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ALMATY UNIVERSITY OF POWER ENGINEERING & TELECOMMUNICATIONS

Department of Automation and Control

METROLOGY, STANDARDIZATION, CERTIFICATION AND QUALITY MANAGEMENT

Lecture notes
for specialty 5B070200 – Automation and control

Almaty 2017

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This lecture abstract is based on the working program to help students study theoretical material on metrology, standardization, certification and quality management and includes ten themes. At the end of each topic there are references to additional literature for a deeper exploration of the subject. Electronic versions of the lecture material are placed on servers of computer classes of the department "Engineering Cybernetics" and in the electronic library of AUPET.
The lecture notes are intended for students of the specialty 5B070200 - Automation and Control.

Il.15, table 1, references – 12.

Reviewer: Buchina S.B., senior instructor of department for language studies

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Content

Introduction

One of the basic conditions for the accession of the Republic of Kazakhstan to the World Trade Organization (WTO) is the harmonization of the national system of standardization, certification and metrology with international rules. Modern specialists need sufficient knowledge in this area in order to use creatively foreign experience, take new progressive solutions that allow producing high-quality competitive products.

Standardization, certification and metrology are inextricably linked, therefore their study in one training course gives a more complete picture of the importance of each of these areas of activity and their totality to establish a market economy in our country, develop foreign economic activity of enterprises on a modern civilized basis, ensure the conditions necessary for country's accession to international certification systems and accession to the WTO, which would positively affect directly the export enterprises (firms).

The purpose of teaching the discipline "Metrology, standardization, certification and quality management" is to form that minimum knowledge of students in the field of metrology, standardization, certification and quality management, which further allowing a young specialist to improve himself, to make technical decisions at international, regional and national levels, as well as to form skills of application of methods and practical bases of the course while calculating errors of measuring instruments, total errors of measuring channels and the calculation of the effectiveness of standards.

The courses "Metrology, standardization, certification and quality management" is developed for the 2-nd year students of the specialty "Automation and control" as a selective disciplines. Nevertheless, the knowledge of the material of this discipline for future specialists (bachelors, engineers) of a technical profile related to the development or maintenance of various equipments or measuring instruments, is, in our opinion, mandatory. The working program of the discipline "Metrology, standardization, certification and quality management" includes a large amount of theoretical and practical material. However, the limited hours of practical classes do not allow the full presentation of the necessary information, so most of the material must be self studied under teacher’s supervision (SWSS).

It should be noted that the proposed publication is only a short abstract of lectures and can’t contain all the necessary information. An electronic version of the lecture notes can be found in the electronic library of AUPET. For successful and comprehensive mastering of the material, you should use other sources of literatures.

There is a vocabulary of new worlds and definitions at the end of lecture notes.

1 Lecture № 1. Metrology - Scientific Basis of State System for Ensuring the Uniformity of Measurements (SSM)

Lecture content: role of discipline "Metrology, standardization, certification and quality management" in training bachelors on the automation and its relationship with other disciplines; law (legal), fundamental and practical metrology; The International System of units of physical quantities.

Lecture objective: study basic definitions and concepts of modern metrology, basic articles of the Law "On ensuring the uniformity of measurements."

The Republic of Kazakhstan has come into a market economy. In order to become an equal member of the world economy and international economic relations, it is necessary to improve the national economy, taking into account global developments and trends. What hinders the integration of Kazakhstan into the civilized economic production? It is:

- lag of the national system of standardization and certification;
- providing only the uniformity of measurements;
- the remnants of soviet planned;
- the difficulties of national enterprises in today's business struggle not only on the external markets, but also in domestic ones.

Due to the fact that it is impossible to transfer mechanically the foreign experience into the domestic production, our specialists need to know it and have the outlook broad enough, to be creative in the development and adoption of new advanced solutions to make products, services that can be implemented in our country or abroad at the proper level. The knowledge in the field of metrology, standardization and certification extremely important for experts, not only in the production sector, but also for specialists in sales, management and marketing. This knowledge is important for the implementation of science and technology in production in order to use the features and benefits of standardization and certification in creating competitive products.

The need of knowledge of metrology, standardization and certification for modern experts is proved by the introduction of this course in the curriculum of the specialty. To determine the place of this course among other subjects studied by students of specialty "Automation and Control", let us consider the structure scheme of the automated process control system (APCS), as contained in appendix A, in the form of individual blocks studied by different disciplines.

Raw materials, reagents are delivered to the subject of automation (SA), which can be a part of a technological process. Various external influences (EI), for example, ambient temperature, vibration, pressure, etc., also effect over the SA. Various products are output then.

Measuring information about SA to form the automation process is obtained by measuring instruments - sensors (S) and secondary devices (SD). Modern productions are characterized by considerable complexity and technological device power and a large number of different parameters that must be measured.

Measurements are carried out by means of special technical instruments of different complexity and operating principles, known as measuring instruments, installations and systems related to measurement technique.

Modern measurement techniques, their classification, metrological characteristics and various properties are studied by the section of metrology.

Students will study computers, software for the development of mathematical models (MM) processes and objects, analog-to-digital converter (ADC), digital-to-analog converter (DAC), automatic regulators (AR), actuators (A), in other disciplines such as computer science, mathematical modeling, components and automation equipment, microprocessors and microprocessor systems, process automation and others.

Metrology is a scientific basis of the State System for ensuring the uniformity of Measurements (SSM). Metrology is the science of measurements, methods and means to ensure their unity and required accuracy. "Metro" means a measure (Greek.), "Logos" means a lerning (knowledge) (Greek.).

Modern metrology includes three types:

- legal metrology;
- fundamental (scientific) metrology;
- practical (applied) metrology.

Legal Metrology is Metrology type that includes a set of interrelated and interdependent common rules, and other issues that need a regulation and supervision of the State, aimed at ensuring the uniformity of measurements and sameness of measuring instruments.

Legal metrology is a means of state regulation of metrological activities by laws and legislative provisions that are introduced into practice by the State metrological service (SMS) and the metrological services of state authorities and legal persons.

Legal metrology includes testing and confirming the type of measuring instruments (MI), state metrological control and supervision of MI, as well as actions to real ensuring the uniformity of measurements. One of the main objectives of metrology is to ensure the uniformity of measurements.

This objective can be solved by following two basic conditions:

- to express the results of measurements in a unified legal units;
- to establish allowable errors of measurement results and limits beyond which they should not be exceeded with a given probability.

The uniformity of measurements is a condition of measurements at which their results are expressed in legal units and errors are known with a given probability and do not exceed the specified limits.

The uniformity of measurements is necessary in order to compare the results of measurements made by different measuring devices in different places and at different time.. And the conservation of the uniformity of measurements is important both within the country and in relations between the countries.

The Law "On ensuring the uniformity of measurements" [11] was adopted in 1993. Until 1993, the rules of law in the field of metrology were established by the

Government. The law "On ensuring the uniformity of measurements" set a lot of innovations - from the terminology to licensing metrological activities.

The main articles of the Law set:

a) organizational structure of state control by ensuring the uniformity of measurements;

b) normative documents to ensure the uniformity of measurements;

c) units of physical values and State etalons of the units of physical values;

d) instruments and methods of measurement.

Fundamental and practical metrologies appeared in ancient times. In Ancient Russia ancient Egyptian units of measurement were the basis of measures, taken from ancient Greece and Rome. The names of units and their sizes corresponded to feasibility (possibility) of measuring by "improvised" means, without the use of special devices.

For example, at different times in Russia length units were:

- *cubit* (from the elbow to the end of the middle finger);
- *span* (the distance between the ends of the thumb and index finger of an adult);
- *arshin* (the appearance of an arshin led to the disappearance of an inch = ¼ arshin);
- *sazhen* (Russian measure is equal to 3 cubits = 152 cm);
- *kosaya sazhen* = 248 cm.

