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Uncertainty of measurements - impact on scientific and technological development and the role of quality system development

Isroilov Fakhriddin Murodqosimovich[1]
Islamov Usmonqul Rustamovich[2]
Bozorov Alisher Ganisherovich[3]

Email: metrologiyafaxriddin@gmail.com

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Republic of Uzbekistan,
[1,2,3]*Jizak city, Jizzax Polytechnic Institute*

ABSTRACT: *Extensive work in the field of measurement shows that its role in science and technology and in the life of human society is extremely high. And, of course, the development of society is determined by the status and capabilities of measurements and its metrological support. Ensuring the uniformity of measurements is one of the most pressing issues in metrology. Therefore, any measurement information obtained as a result of measurements (regardless of the conditions, time and place of the measurements) is important and useful in ensuring the unity of measurement in the required accuracy*

Keywords: *Uzstandart, metrologica, label, export, standard, Oz DSt, modification.*

1. INTRODUCTION

The development of human society is closely linked to the emergence and development history of a culture of measurement. This connection is the process of continuous improvement of the system to ensure the uniformity of measurements, measuring instruments and measurements. The essence and importance of metrology, ie measurements, is incomparable in the development of science and technology and opens up a wide range of possibilities in solving related problems.

Extensive work in the field of measurement shows that its role in science and technology and in the life of human society is extremely high. And, of course, the development of society is determined by the status and capabilities of measurements and its metrological support. Ensuring the uniformity of measurements is one of the most pressing issues in metrology. Therefore, any measurement information obtained as a result of measurements (regardless of the conditions, time, and place of the measurements) will be more important (and higher) only if it meets the requirement of providing a unit of measurement with the required accuracy.

Many scientists have praised the importance of measurements. For example, the great Russian scientist D.M. Mendeleev said this about it; "Any science begins with measurement, and exact science cannot be imagined without measurement."

U. Kelvin, on the other hand, said the same about measurement; "Everything is determined by the degree to which it is measured." According to philosophers, the most basic way (method) in the study of physical properties, the study of processes, is measurement.

From a technical point of view, the importance of measurements is determined by the generation of information on the management of technological processes, ensuring high product quality, facility management, control. Now we come to the part where we talk about the middle ground. The history of the science of measurements goes back thousands of years. The creation of complex systems used in the national economy, in turn, in turn, opens up prospects for the development of various areas, especially metrology and measurement technology. The development of the science of measurement, ie metrology, in turn, leads to the opening of new educational specialties in theoretical metrology on the automation of research work on information measurement techniques and technology at our university.

In other words, the development of human society is a path traversed by their sensory organs and a certain level of experience, from simple measurement to the scientific basis of measurement.

This method is the most basic of modern metrology: it teaches the science of measurements, the unity of measurements using its methods and tools, and ways to ensure it with the required accuracy. As far as we know, the observation of measurements means that the measuring instruments (OV), including the standard used in calibration and / or testing, the standard sample (SN), the size measurements, the measuring transducers, instruments, equipment and systems are related to the International System of Units (SI). If the testing and calibration laboratories want to demonstrate that they have a quality system, that they are technically competent and capable of obtaining technically sound results, they must comply with all the requirements of the General Requirements for the Competence of Testing and Calibration Laboratories. Accreditation bodies that recognize their competence should base their activities on this [1] standard. [1] The standard sets many requirements for testing and calibration laboratories (hereinafter - the laboratory). In this report, only two of them are considered, namely:

- requirements for observations of calibrations and measurements carried out by the laboratory;
- requirements for the assessment of the uncertainty of calibration and measurements carried out by the laboratory.

When observing measurements, in relation to SI system units, it can be achieved as an integral chain tool of comparison that connects them with the relevant primary standards of the SI system unit of measurement. This is a comparison national standards are definitely involved in the integral chain. National standards may be as follows.

