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PRELIMINARY NOTES ON METROLOGICAL RELIABILITY

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Abstract – Concerns regarding reliability are present in all spheres of application. There are several uses of the term according to different fields. This paper reports on the importance of addressing metrological characteristics among requirements for reliability evaluation and discuss about the many uses described in the literature of the term "metrological reliability", evaluating the need for a harmonized definition of the concept of "metrological reliability" in a future VIM.

Keywords: metrology, metrological reliability, international vocabulary, concept, reliability

1. INTRODUCTION

Reliability assurance is considered as an important concern in all spheres of interest, but its definitions vary according to the different professional groups of users. The most commonly used meaning of the term considers reliability as the capability of being relied on; presenting repeatable or compatible results in different trials. Hence, reliability is assessed by a wide range of application areas employing a variety of different approaches.

Regarding electrotechnology, according to electropedia, an online electrical and electronic terminology database produced by the Technical Committee 1 of the International Electrotechnical Commission (IEC) [1], reliability is the ability of an item to perform a required function under given conditions for a given time interval. As discribed in the terminology database of electropedia, the reliability performance is quantified using appropriate measures, including, in some applications, its expression as a probability, also referred as "reliability".

The term is similarly addressed in the field of Reliability Engineering, in which "reliability", without any further qualifier, is one of its used concepts, indicating the probability that a device or part will operate properly for a stated period of time under defined operating conditions without failure. Along the time, the term has been most frequently associated to repeatability, failure rate and, more recently, to the development process itself.

The term "reliability" is also applied as one of the criteria to evaluate psychometric assessment instruments, the inventories used for measuring psychological constructs (e.g. abilities, personality traits, emotional states). In this field of application, reliability refers to the reproducibility or consistency of scores from one assessment to another.

The same term designating several concepts (polysemy) generates ambiguities that compromise the communication [2].

A harmonized reference of the concepts related to terms in measurement science, covering a broad spectrum of fields of application, is pursued with the development of the International vocabulary of metrology – Basic and general concepts and associated terms (VIM) [3]. However, a universally agreed definition for reliability is not yet published in the VIM.

Irrespective of the application of the term, to assure reliability of an item, measurements must be performed and their results evaluated. In the broad field of metrology, the science of measurement, efforts are employed on editing documents for disseminating concepts and approaches concerning the appropriate conditions to perform measurements and express their results. These aspects are essential to provide any reliable information about the quantity being measured.

In this work, the importance of a generic and harmonized definition of the reliability concept and a more specific one associated to the term "metrological reliability", as well as its possible application to provide information about devices reliability are discussed.

2. METROLOGICAL FRAMEWORK TO ENSURE RELIABILITY

Aiming to meet the reliability requirements from the diverse fields of science and technology, a global metrological infrastructure on quantities and units has been assembled since the signature of the Metre Convention on 20 May 1875. The International Bureau of Weights and Measures (BIPM) was set up by the Metre Convention with the task of ensuring worldwide unification of measurements. BIPM is an intergovernmental organization through which Member States act together on matters related to measurement science and measurement standards under the supervision of the International Committee for Weights and Measures (CIPM) which is under the authority of the General Conference on Weights and Measures (CGPM), attended by delegates from all Member States of the Metre Convention. In 1960, a practical system of units of measurement suitable for adoption by all countries adhering to the Metre Convention, the International System of Units (SI), was established by the Resolution 12 of the 11th CGPM. Among the basic activities of metrology, is included the definition of internationally accepted units of measurement, realization of these units of measurement in practice and application of chains of metrological traceability to a measurement unit of the International System of Units (SI), linking measurements made in practice to reference standards such as a measurement unit, a reference procedure, and a reference material.

A quantitative indication of the quality of measurement results must be given in order to assess their reliability, allowing to be compared either among themselves or with reference values given in a specification or standard [4]. Therefore, the usefulness and the information provided by measurement results are determined by the quality of the statements of uncertainty. In 1977, recognizing the lack of international consensus on the expression of uncertainty in measurement, the CIPM requested the BIPM to make a recommendation in conjunction with the national standards laboratories. The use of a single approach to the expression of uncertainty would ensure the consistency of the outputs, allowing measurements performed in different countries and in sectors as diverse as science, engineering, commerce, industry, and regulation to be more easily understood, interpreted, and compared.