Russian measures of length have been agreed with British ones by the Decree of Peter 1:

- *an inch* ("finger" = 2.54 cm);
- *english foot* = 12 inches = 30.48 cm;
- *yard* = 3 feet (0.9144 meter).

The first metric system was introduced in France in 1840. Its importance was emphasized by D.I. Mendeleev as a means of promoting the «future desirable rapprochement of peoples".

With the development of science and technology the new measurements and the new units were needed, stimulated the development of fundamental and applied metrology. Originally the prototype of measurement units was founded for in nature, exploring the macro-objects and their motion.

Thus, *the second* was a part of the period of Earth rotation around its axis. Gradually, the search shifted (moved, changed) to the atomic and intra-atomic level. Now *the second* is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two levels of the hyperfine structure of the ground state of the Cesium atom -133 in the absence of perturbation from external fields.

Thus, metrology, as a science, is dynamically developing.

The further development of fundamental metrology is confirmed by the determination of physical values (PV) adopted in the International (practical) System of units (SI), which give an idea of natural origin of adopted units of PV.

The system of physical units is a combination of basic and derived units of physical values.

The General Conference about Measures and Weights (GCMW) in 1954 identified six basic units of PV for their use in international relations: *a meter, a kilogram, a second, an ampere, Kelvin, a candle.*

In 1960, the eleventh GCMW adopted the International System of units of physical values (SI), which was taken by all major international organizations of metrology. In the Soviet Union, this SI- system was adopted in 1963.

The main units of PV in SI are:

a) *unit of length* – a meter - is the length of the path that the light travels in a vacuum during 1/299 792 458 of a second;

b) *unit of mass* – a kilogram - is the mass, which equals to the mass of the international prototype of a kilogram;

c) *unit of time* is a second (definition was given above in lecture №1);

g) *unit of electric current* – an ampere - is the force of constant current which, when passing through two parallel conductors of infinite length and negligible circular cross-section, located at a distance of 1 m from one another in the vacuum, would create between these conductors a force equal to $2 \cdot 10^{-7}$ N for each meter of length;

d) *unit of thermodynamic temperature* - Kelvin – is 1 / 273.16 of the thermodynamic temperature of the triple point of water (the use the Celsius scale is allowed);

e) *unit of substance amount* - a mole - is the substance amount of a system that contains as many structural elements as atoms contained in the nuclide of Carbon-12 having the mass of 0,012 kg;

g) *unit intensity of light* – a candle – is an intensity of light in a given direction of a source that emits monochromatic radiation of frequency $540 \cdot 10^{12}$ Hz, energy force of which in this direction equals to 1/683 W /sr^2.

Steradian - sr - a unit of measuring space (spatial, solid) angle.

More information on terms can be obtained in [1-6].

2 Lecture № 2. Basic Types and Methods of Measurements

Lecture content: basic informations about measurements; basic equation of measurements; classification of measurements; classification of methods of measurements.

Lecture objective: to study the definitions and concepts of measurements, various types and methods of measurements.

Measurement is a process of obtaining experimentally the numerical ratio between the measured value and some of its value taken per unit of comparison.

A number representing the ratio of a measured value to a unit of measurement is named *a numerical value of a measured quantity*. And it can be a whole or fractional, but it is an abstract number. The value taken as *a unit of measurement* is called *a size of a unit*.

Then *a basic equation of measurement* can be written as follows:

$$X = A \cdot u \quad , \tag{2.1}$$

where X - is a measured value;

A - is a numerical value of a measured value;

u - is a unit of measurement (*dimension*).

The value depends on the size of the selected units. For example, X = 1 m = 100 cm = 10 dm.

The result of any measurement is *a denominated number*.

Measurements are usually carried out on measurement objects. *A measurement object (MO)* is a physical value. *A physical value (PV)* is one of the properties of the physical object (phenomenon, process), which is *common in quality* for many physical objects and *individual in quantity* for each one. Examples of the physical value are: temperature, specific weight (gravity), density, length and others. *The size of a physical value* is the quantitative content of properties in the object corresponding to the concept of "physical value ". *The size of physical units* can be of any type. However, measurements should be carried out in adopted units (lecture №1, International system - SI).

A physical value selected for measurement is named *a measurand or measured value*. *A measuring instrument* (MI) (device, tool) is a technical mean used for measurements and having normalized metrological characteristics (figure 2.1).

An influence physical value (IPV) is a physical quantity that is not measured by the MI, but having an impact on the measurement result of this measuring instrument (ambient temperature, humidity, electromagnetic field, vibration, and so on).

A measurement result is *a physical value* found by measuring it.

They are:

a*) a true physical value* is a value, which would really reflect to qualitatively and quantitatively the corresponding property of an object. In the philosophical aspect *a true value is always unknown.* Improving the measurement allows to come close to a true physical value;

b*) an actual physical value* is a value found experimentally and approaching as close to the true value, as for this purpose it can be used instead of him. It was determined experimentally by using the standart (etalon).

To have an idea about a performed or intended measurement is necessary to know its basic characteristics (principle of measurement, method of measurement and error (sometimes accuracy) of measurement).

A measuring principle is a set of physical phenomena on which the measurement is based.

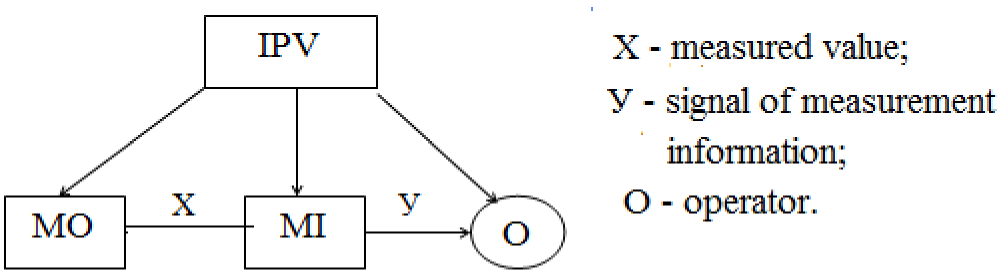

Figure 2.1 - Diagram of a measurement process

A method of measurement is a set of methods to use principles and measuring instruments.

The imperfection of manufacturing MI, inaccuracy of their calibration, IPV effect, subjective human error and other factors are the reasons for the appearance of measuring errors.

A measuring error is a deviation of measurement result X_m from the actual (true) value of measurand X_{act}:

$$\Delta = X_m - X_{act} . \tag{2.2}$$

An accuracy of measurement characterizes the degree of approximation of a measuring error to zero, that is approaching the values obtained in the measurement to the true value.

Quantitatively, the accuracy can be expressed as:

$$\varepsilon = \left| \frac{X_{true}}{\Delta} \right| . \tag{2.3}$$

While determining errors and accuracy instead of *true* physical *value X_{true} actual value X_{act}* can be used.

The classification of measurements is given in Appendix B (Figure B.1).

According to the fifth classification feature - by the method of obtaining the measurement result – there are the following types of measurements.

Direct measurements are the measurements in which a search value is determined directly from experimental data:

$$Y = X, \tag{2.4}$$

where Y – is search value;

X – is value determined directly from experimental data.

These are measurements with instruments graded in units of measuring value.

Examples

1 Current measurement - by an ammeter.

2 Temperature measurement - by a thermometer.

Indirect measurements are the measurements, in which a search value is determined from the known relationship between this value and the values determined by direct measurements:

$$У = f(x_1, x_2, .., x_m), \quad (2.5)$$

where Xm - are the values determined by direct measurement.