- Primary standards, which are the primary realization of the SI system unit;
- Secondary standards calibrated in the National Metrology Institute (MMI) or MMI of another country;
- or working standards calibrated in MMI. Measurement monitoring when using external calibration services should be provided by such services provided by laboratories that can demonstrate their competence, ability to perform measurements, and monitoring of their own measurements. These calibration certificates issued by the laboratories should contain the results of the measurements, including the uncertainty value.

[1] Calibration laboratories that meet the requirements of the standard are recognized as competent. Calibration data with a logo of the accreditation body issued by an accredited calibration laboratory for compliance with the standard UzDST / ISO / MEK 17025: 2007 for this type of calibration is sufficient evidence of observation.

The tracking value of a measurement up to a unit of SI system can be achieved by reference to a natural constant known within the value range corresponding to the unit of measurement of the SI system and recommended by the General Conference of Measurements and Scales and the International Committee of Weights and Measures (IQF). and the SI units of magnetic quantities are generated according to the rationalized form of the electromagnetic field equation.

These equations include the mo-magnetic constant of the vacuum introduced by the decision of the PMU, the exact value of which is 4p • 10-7 N / m or 12.566370614 .... • 10-7 N / m (exact). In accordance with Resolution XVII on the determination of the new unit of length - the meter, the value of the speed of propagation of light (flat electromagnetic waves) in a vacuum is assumed to be s0 299 792 458 m / s (exact). These equations of the electromagnetic field also include the electric constant e0 of the vacuum, the value of which is assumed to be

8,854 187 817 .... 10-12 F / m (exact). In order to increase the accuracy of electrical unit product measurements based on the Josephson effect and Hall's quantum effect, from January 1, 1990 4, 835979 • Josephson constant equal to 10-14 Hz / V (exact) [Recommendation 1, 1988] and 25812,807 Conditional values of the Klitzing constant equal to Ō (exact) [OTXQ, Recommendation 2, 1988] are included.

Calibration laboratories that have their own primary standards or a presentation of a system of SI units based on fundamental physical variables can report the observation of their measurements against the SI system only after this standard has been directly or indirectly compared with other similar NMI standards.

Monitoring up to national measurement standards does not require the use of NMI services in the country where the laboratory is located. If the calibration laboratory wishes or is compelled to obtain observations from the NMI of another country, that laboratory should select an NMI that is directly or directly involved in MBMV activities through regional groups, such as the Eurasian Partnership for State Metrology Institutions (KOOMET). A continuous chain of calibration or comparison can be achieved through a series of steps performed by different NMIs or laboratories that are able to demonstrate the observation. For example, the laboratory compared (calibrated) its OVs at the National Standards Center of the Republic of Uzbekistan (NSEC), calibrated its standard MEMs using appropriate primary standards of SI system units of VNIIM (St. Petersburg, Russia) named after DI Mendeleev. Currently, SI system units have calibrations that cannot be strictly performed. In these cases, the calibration should ensure the reliability of the measurements by setting up observations up to the appropriate measurement standards, e.g.

- use of certified reference materials (certified standard samples of material composition and properties and (SO) materials);
- use of clearly defined and accepted, defined method and / or agreed standards with all stakeholders. Evaluation of measurement uncertainty An accredited laboratory that performs tests or self-calibration and is accredited in accordance with UzDST / ISO / MEK 17025: 2007 must have and apply a measurement uncertainty assessment procedure for all calibrations and types of calibrations. We know from the international document “Guide to the expression of uncertainty in measurements” (hereinafter referred to as the Guide) [2] that measurement uncertainty is a parameter related to measurement results that describes the dispersion of values that can be added based on the measured quantity. The uncertainty of the measurement results, expressed as the standard deviation of the magnitude estimate (arithmetic mean), is called the standard uncertainty of the magnitude estimate.

In addition to the terms “uncertainty” and “standard uncertainty” [2], other terms in the field of measurement uncertainty have been used, in particular: aggregate standard uncertainty; extended uncertainty - an interval description of uncertainty; relative uncertainty.