The Joint Committee for Guides in Metrology (JCGM), chaired by the Director of the BIPM, by means of two working groups, is responsible for preparing and publishing the original versions of the guide to the expression of uncertainty in measurement (GUM) and the International Vocabulary of Metrology – Basic and General Concepts and Associated Terms (VIM), to enhance global access to information about metrology. The JCGM is made up of representatives from the International Bureau of Weights and Measures (BIPM), the International Electrotechnical Commission (IEC), the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC), the International Organization for Standardization (ISO), the International Union of Pure and Applied Chemistry (IUPAC), the International Union of Pure and Applied Physics (IUPAP), the International Organization of Legal Metrology (OIML), and the International Laboratory Accreditation Cooperation (ILAC). This latter officially joined the seven JCGM founding international organizations in 2005.

In 1995, considering the increasingly stringent requirements of science, technology and international trade, with need to demonstrate world-wide equivalence or traceability of measurement standards, in order to ensure international recognition, the 20th CGPM recommended the enhancement of international infrastructure and adequate interconnections between the BIPM and Regional Metrology Organizations (RMO). As a consequence, the CIPM was mandated to investigate the setting up of a Mutual Recognition Agreement in respect of instrument calibration. Any such agreement would require the keeping of records that could demonstrate the traceability of calibrations back to the base standards.

The final text of the worldwide mutual recognition agreement (CIPM MRA), a framework through which National Metrology Institutes demonstrate the international equivalence of their measurement standards and the calibration and measurement certificates they issue, was signed during the week of the 21st CGPM, on 14 October 1999, by the directors of the national metrology institutes (NMIs) of thirty-eight Member States of the BIPM and representatives of two international organizations.

In the CIPM MRA, the RMOs are responsible for carrying out comparisons and other actions within their regions to support mutual confidence in the validity of the calibration and measurement certificates of their member NMIs. Through the Joint Committee of the RMOs and the BIPM (JCRB), they carry out an inter-regional review of declared capabilities before approved calibration and measurement capability (CMCs) are published in the key comparison data base (KCDB), and they make policy suggestions to the CIPM on the operation of the CIPM MRA.

Considering the crucial importance of measurement results comparability for reliability assurance to be complete and worldwide recognized, fundamental metrological characteristics must be taken into account in the process of reliability evaluation.

In general, the process of reliability evaluation does not consider a more rigorous methodology, in which metrological concerns are comprised, regarding the appropriate metrological characteristics of measurement process; OF measuring instrument or system; and FOR expression of measurement results.

The relevance of metrological traceability, the use of harmonized approach to provide quantitative expressions of measurement uncertainty, as well as many other metrological parameters for characterizing the reliability of measurements and measuring results have been widely emphasized [5, 6, 7].

3. METROLOGICAL RELIABILITY

The term “metrological reliability” has been employed as an indicator of the consideration of metrological issues on the reliability evaluation [7] as well as to designate the validity of measurement information using the techniques of the Theory of Metrological Reliability, in which metrological failures are taken into account to evaluate instruments failure rate [8, 9, 10, 11].

In [11], a definition for “metrological reliability” is presented as being “the property wherein measurement hardware maintains established values of metrological characteristics over the course of a certain time under normal regime and operating conditions”. Likewise the other publications mentioning the term, this paper stress metrological traceability and measurement uncertainty as essential metrological requirements to ensure reliability. In fact, errors associated to sensors and appropriate functioning of components of a system are the basic sources of resulting failures.

In the domain of legal metrology, in which a measuring device is tested through a comparison with a measurement standard with uncertainties associated, the single mention of “reliability” in the International Vocabulary of Terms in Legal Metrology (VIML) is referred as “metrological reliability”, but its definition is not provided. In this document, the term “metrological assurance” is used to refer to all regulations, technical means and necessary operations used to ensure the reliability of measurement results in legal metrology.

The international standard ISO 10012:2003 (Measurement management systems -- Requirements for measurement processes and measuring equipment) [12], specifies generic requirements and provides guidance for the management of measurement processes and metrological confirmation of measuring equipment used to support and demonstrate compliance with metrological requirements. Although not being defined in the VIM or VIML, the term Metrological confirmation is addressed in the ISO 9000:2005 Quality management systems - Fundamentals and vocabulary) as the set of operations required to ensure that measuring equipment conforms to the requirements for its intended use.

The International Organization of Legal Metrology (OIML) publishes recommendations containing metrological requirements that directly contribute to the proper reliability evaluation of the measuring device, which could be specified as “metrological reliability”. The use of this term applied to measurement instruments and systems is fairly widespread in the literature.

