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VIM AND CURRENT TENDENCIES IN MEASUREMENT SCIENCE

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Abstract: Some proposals with regard to the future version of the VIM are given. The proposals concern definitions of the terms “measurement,” “nominal property,” “metrological traceability,” “sensor,” “measuring system,” etc. A necessity to apply measurements to new fields and take into account new technologies is grounded.

Keywords: VIM, measurement, nominal property, metrological traceability, sensor, measuring system.

1. INTRODUCTION

At the end of the 20-th century the development of chemistry, biology and medicine turned into a stage calling for accurate and reliable quantitative estimates of the processes and objects properties under investigation. At this stage there appeared a necessity for using the experience accumulated by metrology in getting such estimates. Naturally, the development of the international vocabulary VIM3 [1] was accompanied by its updating connected with a need to broaden measurement fields to the domains of chemistry, laboratory medicine, and biology.

The number of works directed towards getting estimates of food properties and industry products, which are characterized by metrological compatibility, increases. It is possible to name some of them: taste of wine, naturalness of materials, freshness of perfume aroma, and even conveniences of mattresses.

Usually the estimate is obtained using measuring instruments, as well as testing and questionnairing potential customers. For example, the evaluation of mattress conveniences is performed at the KRISS taking into account the data statistics concerning the activity of brain biorhythms and load on a spinal/vertebral column of testees. The VNIIM has gained an experience in forming models for measuring properties which could be considered in the past only as qualitative ones [2].

There is a need of such measurement results which have a property of metrological compatibility, i.e., at a given uncertainty (or error) the results coincide with each other (“the absolute value of the difference of any pair of measured quantity values from two different measurement results is smaller than some chosen multiple of the standard measurement uncertainty of that difference”).

At many scientific forums, for example, such as TC1 & TC7 Joint Symposium, 2008, Annecy, France; Symposium ISMTII-2009, St.Petersburg, Russia; XIX IMEKO Congress-2009, Lisbon, Portugal; Joint International IMEKO TC1+ TC7+ TC13 Symposium. 2011, Jena, Germany, a significant attention was given to measurements performed in non-traditional fields.

At the Symposium IMEKO-2011 mentioned above the paper presented by Prof. V. Uspenskiy [3] was awarded with a diploma. This paper deals with a recognition of cardiogram images obtained using a specialized electrocardiograph. The author managed to diagnose 23 widely spread internal diseases of noninfectious nature at a high reliability.

In [4] on the basis of data obtained with the help of www.google.ru at the beginning of 2010, a conclusion was drawn that the interest in measurements carried out in psychology significantly exceeds the interest in measurements done in medicine and biology.

The authors of this paper made a similar Internet-analysis using the words “measurement” and “measurement in *,” where “*” is the name of various fields of knowledge. For this Internet-analysis, the authors applied Scopus containing abstracts of publications included in scientific journals, proceeding of conferences, as well as those of books. Using the results of analysis, a coefficient was calculated, which is equal to the ratio of the number of abstracts containing the words “measurement in *” to the number of abstracts with the word “measurement”. The results obtained enable a conclusion to be made, that for 20 years a share of publications characterizing the scientific interest in measurements has increased as follows: by a factor of 2.5 in the field of chemistry, by a factor of 3–5 in the fields of psychology, biology, and medicine (a study concerned not only laboratory medicine, but medicine as a whole), while in the field of physics it has increased only by a factor of 2.

The area of researches shifts more and more from the technical sphere to man and his environment, a number of knowledge fields approaching to a level corresponding to the D.I. Mendeleyev’s words: “Science begins when they start measuring”. At the same time, special features of measurements in sciences “assimilating metrology” make metrologists come back to the interpretation of background concepts of metrology [5-9, and many others].

Thinking about the future VIM4 development, it is necessary to have in view that new measurement tasks arise in both sciences “assimilating metrology” and those applying it for a long time.

2. CONCEPTS “MEASUREMENT”AND “NOMINAL PROPERTY”

Metrologists have been discussing the concepts indicated in the heading for many years. Below a number of concrete proposals relating to the VIM are presented.