[2] The uncertainty of the input sizes according to the manual is estimated for type A or type B. Type A (uncertainty) assessment is a method of estimating uncertainty through statistical analysis of a series of observations. Type B (uncertainty) assessment is a method of estimating uncertainty other than the statistical analysis of a series of observations.

The measurement uncertainty assessment procedure includes, among other procedures, the measurement uncertainty reporting procedure.

When preparing a measurement uncertainty report, it should be borne in mind that the amount of information required to document the measurement results depends on the approximate use of the measurement results.

Moving up the technical hierarchy from the technical hierarchy to the precision metrological measurement, it is necessary to provide more details about the evaluation of the measured (output) quantity and how the associated uncertainty is obtained.

At any level of this hierarchy, the uncertainty report should include all the information necessary to allow any metrologist to understand it, to re-examine the quality of measurements in the future if necessary, or to

improve it if new information or data emerges. It is always better to give a lot of information than to give very little information [2].
It is recommended that the Uncertainty Report be prepared in 9 sections.
Section 1 - Measurement function: measurement method and / or methodology; measurement scheme or plan; equipment used; it is necessary to give a brief description of how the measured Y quantity is determined by adding the measurement conditions.
Section 2 - Measurement Model: Mathematically expressing the relationship between the output magnitude Y and the input magnitudes Xi associated with them:
Y = f (X1, X2,..., Xn).
Section 3. Input size analysis.

Access size:_________ ______________________ ______________________	Type of uncertainty assessment: _______ Type of distribution: _________________ Evaluation value: _________________ Interval with input size value: ____________________ Standard uncertainty: ______________
A brief description of where and on what assumptions and grounds the above information is obtained, or an indication of the source from which the above information (reference, calibration certificate or certificate, specifications, passport to the measuring instrument, etc.) is obtained.	

Section 4. Observation results: results of observation of the input size calculated directly from the instrument and determination of their statistical characteristics: arithmetic mean; standard deviation (standard) deviation; standard uncertainty.
Section 5 Correlation: Calculate the correlation coefficient for all correlated input magnitudes, indicating the method of analyzing them and calculating the input magnitude for the purpose of correlation of the input magnitude.
Section 6 Sensitivity Coefficient: Obtain a sensitivity coefficient for each input size either experimentally based on the calculation of the individual ∂f / ∂xi expression or by specifying the method of obtaining.
Section 7. Uncertainty budget: The uncertainty budget is made in the form of the following table.
Table 1. Uncertainty budget.

Size Xi	Unit of size	Estimated value x i	Interval ± ,	Type of uncertainty	Probability distribution	Standard uncertainty, u (xi)	Space phase, c	Sensitivity coefficient, si	Uncertainty contribution, ui (y)	Interest rate,%
X1		x1				u (x1)		c1	u1 (y)	
X2		x2				u (x2)		c2	u2 (y)	
. . .		. . .				. . .		. . .	. . .	
Xn		xn				u (xn)		cn	un (y)	
Y		y				u (y)				

Section 8. Extended uncertainty: Determining the coverage ratio based on the selected level of reliability and calculating the extended uncertainty.

Section 9. The complete result of the measurement: the measured magnitude Y indicates the extended uncertainty as the unit of measurement for U and y,

$$Y = y \pm U$$

to present the complete result of the measurements consisting of estimating y (arithmetic mean value) in the form.
The degree of accuracy required in evaluating and compiling a measurement uncertainty report depends on factors such as the requirements of the measurement method and the customer's requirement. Extensive work in the field of measurement shows that its role in science and technology and in the life of human society is extremely high. And, of course, the development of society is determined by the status and capabilities of measurements and its metrological support.

Ensuring the uniformity of measurements is one of the most pressing issues in metrology. Therefore, any measurement information obtained as a result of measurements (regardless of the conditions, time, and place of the measurements) will be more important (and higher) only if it meets the requirement of providing a unit of measurement with the required accuracy.

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The development of the science of measurement, ie metrology, in turn, leads to the opening of new educational specialties in theoretical metrology on the automation of research work on information measurement techniques and technology at our university. This, of course, requires almost all specialists to raise the knowledge and skills in metrology to a higher level.