Nevertheless, further discussions are necessary to present harmonizing solutions for an overall characterization measuring devices reliability among international guidelines.

On the other hand, in the reliability evaluation process of devices without a measuring function as, for instance, an emitter device, metrological concerns are equally important.

Likewise as mentioned for measuring devices, appropriate metrological characteristics of measurement process; measuring instrument or system; and expression of measurement results should be met in order to assess reliability characterization of a non-measuring device. Metrological requirements included in the reliability assessment are especially relevant for evaluating parameters that significantly affects the adequate function of non-measuring devices.

In fields of application such as human health, environmental protection, among others, the need of accurate measurements traceable to the International System of Units (SI) has been recognized during the 21st CGPM (1999), and an adequate international measurement infrastructure to ensure traceability in biotechnology started to be built since then [7]. Metrological concerns must be included in the reliability analyses of measurement results in the fields of biosciences in order to ensure global safety and health [7]. Therefore, the use of the term “metrological reliability” for this purpose could be important to specify the inclusion of metrological requirements among the parameters evaluated.

Although metrological aspects such as, accuracy, precision, repeatability, metrological traceability, measurement uncertainty, among many others, are commonly addressed in the literature when applying the term “metrological reliability”, the introduction of a more harmonized concept definition would contribute to avoid misunderstanding of its application in different fields.

When the "reliability of a device" is evaluated by means of a comprehensive and adequate approach, with measurements and measuring results properly conducted according to metrological requirements, a more reliable information about the reliability of the device is provided. This condition is sometimes designated by the use of a further qualifier: “metrological reliability”.

Likewise, a generic and harmonized proposal for defining the 'reliability' concept should be provided as well as described its possible specific scale type related branches, in which reliability of a particular device can be evaluated [2].

2.1. Conceptualizing Metrological Reliability

Considering metrological reliability is a reliability categorized by delimiting characteristics with respect to generic reliability, this later should also be harmonized among its several fields of application.

Starting from the generic definition of 'reliability' provided in the International electrotechnical vocabulary (IEV 191-02-06) [1], and considering that not only the performance of the device, but also its safety is essential to be considered reliable, especially in some critical applications, one could figure out the possibility of defining the term as: the ability of an item to perform a required function under given conditions for a given time interval, free from unacceptable risk.

The term metrological reliability could be included in the set of metrological properties defined in the VIM, which aims at characterizing the metrological behaviour of measuring devices. In this vocabulary, there are well defined properties such as sensitivity, selectivity, resolution, stability, bandwidth, that characterize the behaviour of the sensor that is designed to interact with the measurand. Their technical definition is sufficient to make it clear that they apply to devices, not to the results obtained by such devices. However, a challenge about these definitions is that they are usually defined only for devices operating on ratio quantities, being not so well established for a device that operates on ordinal quantities [2].

On the other hand, there are properties that should provide synthetic information on the behavior of measuring devices, but are not clearly defined. It is the case of precision and trueness that are synthesized by accuracy. It is not clear how such synthesis could be made in quantitative way. Alternatives to overcome this limitation have been published in the literature [13], considering that a concept of accuracy can be defined and, in some given cases, can be quantified by an indicator of accuracy in the same way as precision [13]. In addition, precision, trueness, and accuracy are sometimes attributed not only to devices but also to the results they produce. Even if both measurement result and measuring system are accurate, being related to each other, 'accurate device' and 'accurate result' imply different concepts of accuracy.

In this context, metrological reliability could be positioned as a qualitative property, encompassing the multiple results obtained from the evaluation of several parameters designated to ensure the proper functioning of the device.

4. CONCLUSIONS

In this work, aspects indicating the need of inclusion of metrological characteristics among the parameters of the evaluation to ensure reliability of measuring and non-measuring devices are discussed, presenting the specific features associated.

Considerations concerning the need of harmonization of a generic concept to define Reliability, as well as its specific subdivision according to categorized peculiarities are discussed. In special, the features of the term often used in literature with a further qualifier, "metrological reliability", are discussed and its concept definition is proposed.

Taking into account the several usages of the term "metrological reliability" and the relevance of its employment for public security or safety reasons in some domains of application in which compliance to metrological requirements is strategic, the proposal of a harmonized general definition of the concept of "Reliability" as well as for its possible more specific categories is an important issue to be considered for discussion in the future revision of present VIM.

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