E x a m p l e s

1 Density – by weight and volume of the body.

2 Electric resistance - by voltage and current, and so on.

Aggregate (joint) measurements are the measurements, in which search dissimilar values are determined by solving a system of equations relating search values with directly measured values:

$$\begin{aligned} &F_1 (Y_1, Y_2, . . ,X_1^1, X_2^1, . . , X_m^1) = 0; \\ &F_2 (Y_1, Y_2, . . ,X_1^2, X_2^2, . . , X_m^2) = 0; \\ &- \\ &F_m (Y_1, Y_2, . . ,X_1^m, X_2^m, . . , X_m^m) = 0, \end{aligned} \quad (2.6)$$

where $Y_1, Y_2, Y_3,\ldots Y_m$ - are search dissimilar values;

$X_1, X_2, X_3,\ldots X_m$ - are directly measured values.

Depending on the purpose and accuracy the measurements are divided into laboratory (accurate) measurements and technical ones.

Laboratory (accurate) measurements are those measurements that are usually carried out and repeated many times by measuring instruments of high accuracy.

Technical measurements are the measurements performed once by the help of working (technical) instruments graded in the appropriate units of measuring values.

The classification of methods of measurements, widely used in the thermal measurements, is presented in Appendix B (figure B.2).

A measure is MI reproducing a physical value of a given size. This classification feature is the presence or absence of a measure when we do measurements.

The method of direct evaluation (MDE), no measure, is a method of measurement, in which the value is determined directly by a meter reading the measured value from the scale of the direct action device.

E x a m p l e - Weighing a load on the spring balance, t^0 - by thermometer.

To improve the accuracy of measurements, in particular linear ones, one can use the reference scale and vernier (nonius) (auxiliary scale). This method is characterized by using the coincidence of scale marks (based and auxiliary).

The method of comparison with the measure (MCM) is a method of measurement in which the measured value is compared with the value currently reproduced by the measure.

Depending on the presence or absence of the difference between a measured value and the value directly reproduced by the measure, there are a zero method and differential ones.

A zero method is MCM, in which the difference between the measured value and the value reproduced by the measure, affects on the measuring instrument and is adjusted *to zero*.

E x a m p l e - Weighing a load on the equal-arms balance without scale when the mass of the load is determined by the mass of weights balancing the load.

A differential method is MCM, in which *the difference* between the measured value and the value reproduced by the measure, affects on the measuring instrument and is measured.

E x a m p l e - Weighing a cargo on equal-arms arrow scale device and if having the difference between the cargo and the weight reproduced by measure, this difference is indicated by the arrow of the device on the scale.

a) *method of opposition* is MCM, in which the measured value and the value, reproduced by the measure, simultaneously affect on the comparison device which eliminates the relationship between these values;

b*) substitution method* is MCM, in which the measured value is replaced by a known value, reproduced by a measure;

c) *coincidence method* is MCM, in which the difference between the measured value and a value reproduced by a measure is measured using the match of scale marks or periodic signals.

A differential method is possible only at the presence of a high-precision measure, close in value to the measured quantity.

More information on the term can be obtained in [1-5,8,9].

3 Lecture № 3. Measuring Errors

Lecture content: classification of measuring errors; random and systematic errors; laws of random value distribution.

Lecture objective: learn basic definitions of various types of measuring errors, basic characteristics of the distribution law of a random value, evaluations of basic characteristics of a number of observations.

Depending on the nature of appearing, the causes of emergence, the nature of changes there are measuring errors, the classification of which is presented in Appendix C in figure C.1.

Depending on the nature of appearance there are *random and systematic errors.*

Random errors are errors changing randomly *in repeated measurements* of the same values.

The quantities and sign of a random error can't be determined. To account the random error multiple (statistical) measurements are performed. Assessing the random error, one can speak about *an expected error*.

A gross error is a random error that is significantly higher than an expected error in the given conditions.

A blunder is an error, which is really distorts the measurement result. We can take a random subjective experimenter error as a blunder. Gross errors and blunders are usually excluded from experimental data before the statistical analysis of observations.

A systematic error is an error of measurement, remaining constant or changing regularly with repeated measurements of the same value.

If a systematic error is known and has a certain value and sign, it can be eliminated *by correcting at the end of the measurement*. If you know the source of a systematic error, it must be removed before the beginning of the measurement.

By the causes of emergence systematic errors are divided into: errors of measurement method, instrumental errors, installation errors, subjective errors and methodical errors.

The error of measurement method (theoretical error) is an error of the imperfection of a measurement method. Basically it is the imperfection of a measuring principle, insufficient knowledge of the phenomenon, being the basis of measurement.

An instrumental error (the error of an instrument, device) is an error, depending on errors of measuring instruments (imperfections of design and manufacturing technology of measuring instruments, material running out (amortization) and material aging).

An installation error is an error caused by the incorrect installation of measuring instruments.

A methodical error is an error caused by the measurement procedure and it does not depend on the accuracy of measuring instruments.

An influence value error is an error of influence physical value.

A subjective error is an error caused by individual characteristics of an observer.

Systematic errors are divided into constant and variable by the nature of changes.

Constant systematic errors do not change their values in repeated measurements.

E x a m p l e - Incorrect calibration of measuring instruments, incorrect installation of scale beginning, etc.

Variable systematic errors in repeat measurements take different values in accordance with known laws. If an error increases or decreases in repeated measurements, it is a *progressive systematic error*.

A periodic systematic error may change periodically or by a complex law. The causes of a periodic systematic error are: the effect of external factors and design features of measuring instruments.

The measurement result always contains a systematic error (ɵ) and random (Ψ) error:

$$\Delta = \theta + \psi \,. \tag{3.1}$$

Therefore, in general, the result of a measurement error (Δ) should be considered as a random value, then the systematic error is the mathematical expectation of this value and random error is a centered random value.

3.1 Distribution Laws of Random Value

The full description of the random value and, consequently, of the random error Ψ, and of the measurement error Δ, is its distribution law.

There are various laws of distribution. In practice, the most common distribution laws of random errors are two laws: normal distribution law (Gauss) and uniform distribution law.

The formula of probability density of the normal distribution law is:

$$W(\delta)=\frac{1}{\sigma\cdot\sqrt{2\pi}}\cdot e^{-\frac{\delta^2}{2\sigma^2}}, \qquad (3.2)$$

where σ – is mean square deviation of a series of observations;

δ – is random error.

The graph of normal distribution of the random value is shown in figure 3.1.

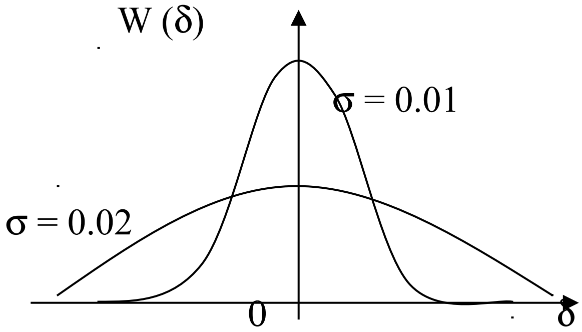

Figure 3.1 – Graph of the normal distribution law

The less σ is the more accurate the measurements are made (more frequent are small random errors).

The uniform distribution law of a random value is relatively frequent, its graph is shown in figure 3.2.

The formula of probability density of the uniform distribution law is:

$$W(\delta) = \begin{cases} 0, & \delta < -\frac{\sigma}{2} \quad u \quad \delta > \frac{\sigma}{2} \\ \frac{1}{\sigma}, & -\frac{\sigma}{2} \le \delta \le \frac{\sigma}{2} \end{cases}, \tag{3.3}$$

where σ – is mean square deviation of a series of observations;

δ – is random error.

Within certain borders measured value may be different, but equiprobable.

Other distribution laws are given in Standard 8.011 - 72 "Performance measurement accuracy and presentations of measurement results".