According to the VIM3 [1], a “measurement” is the “process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity.

NOTE 1 Measurement does not apply to nominal properties.

NOTE 2 Measurement implies comparison of quantities and includes counting of entities.

NOTE 3 Measurement presupposes a description of the quantity commensurate with the intended use of a measurement result, a measurement procedure, and a calibrated measuring system operating according to the specified measurement procedure, including the measurement conditions.”

Is NOTE 1 rightful taking into account the above?

According to the VIM3, “nominal property” is the “property of a phenomenon, body, or substance, where the property has no magnitude.”

From this definition it is not clear whether the nominal property cannot have any magnitude (quantitative estimate) as a matter of principle or it has no magnitude at present.

Taking into account the growth of interest in measurements carried out in psychology, let us consider as an example whether “beauty” is a nominal property or, in other words, whether “beauty” can have a magnitude. To our point of view, the answer is determined by the following.

Is there any need to express the beauty by a magnitude? Since the origin of art up to date, in spite of appearance of masterpieces created by Raphael, Phidias and Monet, there has been no such a need. This means that for the society it was quite enough to operate with the concept “beauty” as with the nominal property.

Provided such a need arises and the society is ready to pay for the possibility to get a corresponding magnitude, then it can be stated that there will be found a totality of quantities which will quantitatively characterize “beauty” and make it possible to measure its magnitude.

All examples given as illustrations in clause 1.30 VIM3 [1] are related to a number of those where at present a consumer is satisfied by a rough estimate that is compared with, for example, a conditional “reference” which he keeps in his memory.

If the requirements to the estimate accuracy increase, then the nominal properties will be converted into quantities the values (magnitudes) of which can be measured. For example, if necessary, a colour of a paint sample can be characterized by a quantitative estimate of RGB-components.

Thus, the authors of the present paper propose the following definition of “nominal property”: property of a phenomenon, body, or substance, to which a magnitude is not assigned (within the frames of the task solved).

At the same time the NOTE to 1.30 should be supplemented:

- A magnitude is not assigned to the property if there is no need for it or if this need has not yet been realized at the present-day level of science.
- One and the same property can be either a quantity or nominal property depending on its usage.

In case of such a definition of the term “nominal quality”, NOTE 1 to the term “measurement,” is a logical limitation of its treatment.

Below there are some remarks with regard to NOTE 3 to the term “measurement.”

At the ISMTII’2009 Symposium the authors of the present paper organized a “round table” under the title “Concept of Measurements: Past, Present, and Future”. Representatives of both the sciences, in which metrologists feel comfortable, and humanitarian sciences (psychology, culturology) took part in the “round table”.

The most heated debate was developed around NOTE 3 to the term “measurement” on account of the words “a calibrated measuring system” used as an obligatory feature of measurement.

Long ago measurements were carried out with regard to objects of the world that surrounded man. Measurements were decentralized and supported not with an artificial calibrated system, but with intrinsic (“natural”) material measures determined by physical characteristics of man. Among such measures there were a “cubit,” “foot,” “sazhen,” “stadion,” etc. While measuring at the early stage, one practically posed a problem to provide metrological compatibility of results rather than their metrological traceability. In essence, the values of these material measures were determined on the basis of “validated procedures.” A need for measurement standards has originated later.

To-day measurements of human characteristics relating to intellectual, emotional, sensory, social, and other spheres have got significant. Such measurements are at the stage similar to that which is considered above. They are decentralized; the intrinsic (“natural”) measures determined by human characteristics but relating to the inner life of man are widely used. At the same time here the task to provide the metrological compatibility of measurement results is of great importance.

In other words, the availability of a calibrated measuring system is connected with an approach to a certain level of measurement development in one or another field, but not the feature that determines them.

On the basis of the above it would be useful to exclude “a calibrated measuring system” from NOTE 3.

