July 9, 2012

Changes to the International Vocabulary of Metrology: Proposed Changes to Some Definitions in the Uniform Weights and Measures Law in NIST Handbook 130

Byline: Dr. Charles Ehrlich

This article has been written to provide some background information on the development of the International vocabulary of basic and general terms in metrology (VIM) documents over the past several years, and to provide some explanation and elaboration on several of the definitions in the International vocabulary of metrology — Basic and general concepts and associated terms (VIM), 3rd edition, also known as the "VIM3." Some of the terms from VIM3 have been proposed for inclusion by the National Institute of Standards and Technology (NIST) Office of Weights and Measures (OWM) in the National Conference on Weights and Measures (NCWM Publication 16, Laws and Regulations Committee agenda Item 221-1). The purpose of the proposal is to incorporate the VIM3 definitions into the Uniform Weights and Measures Law (UWML) in Handbook 130 (HB 130), *Uniform Laws and Regulations in the Areas of Legal Metrology and Engine Fuel Quality*, updating the VIM2 definitions it contains. Incorporating these updated definitions will better align the HB 130 definitions with the philosophy of the Guide to the expression of uncertainty in measurement, commonly referred to as the "GUM," which serves as a key document underpinning requirements for the accreditation of state metrology laboratories. Incorporating these updated definitions will also better reflect current international agreement on metrology-related terminology.

In order to promote having a "common language of metrology" at the international level, in 1984 a small group of people representing the International Bureau of Weights and Measures (BIPM), the International Organization of Legal Metrology (OIML), the International Standardization Organization (ISO), and the International Electrotechnical Commission (IEC) developed the first edition of the "VIM." ISO published the document on behalf of the four organizations.

In 1993, the second edition of the VIM (also known as the "VIM2") was published, with three additional cosponsoring organizations: the International Federation of Clinical Chemistry (IFCC), the International Union of Pure and Applied Chemistry (IUPAC), and the International Union of Pure and Applied Physics (IUPAP). The second edition was developed in order to "remove some anomalies, ambiguities and circularities[1]" from the first edition, and to better address some of the needs of chemistry and other related fields. Further, it incorporated terminology associated with the GUM, which was also published (again by ISO) that same year.

In 2005 the National Conference on Weights and Measures (NCWM) adopted several of the definitions from the VIM2 into the UWML in NIST HB 130. The definitions were adopted almost verbatim, with some small changes to accommodate the HB 130 format for definitions. Among the VIM2 definitions

added to HB 130 were those for “calibration”, “traceability,”“uncertainty,” “reference standard,” and “working standard.”

The VIM3 was published by the Joint Committee for Guides in Metrology (JCGM) in 2008, and was subsequently published with corrections in early 2012. The JCGM, established in 1997 by the seven cosponsoring organizations mentioned above, and joined in 2005 by the International Laboratory Accreditation Cooperation (ILAC), now has assumed oversight responsibility from ISO for both the VIM and the GUM. Development of the VIM3 was motivated in part by the desire to further address measurements in chemistry and laboratory medicine, and to incorporate additional concepts related to measurement uncertainty, metrological traceability, and nominal properties. A set of concept diagrams was added to the VIM3 that demonstrates the relationships among the various concepts contained in the VIM3 definitions.

The VIM3 is somewhat more formal than the VIM2 in its use of language. This was done primarily in order to reduce the possibility of ambiguity, while maintaining the efficiency of use of words and rigor of the concept system. While some readers have found the VIM3 to be equally or more useful than the two earlier versions, others have found its style of language and level of complexity to be too different than that in the earlier versions, leading to difficulty in following the language in some of the definitions.

The first definition in the UWML proposed to be updated is “calibration.”

Historically, a calibration has been defined (such as in the VIM2) as a “process of comparing and recording indicated values obtained from a measuring instrument with the corresponding values obtained when using measurement standards.” For example, when calibrating a mercury-in-glass thermometer, the indicated value from viewing the thermometer can be compared with the value obtained from a precision thermocouple that is in the same temperature bath as the thermometer. can be done over a range of discrete temperatures of the bath, and a calibration table can be developed that records indicated values from the thermometer and corresponding values obtained from the thermocouple at each discrete temperature (e.g., 4.4 °C (40 °F), 10 °C (50 °F), 43.3 °C (110 °F), and 48.8 °C (120 °F).