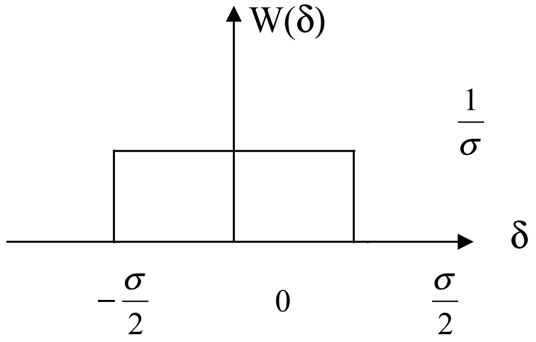

Figure 3.2 – Graph of the uniform distribution law

3.2 Basic Characteristics of Distribution Laws

The mathematical expectation of a series of observations (ME) is a the value around which results of individual observations are dissipated.

If systematic errors are absent, and the scatter of results of individual measurements is caused only by random errors, the mathematical expectation will be the true measured value.

If $\Delta = \theta + \psi$, the mathematical expectation of the number of observations will be shifted from the true measured value to a value of the systematic error.

The dispersion of a series of observations (D) characterizes the degree of distribution (scatter) of results of individual observations around the mathematical expectation. The smaller the dispersion is the less *the scatter* of individual resulting, the more accurate the measurements are made. Thus, the dispersion may serve to characterize the accuracy of measurements.

The standard deviation of a series of observations (S). Since the unit of dispersion is the square of a measured value, to assess the accuracy it is used a quantity equal to the square root of the dispersion and called the standard deviation.

3.3 Evaluations of Basic Characteristics of a Number of Observations

From the theory of probability it is known that the evaluation of *mathematical expectation* is *an arithmetic mean of the results* of individual observations:

$$\overline{X} = \frac{1}{n}\sum_{i=1}^{n} x_i \ , \tag{3.4}$$

where X_i – is i-th result of observation;

n – is number of observations.

The evaluation of dispersion of observations is calculated by the formula:

$$S^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{X})^2 \ . \tag{3.5}$$

The evaluation of standard deviation of a series of observations is *a mean square deviation,* the main characteristic of the size of random errors of observation results. The formula for calculating *the mean square deviation is:*

$$\sigma = \pm\sqrt{S^2} \ , \tag{3.6}$$

when $n \to \infty$ (practically for $n > 30$), $S^2 \to D$, $S \to \sigma$.

More information on the topic can be obtained in [1-5,8,9].

4 Lecture №4. Measuring Errors (Continuation)

Lecture content: evaluation and accounting errors in accurate (exact) and technical measurements, axiom of randomness and distribution; probabilistic estimates of measuring errors based on a number of observations, methods to increase the accuracy of measurements and measuring instruments.

Lecture objective: to study probabilistic estimates of measuring errors based on a number of observations: confidence borders, confidence interval and confidence probability; methods of increasing random and systematic errors; methods of increasing the accuracy of MI.

4.1 Evaluation and Accounting Errors in Accurate Measurements

Accurate measurements should be carried out so that there were no systematic errors. The theory of random errors is based on *two axioms*, based on experimental data in their train.

The axiom of randomness: for a very large number of measurements random errors that are equal in value but opposite in sign, occur with equal frequency: the number of negative errors is equal to the number of positive ones.

The axiom of distribution: small errors occur more frequently than larger ones; very large errors do not occur.

The full description of a random value, and therefore of a random error, is *the law of distribution.* There are various laws of distribution of a random value. In the measurement practice the most common laws of distribution of random errors are normal and uniform distributions.

4.1.1 Probabilistic estimations of an error of the measurement result based on a number of observations.

The purpose of processing the results of observations - is to establish the actual measuring value, which can be taken instead of the true measuring value and degree of closeness of the actual value to the truth.

The actual measuring value necessarily contains a random error. Therefore, the closeness of the actual measuring value to the true value must be evaluated from the perspective of the theory of probability. This evaluation is the confidence interval.

The confidence interval of random errors - is the interval at which values of the random error are with a given confidence probability.

The confidence interval can be set, if you know the law of distribution of random errors and characteristics of this law (lecture №3).

In the probability theory, it proved that for a normal distribution law of a random error, $\frac{\overline{X}-X_m}{\sigma}$ is a random value distributed normally with ME = 0 and D = =1; and $\frac{\overline{X}-X_m}{S}$ is a random value distributed according to law of the Student's distribution.

For Z_p *and* t_p there are tables, on which you can find theirs values and define confidence borders $\Delta_{low}, \Delta_{up}$ with confidence probability P for Z_p *and* t_p respectively.

When n →∞ (tend to infinity), S → σ, i.e with increasing number of observations the law of Student's distribution is closer to the normal law (practically for n> 30, t_p becomes equal to Z_p).

In practice of measurements various values of confidence probability P = 0.90; 0.95; 0.98; 0.99; 0.9973 and 0.999 are used.

For a normal distribution of random errors the confidence interval *from* -3σ *to* $+3\sigma$ with a confidence probability equaled 0.9973 is often used. This confidence probability means that an average of 370 random errors, only one will exceed the value = 3σ. Since, in practice, the number of individual measurements are rarely more than a few dozen, then "The Law of three sigma" is applied**:** *all possible random errors of measurement, distributed by the normal law, practically do not exceed absolute value of* 3σ.

The final purpose of the analysis of measurements is *to determine the error of observation results* of a number of measured values $X_1,...,X_n$, *the error of their arithmetic mean*, taken as the final result of the measurement, the relative frequency of errors and probability.

4.1.2 Evaluation of observation errors (accuracy).

According to GOST 8.011 - 72 the confidence interval is one of the main forms of accuracy of measurements. This Standard sets the following presentation of measurement result:

$$\overline{X}; \quad \Delta \quad from \quad \Delta_{low} \; to \; \Delta_{up}; \quad P \quad , \tag{4.1}$$

where $\overline{X}$ - is a result of measurement (arithmetic mean),

$\Delta, \; \Delta_{low}, \Delta_{up}$ - are absolute errors of measurement with lower and upper borders;

P - is a confidence probability at which the error is within these borders.

Here the absolute error of measurement is random error:

$$\Delta = \pm k\sigma_X \, .$$

Here σ_X, the standard deviation, is the evaluation of measurement accuracy (lecture №3).

For a complete understanding evaluation of the accuracy and reliability of random deviation of observation results the confidence borders, confidence interval and confidence probability should be given.

At a certain σ confidence borders are specified as follows: lower border (-σ), upper border (+σ), outside which the values of random deviations ($x_i - \overline{X}$) will not come out with probability P = 0.683 (or 68.3%). In this case, the confidence interval is expressed as $I_p = (\overline{X} - \sigma; \overline{X} + \sigma)$.

Depending on the purpose of measurement other confidence borders $\Delta = \pm k\sigma$ can be specified and the confidence interval of observation results is equal to:

$$I_p = (\overline{X} - k\sigma; \overline{X} + k\sigma), \tag{4.2}$$

where σ - is mean square deviation of the observation results;

k - is quantile coefficient whose value depends on the distribution law of random error.

So, for a uniform distribution law $k = \sqrt{3}$ and does not depend on the confidence probability. For normal distribution k depends on confidence probability (P) and number of measuring values (n): $k = Z_P$ for n> 30; $k = t_P$ for n <30 (the Student's law).

The values of k for the most common probabilities P and for various *n* is shown in special table A.6 [6].

4.1.3 Error (precision) evaluation of a measurement result.

The measurement result is assumed to be equal to the arithmetic mean value. According to the theory of errors, the evaluation of standard deviation of measurement result, the mean square deviation, σ_X in $\sqrt{n}$ less than the evaluation of standard deviation of observation result:

$$\sigma_X = \frac{\sigma}{\sqrt{n}}. \tag{4.3}$$

The confidence interval of measurement result is expressed as:

$$I_p = (\overline{X} - k\sigma_X; \overline{X} + k\sigma_X), \tag{4.4}$$

where k - has the same meaning as in formula (4.2);

$\sigma_{\overline{X}}$ - is mean square deviation of the measurement result.