3. ABOUT METROLOGICAL TRACEABILITY OF A MEASUREMENT RESULT

Expansion of the concept “measurement” and that of a spectrum of measurands has put a question concerning new approaches to the measurement uniformity assurance. First of all, this has resulted in an expansion of the concept “measurement standard” and appearance of a concept “reference” that can be considered to a certain extent as an expansion of the concept “measurement unit”.

The relationship of main concepts is shown in Fig.1.

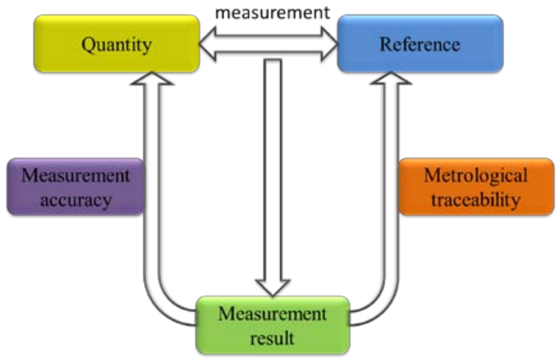

Fig.1 Relationship of main concepts with regard to measurements

The essence of measurement consists in comparing a measurand with “reference.” A result of this comparison provides a measurement result, including information on measurement accuracy. Metrological traceability gives grounds for quantitative measure of measurement accuracy.

The concept “reference” in itself has no definition in the VIM [1], it relates to original concepts (“primitives”). Its meaning is concretely defined in various concepts.

In Table 1 there are given two groups of the VIM terms, the definitions of which include the concept “reference”, and interpretation of the term “reference” for each of them. It should be noticed that for two groups mentioned, there are two forms of interpretation of the concept “reference. For the first group it is of a generalized character, while for the second one it is a specific implementation of the first group concepts.

The concept “metrological traceability” is a relatively new one. It is defined as “property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty.”

Metrological traceability is a property of a measurement result. In this sense it should be interdependent with such concepts as “metrological comparability of measurement results” and their “metrological compatibility.”

The relation of these concepts is illustrated by Fig.2.

In Russia the system of main concepts of metrology includes the concept “uniformity of measurements” [10, 11]. This concept it defined as a state of measurements at which measurement results are expressed through legal quantity units and accuracy characteristics do not exceed specified limits.

The concept “uniformity of measurements” implies availability of comparability and compatibility of measurement results. It is possible to say that uniformity of measurements is a result of mertological traceability of measurement results, where traceability is interpreted as a process.

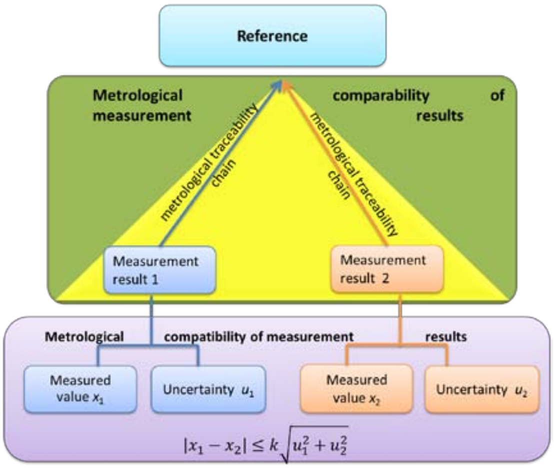

Fig.2. Relation of the terms concerning a description of a quality of measurement results

As it follows from the definition, the calibration hierarchy underlies the traceability of measurement results. However, in the sciences “assimilating metrology” validated measurement procedures plays the most important role.

Table 1. Interpretation of “reference” in various concepts

Terms given in the VIM3	Interpretation of the term “reference”
1.1 Quantity 1.19 Quantity value, value of a quantity value 1.20 Numerical quantity value, numerical value of a quantity, numerical value	• A measurement unit • A measurement procedure • A reference material
2.40 Calibration hierarchy 2.41 Metrological traceability 2.42 Metrological traceability chain, traceability chain 2.43 Metrological traceability to a measurement unit, metrological traceability to a unit 2.47 Metrological compatibility of measurement results, metrological compatibility	• A measurement unit through its practical realization • A measurement procedure including the measurement unit for a non-ordinal quantity • A measurement standard

It should be recognized that in NOTE 7 to the term "metrological traceability," there are listed elements confirming it. These elements are used by the ILAC.