For this reason, the low-power, inert instruments that have been used in the past are gradually being replaced by very fast, high-performance devices, which is changing the performance of those who perform the measurement and, of course, the demand for them.

In assessing measurement uncertainty, all constituent uncertainties that are significant in this situation should be considered using appropriate analysis methods. The source of uncertainty is the standards used, the OV, the methods and equipment used, the environment, the nature and condition of the product being tested or calibrated, as well as the operator (not limited).

When a non-standard method is required, an uncertainty assessment procedure should be developed prior to testing and / or calibration. Non-standard methods should be agreed with the customer and include a clear description of customer requirements and the purpose of testing and / or calibration. In 1978, the International Committee of Measurement and Scales (ICMC), the world's largest metrology authority, appealed to the International Bureau of Weights and Measures (MBMV, BIPM) to consider this issue, acknowledging the lack of international unity in assessing the accuracy characteristics of measurements did. As a result, national metrological laboratories of 32 countries and 7 international organizations were involved in solving this problem:

- International Committee of Weights and Measures (MKMV, CIPM);
- International Bureau of Weights and Measures (MBMV, BIPM);
- International Electrotechnical Commission (IEC, IEC);
- International Federation of Clinical Chemistry (MFKX, IFCC);
- International Organization for Standardization (ISO, ISO);
- International Association of Pure and Applied Chemistry (IUPAC, IUPAC);

- International Association of Pure and Applied Physics (IUPAP, IUPAP);
- International Organization of Legal Metrology (MOZM, OIML).

In 1993, the international document "Guide to the expression of uncertainty in measurements" [1] was developed in French and in 1999 was published in Russian [2].

The purpose of this guide is:

- provide complete information on how to compile a measurement uncertainty report;
- to create a basis for international comparisons of measurement results.

After its publication in 1993, the manual introduced the status of an informal international standard, which was agreed upon in the assessment of all scientific and technical measurements and the global unity and uncertainty of measurement tariffs.

Other countries have made it mandatory for regional and national standards, European Standards for Accreditation of Sample Comparison and Testing Laboratories EN 45001, to provide quantitative results of measurements with uncertainty values.

After the adoption of the international standard ISO / MEK 17025: 1999 [3], the validity of the requirements for testing and calibration laboratories became the international requirements for the assessment of uncertainty in accredited laboratories.

Various foreign metrological organizations and institutes have developed guidelines for a specific area of metrological activity based on this requirement [4-6].

Based on the above, if testing and calibration laboratories want to demonstrate that they have a quality system in place, that they are technically competent and able to obtain technically sound results, they are entitled to “General Requirements for the Competence of Testing and Calibration Laboratories”. Must comply with all requirements of UzDST / ISO / MEK 17025: 2007. One of these requirements is the requirement to assess the uncertainty of calibrations and measurements performed by the laboratory.

Measurement uncertainty is a parameter that is related to the measurement result and describes the scattering of them (values), and it may be reasonable to assume that it corresponds to the measured quantity.

In relation to the results of measurements, the standard deviation (RMS) of the result of individual measurements is usually used as a parameter characterizing the scattering of values. The measurement uncertainty of the arithmetic mean expressed in terms of OKO, i.e. standard deviation, is called standard uncertainty.

The term “uncertainty” implies that uncertainty refers to the degree to which a measurement quantity corresponds to the measurement result and the level of confidence that the measured value lies within (within) certain intermediate values under the measurement conditions.

Thus, the measurement uncertainty:

• our knowledge of the measured quantity after measurement;
• the quality of their measurements in terms of accuracy;
• can be called a measure of the reliability of the measurement result as an estimate for the measured magnitude value.

The process of estimating the value of the measured quantities and its uncertainty can be visualized in the following 8 steps:

• definition of measurement and its modeling;
• estimate the values of input catalogs and their standard uncertainties;
• correlation analysis;
• budgeting uncertainty;
• calculate the value of the output size;
• calculation of standard uncertainty of output size;
• calculation of extended uncertainty;
• provide the final (final) result of the measurement.