4.2 Evaluation and Accounting Errors in Process of Technical Measurements

Technical measurements are measurements of practically constant values, made *once* with the help of working measuring instruments.

Random errors in most cases do not determine the accuracy of measurement, so there is no need for repeated measurements. The indication of a measuring instrument is taking as the result of a single measurement. The resulting error of a single measurement by a measuring instrument of direct action can be estimated by an approximate maximum (or limit) error determined by the formula:

$$\delta_{mi} = \pm(\delta_{base} + \delta_{add} + \delta_{ms}), \tag{4.5}$$

where δ_{base} - is limit of an admissible basic error of used measuring instrument during its operation in the normal range of influencing physical values (normal conditions - NC),%;

δ_{ms} - is methodical systematic error,%;

δ_{add} - is limit of admissible additional error of a used measuring instrument, %, defined by the deviation of influencing physical values outside the limits established for their normal range of values (NC), according to the formula:

$$\delta_{add} = \pm\sqrt{\sum_{i=1}^{n} \delta^2_{add\ i}}, \tag{4.6}$$

where $\delta_{add\,i}$ - is value of the limit of admissible additional error of MI caused by deviation of the i-th influencing physical value, %.

To determine the accuracy of technical measurements only by value δ_{base} it is needed to exclude δ_{add} and δ_{ms}. To do this, you need to ensure the correct and careful installation of MI, and create working conditions that are close to normal ones (NC).

4.3 Methods to Increasing the Accuracy of Measurements and Measuring Instruments

4.3.1 *Methods of decreasing random error of measurement:*

a) method of multiple repeated measurements; increasing the number of measurements, it is theoretically possible to make an evaluation σ_X, according to (4.3), which determines the random error, as small as desired;

b) method of multi-channel measurements (using parallel measurements of the same physical value); to do this, it is necessary to use several MI at the same time and handle the results of these observations together.

4.3.2 *Methods of decreasing the systematic measurement errors:*

a) elimination (exclusion) of sources of systematic error before starting measurements;

b) methods of excluding systematic errors by making a correction at the end of measurements;

c) using of more accurate MI.

4.3.3 Methods of increasing the accuracy of MI: one can use the above methods for increasing the accuracy of measurements:

a) method of multiple repeated measurements;

b) method of multi-channel measurements;

c) method of parametric stabilization (design and technological method), which is to stabilize static characteristics of MI; parametric stabilization is realized by making MI of accurate and stable elements, thermal stabilization and protection of MI against magnetic and electric fields, etc .

This method increases systematic and random errors of MI;

d) structural methods, which are based on the fact that MI includes additional components, elements and measures for improving the accuracy of MI by the information obtained with their help.

More information on the topic can be obtained in [1-5,8,9].

5 Lecture №5. Basic Information About Measuring Instruments

Lecture content: base types of measuring instruments (MI); standards, working measuring instruments and their classification, static characteristics of measuring devices.

Lecture objective: to study classification and definition of the different types of measuring instruments, static characteristics of MI.

5.1 Classification of Measuring Instruments

Measuring instruments (MI) are the technical means used to measure and which are having normalized metrological characteristics.

Metrological characteristics (MC) are characteristics of properties of MI influencing on results and measuring errors.

The classification of measuring instruments is presented in Appendix D.

Measure is MI designed to reproduce physical values of a given size.

E x a m p l e s - Kettlebell - a measure of weight; resistor - a measure of resistance; ruler-measure of length.

Instrumentations are used alone or as a part of measuring equipments or systems. Depending on the form of information Instrumentations are divided into measuring devices (MD) and measuring transmitters (transducers) (T).

Measuring device (MD) is MI, designed to produce a signal of measurement information in a form accessible to the direct perception by an observer. Measuring devices are divided into:

- analog and digital devices;
- showing and recording devices;
- direct action devices and devices of comparison.

Transducers (measuring transmitters) is MI, designed to produce a signal of measurement information in a form suitable for transmission, further conversion, processing and (or) storage, but it's not amenable to the direct perception by the observer. Transmitters can be: primary and mediate and transmission.

Measuring equipment and system is a set of MIs joint on a functional feature with auxiliary devices for measuring one or more PV of measurement object.

Unified MIs are MIs included in the SSI (the State System of industrial Instrumentations and automation). This system is based on the block-modular principle:

- instrumentations with pneumatic input and output signals of 0.2 - 1 (0.02 - 0.1 MPa);

- instrumentations with electrical input and output signals:

a) direct current 0-5, 0-20, 0-100 mA or 0-10 V;

b) alternating current at 50 or 400 Hz; In 1-0-1, 0-2, 1-3 V; 0-10 MHz, 10-0-10 MHz;

- instrumentations with electrical frequency of input and output signals 1500 and 4000 -2500 Hz - 8000 Hz.

These instrumentations have unified input and output signals, providing the interchangeability of measuring instruments, contributing to reduce the variety of secondary measuring devices, improving the reliability of automation devices, providing broad prospects for the use of computers.

Depending on the application MsI are divided into three categories:

a) *working* measures, measuring instruments, measuring transducers;

b) *exemplary working* measures, measuring instruments, measuring transducers;

c) *standards (etalons).*

Working MI is MI, designed for everyday practical measurements in all economic sectors. Working MI can be: extra accuracy (laboratory) MI and technical MI.

Exemplary MI is MI, designed for verification and calibration of working measuring instruments. The upper border of measurement exemplary MI must be greater or equal to the upper border of the measuring instrument under test. A permissible error of the exemplary MI must be much less (4-5 times) than a permissible error of tested device.

Working MI are tested in control laboratories of the State Standard. Exemplary MI are tested in state control laboratories of the 1st category for even more accurate exemplary measures, instruments and transducers. Exemplary MI of the 2nd category are tested by a comparison method with exemplary MI of the 1st category, etc.; exemplary MI of the 1st category are tested in the State Institute of measures and measuring devices by appropriate working standards.

Standard (etalon) is a high-precise measure, designed for reproduction and storage of quantity unit to transfer its size to other MI. From the standard a unit of PV is transmitted to bit standards, from the bit standards to working standards. There are standards: primary; secondary and working (bit).

A primary standard is a standard that reproduces the unit of PV with the highest accuracy possible in this area of measurement at the current level of scientific and technical achievements. The primary standard may be *national (state)* and *international.*

The national standard is approved as an original MI by the national metrology agency.

International standards are stored and maintained by *The International Bureau of Weights and Measures (IBWM).* Its objective is to compare on a regular basis national standards of different countries with international standards, as well as among themselves. Both standards of basic units of SI system and those of derived quantities are subjected to be compared. Certain periods of comparison are established: a standard meter and kilogram - each 25 years; electrical and lighting standards – once per 3 years.

Secondary standards are "etalon - copies" compared with state standards and are used to transfer the size to working standards, and working standards - to standards of a lower bit.

The first standards have been officially approved in France in 1799 and transferred to the National Archives of France for safekeeping.

5.2 Static Characteristics of Instrumentations

The operation mode of MIs during which input X and output Y signals do not change, is called *static (stationary*).

Static characteristics of MI is called a functional dependence of an output signal from an input signal in the static operation mode of the given instrument (figure 5.1). In general, this is a nonlinear dependence Y = f (x).

For MI with unnamed scale or the scale graduated in units different from units of the measured value, the static characteristic is called *a conversion function*. For measuring instruments the static characteristic is also called *a characteristic of the scale*. Determining the static characteristics associated with the implementation of calibration, so for all MI we use the concept of *calibration characteristic*, which refers to the relationship between the values on the output and input of MI, compiled as a table, graph or formula.

