

The current state of application of internationally accepted terminology in the field of metrology in Ukraine

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Abstract

The article considers the current state of the practical use of the terms measurement standard (hereinafter standard), national standard, state standard, primary standard, and secondary standard in the internationally accepted interpretation. A comparative analysis was conducted and the main differences in the definitions of these terms before and after the entry into force of the latest version of the Law of Ukraine «On Metrology and Metrological Activity» were presented. Based on the example of the mass standard, it was revealed the meaning of the terms «primary standard» and «national prototype» and pointed out the main mistakes in their application. It was shown in the specific examples how fundamental the difference in definitions of the same terms can be in different terminology systems and how important it is to adhere to terminology in metrology. Examples of incorrect granting of the status of «primary standard» to some national standards of Ukraine are given.

Keywords: metrology, terminology, standard, national standard, primary standard.

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1. Introduction

Terminology is one of the key elements of any science. It incorporates the most accurate and concentrated information of a particular field of science and plays an important role in the preservation and dissemination of knowledge and information exchange.

Thanks to the terminology, the understanding and perception of the disseminated knowledge become as unambiguous and clear as possible. However, for this purpose, it is extremely important to use unified and harmonized terminology systems, in particular, at the international level. Terminology

plays an extremely important role in metrology mainly because the field of metrology is very wide, as many different things need to be measured in daily life.

The main tasks of metrology are ensuring the quality of goods and processes, implementation of scientific and technological developments and innovations, protection of life, health, and environment, and establishing a basis for fair and competitive trade on both national and global markets. The implementation of these tasks is possible not only thanks to accurate and reliable measurements but also in consequence of the implementation and application of unified terminology systems.

2. Brief historical survey and state of affairs

Depending on the tasks assigned to metrology, there are three main areas of metrology: scientific (so-called fundamental) metrology, applied (so-called industrial) metrology, and legal metrology. In order to arrange the system of terms in the field of metrology at the international level, two international vocabularies of basic terms have been developed by leading international organizations ^[1] and ^[2]. Both vocabularies aim to promote the international coherence of terminology used in scientific, applied, and legal metrology. In ^[1] the terms and their definitions are given, which are mainly used in scientific and applied metrology, while the major part of terms in ^[2] are used in legal metrology.

The process of introducing international terminology in the field of metrology in Ukraine was quite long and was not easy. The first attempts to introduce international terminology were made in 1998, when ^[3] was adopted. However, this was more like an unsuccessful attempt to combine the Soviet/post-Soviet terminology with the international one. At the end of the 1990s, Ukraine, step by step, became a member of the international metrology community and actively participated in the international metrology organizations. This, in particular, required bringing the national terminology system in line with international paper standards. Thus, national paper standards harmonized with international ones begin to be implemented. These paper standards introduced new terms and concepts in the sense in which they were accepted by the world community. The national terminology system began to be gradually supplemented by international metrological terms, which later became widely used. It is safe to say that the final stage of the implementation of international terminology in the Ukrainian metrology system began in 2014 when the Law of Ukraine was adopted ^[4]. From the point of view of terminology, the importance of the adoption of this legislative act was not only that international metrological terms were introduced in the sense as they were described in ^[1] and ^[2], but also that these

terms and their definitions were recognized at the statutory level. Subsequently, there were adopted by laws that introduced «special» metrological terms harmonized with the relevant international, which significantly complemented the enshrined in ^[4] national terminology system in the field of legal, scientific, and applied metrology.

However, despite the statutory level of certain terms and their definitions, there are still many cases of misinterpretation, misunderstanding, and misapplication of some of them. This applies mostly to terms whose current definition differs significantly from previously used. As a rule, such incorrect use of terminology often leads to misunderstandings, false statements, judgments, opinions, or conclusions that may have extremely serious negative consequences.

One of the measures that can significantly improve the situation with the use of internationally accepted terminology in Ukraine is the adoption of ^[1] as a national paper standard, once proposed in ^[5].

3. The purpose of publication

The use of outdated terminology is a barrier to Ukraine's path to integration into the international metrology community. Therefore, the purpose of this publication is to call for compliance with the terminology adopted by the international metrology community and Ukrainian law.

It is especially important to bring related to the measurement standards terminology to the internationally accepted regulations.

4. Terms national standard, state standard, primary standard, and secondary standard

One of the common cases of incorrect use of terms is concerned with the use of terms that characterize the so-called «statuses» of the standards. The Table below shows the definition of such terms in their meaning before and after entry into force ^[4].