Uncertainty is usually evaluated using a mathematical model of measurement and the law of distribution of uncertainty. Thus, the measured quantity Y should be expressed in general terms, which is reflected by the functional dependence:

Y = f (X1, X2,…, Xn), (1)

where, the quantities Xi (i = 1, 2,…, n) are called the input magnitudes and Y is the output magnitude.

A list of sources of uncertainty is used to simplify the construction of a mathematical model of measurement and to determine the input quantities for each specific measurement required.

Sources of uncertainty are: measurement methods (number of observations, duration of measurement, selection of measurement method, selection of standard or measuring instrument, selection of appropriate filter, standard sample, etc.); measuring devices (calibration uncertainty, variation of readings, time elapsed from the last calibration moment, software used, sensitivity threshold or last allowable capacity, temperature, etc.); environment (temperature, humidity, pressure, building

purity, magnetic and gravitational fields, vibration, various radiation, light, etc.); the object being measured (deviation from shape for temperature, surface, material, dimensions, geometric measurements, etc.); operator (effort to measure, work experience, choice of measuring tool, information, parallax, conscientiousness, dexterity of hand, etc.).

The laboratory should evaluate the suitability of non-standard methods to confirm the suitability of the method for its intended use. The laboratory should record the results obtained, the procedures used to assess suitability, and the decision as to whether the method is appropriate for the intended use.

Assessing the validity and effectiveness of a method is determined by several methods or their combination, including an assessment of the uncertainty of the results based on a scientific understanding of the theoretical principles of the method and practical experience.

Depending on the type (statistical or non-statistical) of the available data on the change in magnitude and magnitude values, the input quantities are evaluated for standard uncertainties type A and type B.

If the magnitude information is statistical, i.e. obtained as a result of multiple measurements by experiment or test, then the standard uncertainties of the input magnitudes are evaluated according to type A.

If the size information is non-statistical, that is, the result of some independent assessment without assessment during this measurement (in the calibration certificate and other certificates, standard, specifications, passport, manufacturer

if the output is obtained from the classification, directory and other data sources) and the limits of the scope in which only one value, or magnitude value can be located, then the input uncertainties are evaluated according to the standard uncertainty type V.

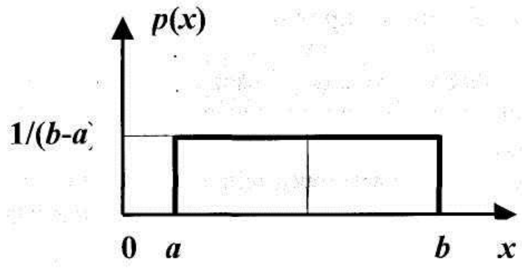
Estimation of the standard uncertainty on type A is based on any method used in the processing of statistical data [7-10], i.e. on the basis of a series of standard deviations and average value observations, e.g. based on calculations using a formula.

$$u(\bar{x}) = S_{\bar{x}} = \sqrt{\frac{1}{n(n-1)} \cdot \sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2} \qquad (2)$$

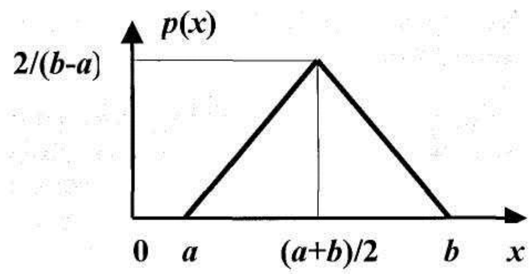
The assessment of standard uncertainty for type B is based on scientific discussion. Evaluation on type B is based on all the information about the value of magnitude and its possible variability, and requires great skill, knowledge, experience from the specialist.

It is necessary to correctly describe the available data on Xi, then their magnitude and standard deviation using the probability distribution function, or to determine whether it belongs to the probability distribution function.