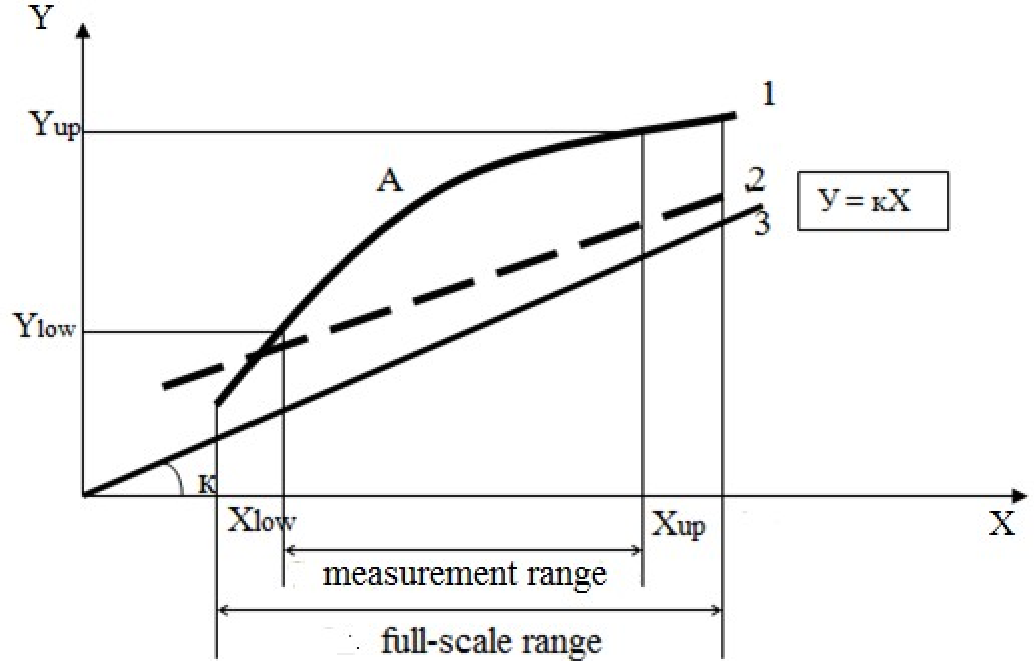

Figure 5.1 - Static characteristic measuring device

Except special cases, the main requirement for static characteristic of MI is to obtain a linear relationship between input and output values. In practice, this requirement is implemented with some previous accepted error.

The full-scale range is an area of the scale bounded by final and initial values of the scale.

The measurement range (working part of the scale) is the range of a measured value (on the scale), for which permissible errors of measuring instruments are normalized:

$$(X_{up} – X_{low};\ У_{up} – У_{low}),$$

where Y_{low}, X_{low} – are lower borders of the measuring range;

Y_{up}, X_{up} – are upper borders of the measuring range.

To quantify the effect on the output of MI input signal at any point of the static characteristic is the limit of the ratio of $\Delta У$ output increment to ΔX input increment when $\Delta X \rightarrow 0$, that is, the derivative at a selected point is

$$S = \lim_{\Delta x \to 0} \frac{\quad}{\Delta X} = \frac{\quad}{dX},$$

where S - is MD sensitivity, defined as the ratio of the change of signal output to the change of a measured value.

Sensitivity is graphically the tangent slope to the static characteristic.

If the static characteristic is non-linear, the sensitivity will be different at different points of the scale (the scale is non-uniform). MI with a linear scale have a uniform scale and constant sensitivity.

For transducers the static characteristic is usually linear $У = \kappa X$ (curve 3 in figure 6.1).

Scale spacing is the difference between two nearby scale marks.

The threshold of sensitivity is the smallest change in measured value X which can confidently change readings of the device or an output value of the transducer.

All of the above characteristics of MI are called metrological, as they affect the accuracy of measurements performed by using these instruments.

MI are permitted for the use only in the event that set the standards on their metrological characteristics - *normalized metrological characteristics* (NMC). For information about NMC given in the technical documentation for MI.

More information on the topic can be obtained in [1-5,8,9].

6 Lecture №6. Basic Metrological Characteristics of Measuring Instruments

Lecture content: accuracy class, classification of errors of measuring instruments and measuring transducers.

Lecture objective: learn the basic metrological characteristics of the MI: accuracy class and errors, their calculation and presentation.

6.1 Accuracy Class and Permissible Errors

Metrological characteristics (MC) are characteristics of the properties of MI which influence on the results and on measuring errors.

An accuracy class is a generalized metrological characteristic (MC), is defined by the limits of basic and additional permissible errors, as well as other properties of measuring instruments, affecting on the accuracy. An accuracy class is a dimensionless quantity.

Limits of basic and additional errors are established in standards for certain types of measuring instruments (MI).

Accuracy classes to measuring instruments are assigned from the series (Standard 136-68):

(1; 1.5; 2.0; 2.5; 3.0; 4.0; 5.0; 6.0)*10^n; n = 1; 0; -1; -2, ...

Specific accuracy classes are established in the standards for certain types of MI. The lower the number indicating the accuracy class, the lower the limits of permissible basic error.

Accuracy classes, normalized for reduced errors, are connected with a particular value of error limit, i.e, accuracy class is numerically equal to the value of reduced error, expressed as a percentage.

MI with two or more ranges (or scales) may have two or more classes of accuracy.

6.2 Errors of Measuring Instruments

The classification of MI errors is shown in figure E.1 (Appendix E):

a) *by character of appearance in repeated applications of MI*: systematic and random errors of MI have the same meaning as systematic and random measuring error (lecture №3);

b) *by operating conditions of MI*:

1) *basic (fundamental, main) error* of MI is MI error used in normal conditions (NC). The NC of MI application is conditions under which the influence physical value (ambient temperature, barometric pressure, humidity, voltage, current and frequency, etc.) are normal values or are within normal range of values, when no vibration and an external electromagnetic field, except the Earth's magnetic field. The NC are not usually working conditions of the MI application;

2) *the limit of permissible additional error* is referred to the maximum additional error caused by the influence physical value within *the extended range of values (ERV)*, in which measuring instrument can be found as fit and approved for use.

In standards or specifications an extended range of influence physical value is determined for each type of MI, within which the value of additional error should not exceed established limits.

The terms "basic" and "additional" errors correspond to actual errors of MI which occur under these conditions;

c) *by mode of MI application*:

1) *static error* is MI error appearing at using it to measure the value which is constant in time;

2) *dynamic error* is MI error appearing at using it to measure the value which is variable in time;

d) *by the presentation form.*

Definitions of the absolute, relative and reduced errors for a measuring device and transducer are specific. The measuring device has a scale calibrated in units of the input value, so the result of measurement is represented *in units of the input value*. So it is easy to define errors of measuring devices. For transducer the measurement results are presented in units of output value. Therefore one can distinguish *errors of transducer at the input and output.*

Absolute error of a measuring device is the difference between the device readings and actual measured value:

$$\Delta = X_{dev} - X_{act} \ , \tag{6.1}$$

where X_{act} - is determined by the exemplary device (standart) or reproduced by a measure.

Relative error of a measuring device is a ratio of absolute error of measuring device to the actual measured value:

$$\delta = \frac{\Delta}{X_{act}} 100\%. \tag{6.2}$$

Reduced error of a measuring device is a ratio of absolute error of measuring device to the *normalizing value* of a measured value:

$$\gamma = \frac{\Delta}{X_N} 100\% \,. \tag{6.3}$$

The upper limit of measurement or measurement range of the device is used as a normalizing value X_N.

While determining an error of transducer (T) the following values are used:

X_{act} - actual value at the input of T is reproduced by the measure or determined by the exemplary MI at input.

Y_t - value at the output of T, is determined by the exemplary MI at output;

$Y=f(X)$ - conversion function of a transducer;

$X=\varphi(Y)$ - reverse conversion function of a transducer.