Among them the documented measurement procedure is mentioned too. But we believe that the measurement procedure has to be mentioned right in a future definition of the metrological traceability.

Moreover, the measurement procedure has to become a link in the "metrological traceability chain" along with a series of measurement standards and calibrations. The calibration "connects" a measurement standard with another one or with a measuring instrument in the end of the chain. As a result of calibration, the metrological characteristics of measuring instruments are evaluated.

Therefore, it is necessary to have a final link which would "connect" the measuring instrument with a measurement result, the metrological traceability of which to a "reference" is spoken about.

The following definition of "metrological traceability of measurement results" is proposed: "Property of a measurement result whereby the result can be related to a reference through a documented measurement procedure and unbroken chain of calibrations, each contributing to the measurement uncertainty."

4. ABOUT TERMS RELATED TO MEASUREMENT INSTRUMENT COMPUTERIZATION

A number of metrological problems became particularly topical in the 21-th century. Computerization of measuring instruments opened up new possibilities enabling them to be solved.

In particular, lately for conventional fields of measurements, the significance of the problem to obtain reliable measurement results using measuring instruments, including sensors and MEMS built in transport and power station equipment, as well as machines, and so on, has sharply risen.

Practically, such measuring instruments have to operate for many years without any metrological maintenance. In many countries an intensive development of methods for solving this problem, is being carried out. This has formed a need for specific terminology [12-14].

Another issue of the day is the assurance of measurement results reliability in case of using universal calculation equipment, in particular, a PC with special software and numerous measuring facilities (hardware) connected to the computer. Such measuring instruments and systems, called virtual, are used to solve a great number of tasks as applied to measurements of various quantities. Quite often so-called cloud systems are used in the capacity of a universal calculation equipment. Since virtual instruments and systems are characterized by significant economical efficiency, they are applied more and more. Metrologists should be particularly attentive when using such instruments and systems in the spheres subjected to the state regulation. Development and use of such means requires a clear definition of terms related to this domain.

In the nearest perspective, intensive development of instruments, intended for measuring multiparameter (multidimentional) quantities, including those carrying out an image recognition, will take place. It is impossible to do without new terms in this field.

The list of examples can be continued. Unfortunately, in the VIM [1] there is no terminology related to computerized measuring instruments. There are no terms concerning validation of measuring instrument software too.

In scientific and technical literature new terms can be found, but a number of them are synonyms or characterized by some ambiguity. To form a system of interrelated terms concerning the solution of the metrological problems mentioned above, it is necessary to take into consideration tendencies of development of corresponding measuring instruments. Such an attempt was made in [14].

Below there are given a number of important terms and their definitions related to computerized measuring instruments, which are proposed to include into a future version of the VIM.

Metrological self-check of a measuring instrument: automatic procedure of testing metrological serviceability of this instrument in the process of its operation, which is realized using a reference value generated with the help of an additional (redundant) embedded element (a sensor, secondary transducer, or material measure) or additional parameter of an output signal.

Metrological serviceability of a measuring instrument in the process of operation: state of this instrument for which its uncertainty or error specified under operating conditions lies within some permissible limits.

NOTE. In the process of measuring instrument operation under working conditions, the metrological serviceability can be automatically checked using a value of the deviation of an uncertainty (or error) or critical uncertainty (or error) component from the corresponding value specified at the stage of preceding calibration.

Self-validation of a measuring instrument: metrological self-check which is accompanied by a current evaluation of uncertainty or error.

Intelligent measuring instrument: measuring instrument with the function of metrological self-check.

Virtual measuring instrument: measuring instrument intended for measuring one or a number of quantities, realized on the basis of universal computing equipment, e.g., PC, with special hardware (measuring transducers and/or material measure and other technical means) and validated software, which applies a display and/or mulimedia capabilities to present an output signal and/or control the measurement process.