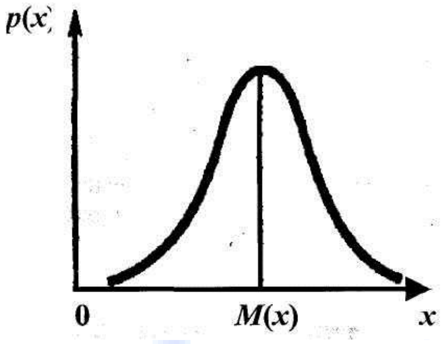
The following basic divisions are used in the assessment of standard uncertainty on type V: tenge probability (right angle or straight), Simpson (triangle), trapezoidal, normal (Gauss) and others. The probability distribution function is presented in the following forms.



Equal probability (right angle or straight)



Simpson (triangular)



Normal (Gauss)

Standard uncertainty of data with different probability distributions The evaluation of u (x) for type B is carried out using the following formula

u (x) = a / k, (3)

where a is the half-width of the probability distribution (polushirina);

k is the coverage factor.

The coverage coefficient k is equal to e for a probabilistic (right-angled or straight) distribution, e for a Simpson (triangular) distribution, and e with a probability of 99.73% for a normal distribution.

We now turn to the methods for estimating the standard uncertainty of the output (indirectly measured) size.

Output quantities standard uncertainties Input (directly measured) quantities are represented using standard uncertainties and therefore it is called the sum standard uncertainty and is denoted by us (u).

The sum standard uncertainty is calculated as follows

$$u_c(y) = \sqrt{\sum_{i=1}^{N} \left(\frac{\partial f}{\partial x_i} \right)^2 u^2(x_i)} \qquad (4)$$

∂ f /∂ xi= ci the sensitivity coefficient. Sensitivity coefficients show a change in the output value with a change in the input values x1, x2,..., xn where the derivative division

For some of the measurements encountered in practice, formulas for calculating their sum standard uncertainty were generated using (4) and are given in the table below.

Mathematical models (functions) of measurements	Summary standard uncertainty
Y = X1 + X2+… ёки Y = X1 – X2–…	$u_c(y)=\sqrt{u^2(x_1)+u^2(x_2)+...}$
Y = X1 . X2 … ёки Y = X1 / X2	$u_{co}(y)=\frac{u_c(y)}{y}=\sqrt{\left(\frac{u(x_1)}{x_1}\right)^2+\left(\frac{u(x_2)}{x_2}\right)^2+...}$
Y = Xn	$u_c(y)=n\cdot x^{n-1}\cdot u(x)$ *ёки* $u_{co}(y)=\frac{u_c(y)}{y}=n\cdot\frac{u(x)}{x}$
$Y=(X_1+X_2)\cdot(X_3+X_4)$ *ёки* $Y=\frac{X_1+X_2}{X_3+X_4}$ *ёки* $Y=(X_1-X_2)\cdot(X_3-X_4)$ *ёки* $Y=\frac{X_1-X_2}{X_3-X_4}$	$u_{co}(y)=\frac{u_c(y)}{y_1}=\sqrt{\frac{u^2(x_1)+u^2(x_2)}{(x_1+x_2)^2}+\frac{u^2(x_3)+u^2(x_4)}{(x_3+x_4)^2}}$
$Y=X_1^n+X_2^m$ *ёки* $Y=X_1^n-X_2^m$	$u_c(y)=\sqrt{\left[n\cdot x_2^{n-1}\cdot u(x_1)\right]^2+\left[m\cdot x_2^{m-1}\cdot u(x_2)\right]^2}$
$Y=X_1^n\cdot X_2^m$ *ёки* $Y=X_1^n/X_2^m$	$u_{co}(y)=\frac{u_c(y)}{y}=\sqrt{\left(n\cdot\frac{u(x_1)}{x_1}\right)^2+\left(m\cdot\frac{u(x_2)}{x_2}\right)^2}$
$Y=(X_1^n+X_2^m)\cdot(X_3^k+X_4^l)$ *ёки* $Y=(X_1^n-X_2^m)\cdot(X_3^k-X_4^l)$ *ёки* $Y=(X_1^n+X_2^m)/(X_3^k+X_4^l)$ *ёки* $Y=(X_1^n-X_2^m)/(X_3^k-X_4^l)$	$u_{co}(y)=\sqrt{\frac{\left[n\cdot x_1^{n-1}u(x_1)\right]^2+\left[m\cdot x_2^{m-1}u(x_2)\right]^2}{\left(x_1^n+x_2^m\right)^2}+\frac{\left[n\cdot x_3^{k-1}u(x_3)\right]^2+\left[n\cdot x_4^{l-1}u(x_4)\right]^2}{\left(x_3^k+x_4^l\right)^2}}$