The absolute error of a transducer at the output is the difference between *the value at the output* of a transducer displaying the measured value and *the actual value at the output*, is determined by the actual value at the input using calibration characteristic of the transducer:

$$\Delta_{Yt} = Y_t - Y_{act} = Y_t - f(X_{act}) \ , \tag{6.4}$$

where Y_t, Y_{act} - are determined at the same input value.

An absolute error of a transducer at the input is the difference between the value at the input of a transducer, is determined by the value at its output with the help of calibration characteristics of the transducer, and actual value at the transducer input:

$$\Delta_{Xt} = X_t - X_{act} = \varphi(Y_t) - X_{act} \,. \tag{6.5}$$

Relative error of a transducer at the input:

$$\delta_X = \frac{\Delta_X}{X_{act}} = \frac{\varphi(Y_t) - X_{act}}{X_{act}} 100\% . \tag{6.6}$$

Relative error of a transducer at the output:

$$\delta_Y = \frac{\Delta_Y}{Y_{act}} = \frac{Y_t - f(X_{act})}{f(X_{act})} 100\% . \tag{6.7}$$

Reduced error of a transducer at the input:

$$\gamma_X = \frac{\Delta_X}{X_N} 100\%. \tag{6.8}$$

Reduced error of a transducer at the output:

$$\gamma_Y = \frac{\Delta_Y}{Y_N} 100\%. \tag{6.9}$$

The measurement range of the transducer $(X_{up} - X_{low})$, or corresponding measuring range of an output signal ($y_{up} - y_{low}$) is used as a normalizing value X_N, Y_N;

e) *by measured value.*

To consider this dependence is to use the concept of *nominal and real conversion functions.*

A nominal conversion function is specified in the passport for the MI. *A real conversion function* is a conversion function of a given type of MI. Deviations of the real conversion function from the nominal one are different and depend on a measured value. These deviations are determined by the accuracy of this MI.

The additive error or error of zero point of MI scale is an error, which remains constant at all values of a measured value (Appendix E, Figure E.2).

If the additive error is a systematic error, it can be excluded (for example, zero adjustment). If the additive error is a random error, it can not be excluded, and the real conversion function is shifted with respect to the nominal conversion function randomly in time. For a real function, you can select a band whose width remains constant for all values of a measured value.

Sources of a random additive error are friction in the bearings, zero drift, set noise.

The multiplicative error or error of MI sensitivity is an error which increases (or decreases) linearly with an increase of the measured value (Appendix E, figure E.3).

Sources of a multiplicative error are the following: changing the conversion factor of individual elements and components of MI.

Linearity error is an error which occurs when the difference between the real function and the nominal function is caused by nonlinear effects (Appendix E, figure E.4).

Sources of linearity error are the design (scheme) of MI, nonlinear distortion of conversion functions associated with the imperfection of technology of schemes production.

Hysteresis error is a flyback error (lag error) (Appendix E, figure E.5). This is the most significant and intractable MI error expressed in a mismatch of the real conversion function with increasing (forward stroke) and decreasing (flyback) of a measured value.

Reasons of hysteresis are gap (clearance), dry friction in mechanical transmission elements, hysteresis effect in ferromagnetic materials, inner friction in spring materials, phenomenon of polarization in elements, piezoelectric elements, electrochemical cells.

MI is allowed to be used only in the case if standards are set on their metrological characteristics. The information about normalized metrological characteristics is given in the technical documentation for measuring instruments.

More information on the term can be obtained in [1-5].

7 Lecture №7. Bases of Standardization

Lecture content: nature of standardization, objects and areas of standardization, normative documents, bodies and services of standardization.

Lecture objective: to learn basic definitions, purposes and objectives of standardization, types of normative documents, concept of national standardization.

Standardization is an activity aimed at the development and establishment of requirements, rules, regulations and characteristics which are both mandatory and recommended for implement action. It ensures the right of consumers to purchase products of good quality at reasonable prices, as well as the right to safety and comfortable working.

Standardization purposes (goals) are:

- general purposes;
- particular purposes.

General purposes are directly connected to the concept of standardization. The general goals are connected to the implementation of the requirements of the standards, which are mandatory:

- safety of products, work and services for the life and health of people, environment and property;
- compatibility and interchangeability of products;
- quality of products, work and services in accordance with the level of development of scientific and technological progress;
- uniformity of measurements;
- saving all kinds of resources;
- safety of industrial objects related with the possibility of occurrence of various disasters and emergencies;
- defense capability and country mobilezation readiness.

Particular purposes are related to specific areas of activity, industry of goods and services, one or the other type of product, company, etc.

Standardization object ia a product, process or service for which certain requirements, characteristics, parameters, rules, etc. are developed.

Standardization considers either any object as a whole or its individual components (characteristics).

Standardization area is a set of interrelated objects of standardization. For example, *the area of standardization* is mechanical engineering, *standardization object* is technological processes, types of engines and safety.

Levels of Standardization depend on what geographic, economic and political region of the world the participants take standardization: administrative-territorial standardization; national standardization; regional standardization or international standardization.

7.1 Normative Documents on Standardization and Types of Standards

Rules, regulations, requirements, characteristics relating to the object of standardization, which are issued in the form of a normative document are developed in the process of standardization.

The Guide of International Standards Organizations ISO / IEC recommends the following *types of normative documents (ND):*

- standards;
- documents of technical specifications;
- rule books;
- regulations (technical regulations);
- provisions.

Standard is a normative document, established based on consensus, approved by a recognized body, aimed at achieving an optimum degree of order in a certain area.

General principles, rules and specifications relating to various activities or their results are installed in the standard for common and repeated usage. The standard should be based on the consolidated results of scientific research, technological achievements and practical experience, then its use will bring optimum benefit to society.

First a standardization body shall make *a preliminary (temporary) standard* and is brought to a wide range of potential customers, as well as to those who can use it. Comments about this document serve as a basis for deciding upon advisability of standard.

Categories of standards are: international, regional, national, administrative-territorial. They are designed for a wide range of consumers, i.e. they are publicly available.

International standard is a standard adopted by the International Organization for Standardization and available for a wide range of consumers.

National standard is a standard adopted by national authorities and available for a wide range of consumers

Types of standards are: fundamental standard, harmonized standard, terminological standard, test methods standard, product standard, process standard, service standard, compatibility standard.

Fundamental standard is a standard that has a wide area of application, or contains general propositions for the specific field of technical regulation.

Harmonized Standard is a standard for ensuring the fulfillment of requirements established by *technical regulations.*

The document of technical conditions (TC) establishes technical requirements for products, services, processes. Typically, the methods or procedures that should be used to verify compliance with the requirements of the normative document in situations when it is necessary should be specified in this document.

Rule books, as well as TC, can be a self-contained standard, or a separate document, as well as a part of the standard. Rule books are usually made for a design process, installation of equipment and constructions, maintenance or operation of facilities, structures and products.

All of the above normative documents are of a *recommendatory character.*

Regulations are a document, which contains the *mandatory legal norms*. Regulations are accepted by the authority, and not by the body of standardization, as in the case of other ND.

Technical Regulations (TR) - a kind of regulations - contains technical requirements to the object of standardization. They can be presented directly in the document or as a reference to another ND. In some cases, ND is completely included in TR. Technical regulations are usually supplemented by methodical documents, documents on monitoring methods or controls of conformity of product, goods, services to the requirements of regulation.

Technical Regulations must contain:

- an exhaustive list of products, processes, which are the subject to its requirements;
- requirements to the characteristics of products, processes, ensuring the achievement of purposes of the adoption of technical regulations.

Technical Regulations may contain:

- rules of sampling and testing products;
- rules and forms of confirmation of conformity (including the scheme of conformity);
- requirements to terminology, packaging, marking or labeling and the rules of their drawing.