In our opinion, since computerization touched measuring transducers, definitions of a number of terms given in [1] need some correction.

A definition of "measuring instrument" in clause 3.1 is rather unclear. A following definition is proposed: "Measuring instrument is a device intended for making measurements, which is characterized by metrological characteristics specified."

As for drawbacks of the terms "sensor" and "measuring system," they were described in [12, 14] in details and some proposals were grounded which will be given below.

It is expedient to treat the term “sensor” as the simplest sensing element of a measuring instrument that is “directly affected by a phenomenon, body, or substance carrying a quantity to be measured.”

For an isolated device containing one or a number of sensors, and in some cases, a number of supplementary transducers of signals, including processing devices (e.g. an amplifier, ADC, micro-controller, interface, etc.), a special term is needed too. It is very important since such a unit is often sold as a separate product, metrological characteristics being specified. For these means, the term “sensor device” or Russian word “datchik” (it originates from the word “to give”, because this device gives information) is proposed.

Examples of “sensor devices” or “datchiks”:

- platinum resistance thermometer;
- pressure “sensor device” that contains a sensor including a diaphragm with a tensoresistive bridge;
- pressure “sensor device” containing, in addition to the diaphragm and tensoresistive bridge, an extra temperature sensor (for correcting a complementary error caused by temperature influence), as well as an amplifier, ADC, microcontroller;
- “sensor device” that contains two independent resistance thermometers or two thermocouples the measurement signals of which are jointly processed in a remote device.

The following definition can be suggested as a definition of “measuring system.”

“Measuring system” is a set of sensors located in various points of space, other technical means, and common device for processing measurement information, functionally combined with the purpose to measure one or a number of quantities characterizing phenomenon, body, or substance.

Examples:

- Measuring system at a thermal power plant enabling measurement information with regard to a number of physical quantities in different power units to be obtained. It can contain hundreds of measuring channels.
- Radio navigation system determining position of various objects which consists of a number of measuring instruments located at a long distance from each other.

Certainly, the “system” is a more general concept than “instrument.” Therefore, a measuring instrument “used alone” cannot be a “measuring system.”

Taking into account the definitions suggested, NOTE 1 to clause 3.1 and the NOTE to the clause 3.2 should be removed.

Generally, the above proposals correspond to the terms and their definitions given in two state standards [15, 16] issued in Russia, as well as in drafts of the state standard “Virtual measuring instruments and virtual measuring systems. General statements” and new edition of the recommendation on intergovernmental standardization “Metrology. Basic terms and definitions.” Both drafts are included into the State system for ensuring the uniformity of measurements. The documents mentioned were developed with the participation of the authors of the present paper.

It should be noticed that the suggestions given do not cover a possible list of concepts which have to be added to the VIM or corrected due to computerization of measuring instruments.

In particular, the concept “measurement method” is very important. For example, with the help of computerized instruments special measurements which are called invariant ones, are carried out more and more often. They are distinguished by the fact that to obtain the result of measurement a number of measurements are fulfilled in a special way. Solving a system of mathematical equations it is possible to exclude practically an impact of a dangerous influence quantity on the measurement result. It is necessary to include the concept “method of invariant measurements” into the VIM.

At the same time, the analysis of clause 2.5 has shown that the formulation of “measurement method” definition needs correction. Statements given in clauses 2.5 and 2.6 differ insufficiently.

In our opinion, it is expedient to define the concept “measurement method” as a technique or set of techniques for comparing a measurand with its unit or a corresponding scale taking into account a measurement principle realized.

Moreover, the set of methods listed in clause 2.5, on one hand, does not coincide with the list given in [17], to which the VIM is referred, and, on the other hand, this list is not an exhaustive and systematized one.

5. CONCLUSION

The VIM [1] is accorded wide recognition among specialists. To remove imperfections of terms and their definitions efficiently, it is expedient to organize a long-term forum in the Internet.

In future editions of the VIM it is necessary to pay more attention to the concepts related to new fields of measurements and capabilities of measuring instruments, caused by development of new technologies.

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