Evaluations (OIML MAA)	E	2 CD	TC 3/SC 5	US
Instruments for continuous measurement of CO, NO_x in stationary source emissions	E	2 CD	TC 16/SC 1	NL
Revision of D 11: General requirements for measuring instruments - Environmental conditions	E	2 CD	TC 5/SC 1	NL

André Perlstain 1919–2012

It is with deep regret that we inform our readers of the recent passing away of Dr. André Perlstain, CIML Honorary Member, who died in March 2012 at the age of 93.

Dr. Perlstain joined the Federal Office of Metrology (METAS), Switzerland, in 1947 as a physicist and worked there throughout his career. He first specialized in metrology for aircraft, then worked on electrical measuring techniques in the fields of mechanical quantities, acoustics and thermometry.

He became director of METAS in 1970. During his time as director a new federal law on metrology was elaborated; this law came into force at the beginning of 1978 and is still valid in Switzerland today. Only at the beginning of next year will it be replaced by a new federal law on metrology.

In 1970, at the time of his appointment as director of METAS, the Swiss Government nominated him representative of Switzerland on the International Committee of Legal Metrology (CIML). He was immediately also appointed Member of the Presidential Council and remained on the Council for 14 years until his retirement in 1984.

His valuable participation in the work of the CIML and of the Presidential Council was recognized by the Committee, which appointed him CIML Honorary Member in 1984.

He will be dearly missed by his family, colleagues and friends and will be remembered as an active participant in the development of the OIML. ■

Call for papers

OIML Members
RLMOs
Liaison Institutions
Manufacturers' Associations
Consumers' & Users' Groups, etc.

- Technical articles on legal metrology related subjects
- Features on metrology in your country
- Accounts of Seminars, Meetings, Conferences
- Announcements of forthcoming events, etc.

The **OIML Bulletin** is a forum for the publication of technical papers and diverse articles addressing metrological advances in trade, health, the environment and safety - fields in which the credibility of measurement remains a challenging priority. The Editors of the Bulletin encourage the submission of articles covering topics such as national, regional and international activities in legal metrology and related fields, evaluation procedures, accreditation and certification, and measuring techniques and instrumentation. Authors are requested to submit:

- a titled, typed manuscript in Word or WordPerfect either on disk or (preferably) by e-mail;
- the paper originals of any relevant photos, illustrations, diagrams, etc.;
- a photograph of the author(s) suitable for publication together with full contact details: name, position, institution, address, telephone, fax and e-mail.

Note: Electronic images should be minimum 150 dpi, preferably 300 dpi.

Technical articles selected for publication will be remunerated at the rate of 23 € per printed page, provided that they have not already been published in other journals. The Editors reserve the right to edit contributions for style, space and linguistic reasons and author approval is always obtained prior to publication. The Editors decline responsibility for any claims made in articles, which are the sole responsibility of the authors concerned. Please send submissions to:

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BIML, 11 Rue Turgot, F-75009 Paris, France
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