The revised definition of “calibration” in the VIM3 recognizes that the VIM2 (and the current UWML) definition is missing two things. First, nothing is said about recording the measurement uncertainties associated with any of the values in a calibration table. Second, nothing is said about how the information in a calibration table is to be when the mercury-in-glass thermometer is subsequently used to measure the temperature of something (for example, the body temperature of a patient). While a calibration table typically has information at a few discrete points, the calibration report accompanying a calibration certificate typically gives either a “fit to a curve” (chart, graph or diagram), or a computer-generated table based on such a curve fit, along with the appropriate measurement uncertainty to associate with any indicated value of the thermometer over the range of the calibration. By incorporating the VIM3 definition of “calibration” into the UWML, these missing aspects of the definition will then be included.

The second definition in the UWML that is proposed to be updated is “(metrological) traceability”.

The term "metrological" is added to distinguish this type of traceability from other types of traceability (e.g., document traceability). Probably the most significant aspect of the updated (VIM3) definition is that traceability is now explicitly considered to apply to both values and uncertainties, rather than just to values. This is an important addition, since it reflects the growing international agreement that a statement of traceability that does not include information about measurement uncertainty is of limited value, since no one then really knows how good the measured value is thought to be.

Other changes to the updated definition of "traceability" are that the unbroken chain is a chain of calibrations (rather than a chain of comparisons), and that the chain must be documented. The reason that the chain is a chain of calibrations (and not comparisons) is that calibrations transfer values and uncertainties along the chain, whereas comparisons alone do not do that.

A new definition from the VIM3 that is proposed to be added to the UWML is "metrological traceability chain," which is intended to further support the updated definition of "traceability" by explaining what is meant in the definition by "chain."

Another aspect of the updated definition of "traceability" is that it recognizes that references for traceability do not have to be national or international standards. Rather, any well-characterized reference standard can be used. For example, one can talk about a measurement result obtained "in the field" being traceable to a reference standard in a state metrology laboratory.

Usually, however, it is important that traceability eventually lead back to internationally agreed reference standards, such as the measurement units of the International System of Units (SI). Therefore, a new definition from the VIM3 (for "metrological traceability to a measurement unit") is being proposed to be added to the UWML to help clarify what is meant by "traceability to the SI." For example, "(metrological) traceability to the SI" means metrological traceability to the definition of the measurement unit "kilogram" (kg) through the practical realization of the kg at NIST, obtained by calibration of a NIST mass artifact, having a mass of about 1 kg, against the international kilogram in Paris.

The third definition in the UWML that is proposed to be updated is "measurement uncertainty."

The VIM3 definition clarifies that measurement uncertainty can only be positive (or zero), and, more importantly, the definition eliminates the subjective term "reasonably" that appears in the VIM2 (and UWML) definition. The updated definition also clarifies that measurement uncertainty characterizes a dispersion or range of values believed to contain the true value of the quantity intended to be measured (the measurand).

Two additional definitions in the UWML that are proposed to be updated are "reference measurement standard" and "working measurement standard."

The revision of "reference measurement standard" will update the current UWML definition in two ways. First, it would no longer be required that a reference measurement standard be of the highest quality available (for example, it could be lower in a metrological traceability chain). Second, it is

specified that a reference measurement standard is intended to be used for calibration of other measurement standards and not for making routine measurements, such as working measurement standards are. The term "measurement" was added to the term in order to distinguish this type of reference standard from other types, such as a reference documentary standard.

The revision of "working measurement standard" will also update the current UWML definition in two ways. First, a working standard would no longer be required to be directly calibrated by a reference standard (it could, for example, calibrated by another working standard). Also, this revision will clarify that a working standard can be used for both calibration and verification of measuring instruments. The word "measurement" was again added in order to distinguish this type of standard from other types of working standards. By updating both of these definitions, the UWML will reflect current international agreement about measurement standards that is consistent with the VIM3.

The explanations given above cover the proposed VIM3 updates of definitions in the UWML. For those interested in other entries in the VIM3, a set of frequently asked questions (FAQs) on the VIM3 is being developed by the group responsible for its creation, in order to address some of the expressed complexity and difficulties with understanding some of the definitions. The initial set of finalized FAQs is anticipated to be available online later this summer at http://www.bipm.org/en/publications/guides/vim.html. It is anticipated that the FAQs will be a living document, with possible improvements and new entries as time progresses.

ENDNOTE

[1] "Circularity" here means defining one word in terms of another that is itself defined in terms of the first word.