As it can be seen from the Table, in most cases, the definitions of the same term at varying times differ substantially. Outdated definitions of some of the

Term	Term's definition	
	Before entry into force ^[4]	After entry into force ^[4]
Standard (measurement standard)	– measuring instrument that reproduces and/or conservates a unit of measurement of one or more values, as well as transfers the quantity of this unit to another measuring instrument.	– realization of the definition of a given quantity, with stated quantity value and associated measurement uncertainty, used as a reference.
National standard		– measurement standard recognized by central executive body that implements state policy in the field of metrology and metrological activity, to serve in a state as the basis for assigning quantity values to other measurement standards for the kind of quantity concerned.
State standard	– measurement standard recognized by specially authorized central executive body in the field of metrology as a basis in a state for assigning quantity values to other measurement standards for the kind of quantity concerned.	– primary or secondary measurement standard that is in state ownership.
Primary standard	– a measurement standard that reproduces a unit of measurement with the highest accuracy in a state (compared to other standards of the same unit).	– measurement standard established using a primary reference measurement procedure, or created as an artifact, chosen by convention.
Secondary standard	– a standard that receives the quantity of a unit of measurement directly from the primary standard of this unit or, in its absence, from the appropriate measurement standard of another state.	– measurement standard established through calibration with respect to a primary measurement standard for a quantity of the same kind.

Table. Comparison of terms standard, national standard, state standard, primary standard, and secondary standard

terms are partially reflected in the new ones. For example, the current definition of the term «national standard» combines partially wordings of outdated definitions of the terms «state standard» and «primary standard» and now refers to the fundamentality of such a national standard, its highest status in the hierarchy of standards and its recognition at the national level. The term «state standard» in its current sense refers exclusively to the type of property in which the standard is. This is because, unlike the provisions of the old Law ^[3], the new Law ^[4] provides that national, primary, or secondary standards can be

state property as well as the property of enterprises and organizations, including private ownership.

The term «standard» has also undergone significant changes. Thus, in addition to the introduction of the term «uncertainty» in the new definition, as one of the main characteristics of the standard, the concept of «realization of the definition of a given quantity» was introduced. According to ^[1], «realization» in this case should be understood as either the physical realization of the measurement unit from its definition, setting up a standard based on a physical phenomenon, or adopting a material measure as a standard.

However, the most controversial issues and misunderstandings arise using the term «primary standard». This is most often due to the fact that the old and new definitions have completely different meanings. Thus, according to the new definition, the primary should be considered a standard that was established using the primary reference procedure or created as an artifact. While according to the old definition, in order to acquire the status of a primary standard, it was sufficient for it to reproduce a unit with the highest accuracy in the country, regardless of the measurement procedure used to establish such a standard. In the current sense, the primary standard should realize the definition of a given quantity using the highest-level experimental method based on the realization of the unit with the help of physics equations. In this case, an important feature of this method is that it should allow measuring a quantity in a certain unit, using only the measurement of quantities that do not involve that unit.

Conventionally, the definition of the term «primary standard» can be divided into two parts. According to the first part of the definition, the primary standard should realize the definition of the unit using a special measurement method. While the second part of the term allows the use of an artifact (a material measure) as the primary standard. One of the illustrative examples fully reveals the meaning of both parts of the term is the standard of the unit of mass.

Prior to the introduction of the new definition of the kilogram, an artifact was sanctioned as the primary standard of the kilogram by the convention between the signatories of the Metre Convention.

This approach to the realization of the unit of mass is reflected in the second part of the definition of the term «primary standard». A cylinder with a diameter and height of 39 mm, made in 1879 from an alloy of platinum (90%) and iridium (10%), served as such artifact, so-called the International Prototype of the Kilogram (IPK). Until 2020, for the needs of the signatories of the Metre Convention, official copies of the IPK were made. They were periodically compared (calibrated) against the IPK at the International Bureau of Weights and Measures (BIPM), receiving a quantity

value from the IPK, and used as national standards. Such official copies of the IPK were called the «national prototype». However, there are often cases when the term «national prototype» is applied to a weight that represents the national standard, not being an official copy of the IPK. This statement is incorrect and contrary to international practice, regardless of whether such a weight was calibrated in the BIPM or not.