When calculating the sum standard uncertainty, formula (4) can be used only in cases where the input quantities are not correlated.

There may be a certain correlation between the two input sizes, if in determining them:

- only one measuring instrument;
- or measuring instruments of different copies calibrated in one standard;
- reference information with a certain standard uncertainty;
- and others.

Ignoring the correlation between the input sizes can lead to an incorrect estimation of the standard uncertainty of the output size. Since it is not possible to dwell on the issues of determining the correlation between the two input sizes and calculating their standard uncertainty, this issue will be covered in the scientific and technical journal of the Agency "Uzstandard".In most cases, the level of uncertainty has to be set in the form of an interval. Most of the measurement results lie in this interval, and it can be said that it applies to a measured quantity with sufficient accuracy. Such a level of uncertainty is called extended uncertainty.

Extended uncertainty The sum of the output size U is found by multiplying the standard uncertainty by the us (u) coverage factor

$$U = k \cdot uc(y) \qquad (5)$$

In many practical cases, for example, the confidence level is assumed to be k = 1 in the range of 68%, k = 2 in the range of -95%, and k = 3 in the range of -99%.

The final result of the measurement - the estimate of the magnitude - should be presented together with its uncertainty report. The result of the magnitude value measurement can be described in the interval view as follows:

$$Y = y \pm U, \quad \text{ёки} \quad y - U \le Y \le y + U \qquad (6)$$

This notation states that the best estimate of a value belonging to the measured Y quantity is y, and that the interval from (y – U) to (y + U) is R, e.g., 95%, with reliability.

The amount of information reflected in the uncertainty report depends on where and for what purpose the measurement result is used. For example, the higher the rank of measurements in the hierarchy of precision metrological measurements from technical measurements, the more detailed the report on the value of the measured quantity and how its uncertainty was found.

The report on uncertainties at any stage of this hierarchy should include all necessary information. This is because this report should be understood by any other metrologist. It should be possible if new information or data on this magnitude later arises and it is necessary to re-evaluate the quality of the measurements in the future. In this case, it is better to give a lot of information, even if it is superfluous, than to give very little information [11]. Today, the automation, computerization and use of modern technologies of measurement processes can be achieved only on the basis of a programmed system. The application of complex empirical (selection, selection) methods, statistical methods based on the theory of probability plays an important role in the development of modern metrology, which forms the scientific basis of metrology.

In order to make a measurement in scientific research or production, it is first necessary to: 1) determine what is to be measured or the object of measurement, and by what physical quantities that object is characterized; 2) what tool is used, that is, it is necessary to use the most optimal variant measuring tool to achieve the required result, and finally; 3) how accurate the measurement should be. In other words, the issue of measurement must first be clearly defined.

Measurements can be made by summarizing the requirements for the accuracy of measurements in any industry, such as electrical engineering, mechanics, medicine, scientific research, etc. (Figures 1, 2).

The above set of measurements can be carried out using a national measurement system, which is of course highly organized and equipped with modern instrument infrastructure, as well as compliance with the conditions of ensuring the unity of measurements, their reliability and accuracy.

Based on the above, it is time for bachelors and masters to master the assessment of the uncertainty of measurements and tests in the process of training specialists to work in accordance with the requirements of international standards in the field of product quality management, metrology and certification.

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