However, due to the temporal instability of the IPK and the relationship between the kilogram and other SI units, which also influence the stability of such units, the General Conference on Weights and Measures decided to redefine the kilogram through known physical constants. Thus, according to the new definition, starting from May 2019, the kilogram is defined through the Planck constant and the constants through which the meter and the second are defined. To date, there are two internationally recognized independent primary methods of the practical realization of the kilogram with relative uncertainty within a few parts in 10^{-8} . Such primary methods allow determining a mass in terms of the Planck constant without the use of any other mass standard. Today, practical realization of such primary methods are Kibble balance (sometimes called Watt balance) and a sphere made of high-purity single crystal of silicon (so-called X-ray-crystal-density method). Both methods and their practical realizations are described in [6], and they are mentioned in the first part of the term «primary standard». Based on the definition of «primary standard» in [1], and considering [6], it can be concluded that an artifact (material measure, atom or other entity) whose mass was measured by a primary measurement method to realize the definition of kilogram can be called the primary mass standard. For example, the primary standard can be a material measure (weight) calibrated directly on the Kibble balance or the silicon sphere, which mass is determined by the X-ray crystal-density measurements.

Considering this, it should be considered incorrect to use the term «primary standard» regarding the national standard, which realizes a unit of mass with the help of a material measure that is not a silicon sphere or was not calibrated directly on the Kibble balance.

Some changes also affected the definition of the term «secondary standard». Thus, according to the new definition, the secondary standard is a standard established through calibration with respect to a primary measurement standard. The main difference between the new and the previous definitions is that the standard used to calibrate the secondary standard must exclusively be the primary one, regardless of the country in which the standard is established.

5. Examples of incorrect applications of related to the standards terminology

There is also a practical aspect to the issue raised in this article. In practice, the terms described above are not always used in the sense defined in [4]. For example, this applies to the list of national standards registered in Ukraine, posted on the official website of the Ministry of Economy of Ukraine. This list analysis shows that regardless of the accuracy of the national standards of Ukraine, some of them are unreasonably considered to be a primary.

For example, the state's primary standard of a unit of force (DETU 02-07-11) has been recognized as the national standard in accordance with [4]. The measurement range of this standard above 2000 N is provided by the lever-amplification force standard machines. The unit of force in such machines is realized by means of gravitational force acting on special dead loads and a lever load-transmitting mechanism that transmits gravity from special loads to the equipment under test, amplifying it proportionally to the gear ratio of the lever mechanism. The primary realization, in contrast to the above, is considered the realization of a unit of force in a way that ensures the direct application of the load from special dead loads to the equipment under test. The primary realization of the unit of force is provided by the so-called dead weight force standard machines. Therefore, the realization of a unit of force with the help of the lever load-transmitting mechanism cannot be considered as a primary realization, as well as the national standard established using lever-amplification force standard machines cannot be considered as a primary standard.

Another example of unjustified granting of the status of the primary standard is the national (state primary) standard of the unit of mass (NDETU M-07-2020). This standard realizes a unit of mass using a reference weight of the nominal mass of 1 kg, made of special stainless steel. Provided that this reference weight was not calibrated directly on the Kibble balance, the national standard of the unit of mass NDETU M-07-2020 cannot be considered a primary standard.

These examples show the need to review the status of other national standards of Ukraine in order to bring their status in line with the definitions of the terms primary and secondary standards in [4].

6. Conclusions

It is shown in the article how fundamental is the difference in old and new definitions of the terms standard, national standard, state standard, primary standard, and secondary standard. However, there are many other terms using of which that require no less attention, such as «calibration», «measuring instrument», etc. It can be assumed that the examples of misinterpretation and incorrect use of terms described in this article can be found not only in articles and publications but also in official documents, on the official websites of authorities, and metrological organizations. This applies, in particular, to the list of national standards of Ukraine, published on the official website of the Ministry of Economy of Ukraine, which should be updated and brought in line with the terminology introduced in Ukraine. The problem of incorrect application of terminology can concern not only the field of mass and related quantities measurements but also other fields of measurement having their own standards and primary measurement methods. The authors would like to draw the attention of the Ukrainian metrology community to the importance and urgency of this issue, call on all stakeholders to introduce international terminology in metrology in Ukraine, widely use it, and maintain it at the current international level. All of this should

contribute to the international recognition of the national metrology system, including national standards, the elimination of ambiguities and misunder-

standings related to the incorrect use of terminology, as well as the integration of Ukraine into the international metrology community.

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