Normative documents on standardization in the Republic of Kazakhstan are established by the Law "On Technical Regulation" (2004) [12]:

a) international standards;

b) regional standards and classifiers of technical and economic information, rules and recommendations on standardization;

c) state standards and classifiers of technical and economic information of the Republic of Kazakhstan;

d) standards of organizations;

d) recommendations for the standardization of the Republic of Kazakhstan;

e) national standards, industry standards, classifiers of technical and economic information, rules, norms and recommendations on standardization of foreign states.

7.2 Bodies and Services of Standardization

According to the Guide 2 of ISO / IEC standardization activities are performed by relevant bodies and organizations. Under the body of standardization we mean a body whose activities in the field of standardization is generally recognized at the national, regional or international levels.

Main functions of the body are the development and approval of normative documents available to a wide range of consumers. However, it can perform many other functions, which is particularly characteristic of the national standardization body.

The National Standards Body in Kazakhstan is the national authorized body - *Committee for Technical Regulation and Metrology* (figure 7.1). The national authorized body is the state body authorized in accordance with the legislation of the Republic of Kazakhstan to manage, monitor and supervise the work in the field of technical regulation and represent the Republic of Kazakhstan at international and regional organizations on standardization, confirmation of conformity and accreditation.

The authorized body of standardization has the following functions:

a) to establish the procedure of development, coordination, registration, approval, verification, change, cancellation and introduction of state standards and classifiers of technical and economic information;

b) to organize the analysis and development of standards harmonized with the normative legal acts in the field of technical regulation;

c) to establish the accounting treatment and application of international, regional and national standards, classifiers of technical and economic information, rules, and foreign states recommendations on standardization, confirmation of conformity and accreditation in the Republic of Kazakhstan;

g) to organize the publication and distribution of official publications of state, international, regional standards and standards of foreign countries, rules and recommendations on standardization, confirmation of conformity and accreditation, to publish the information about them;

d) to establish the procedure for the development of plans and state standardization programs;

e) to organize the confirmation of transferring standard documents on standardization in the state and Russian languages.

Committee for Technical Regulation and Metrology (until 2005 - Committee of Standardization, Metrology and Certification) (Statestandart) carries out its activities in accordance with the "Regulation on the Committee of Standardization, Metrology and Certification of the Ministry of Industry and Trade RK" approved by Resolution of the Government of the Republic of Kazakhstan dated October 18, 2000 № 1552 guided by Laws "On technical regulation" of November 9, 2004, "On ensuring the uniformity of measurements" of June 7, 2000, "On Consumer Rights Protection".

New laws fully conform to the international requirements. The Committee creates and realizes the state policy in the field of standardization, metrology, certification and accreditation; it supervises over compliance with the mandatory requirements of normative documents on standardization, certification rules, quality of certified products, metrological rules, condition and application of measuring instruments, as well as state control over activities of certification bodies and testing laboratories; it provides international scientific and technical cooperation on standardization, metrology and certification in order to eliminate technical barriers in trade.

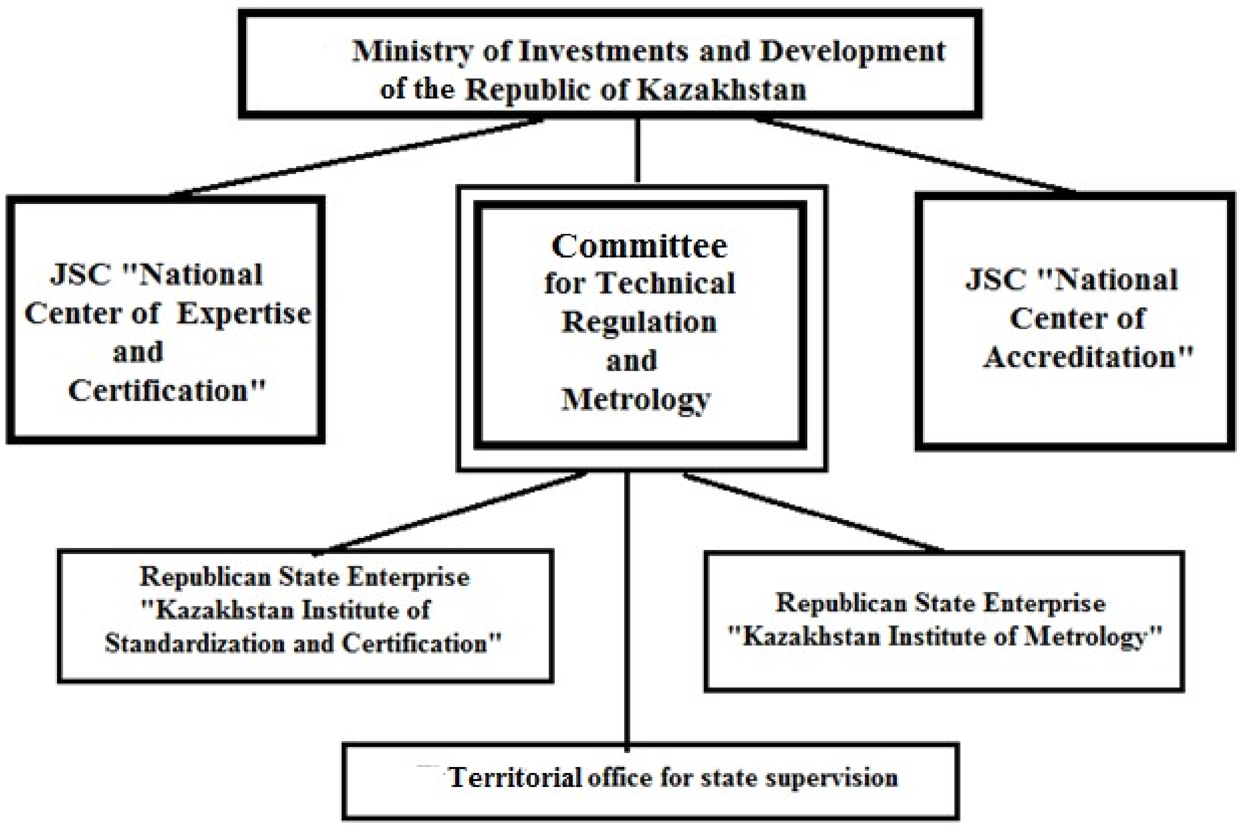

Figure 7.1 - Organizational scheme of RK Standardization services

Permanent working bodies on standardization are *the Technical Committees (TC)*, but it does not exclude the development of normative documents by enterprises, public institutions and other business entities.

More information on the term can be obtained in [2-5,8,9].

8 Lecture № 8. International Standardization

Lecture content: Organizations for Standardization: ISO, IEC, ISC CIS (EASC), CEN (European Union), ANSI (USA), Russian State Standard.

Lecture objective: to study the tasks, functions and structure of international standardization organizations.

8.1 International Organization for Standardization

The first International Organization for total Standardization - International association of national organizations for standardization - was established in 1926, but because of the beginning of World War II in 1939, it broke.

International Organization for Standardization, which exists novadays, ISO was created in 1946 by 25 countries. The field of activity of ISO is standards in all areas except electrical engineering and electronics. The *International Electrotechnical Commission (IEC)* deals with standardization in these areas. Some of works are carried out jointly by ISO and IEC.

The official languages of ISO are English, French and Russian. ISO has developed more than 12,000 standards, annually formulated and reviewed 500-600 standards. More than 70% of all standards are translated in Russian.

Tasks of ISO are: to promote the development of standardization and adjacent activities in the world to ensure the international exchange of goods and services, as well as the development of cooperation in intellectual, scientific, technological and economic fields.

ISO standards do not have a mandatory status. Any country has the right to use them or not to use. About half of the ISO standards are used in Kazakhstan. Only 20% of standards have requirements for specific products. Most of standards are related to security, interchangeability, technical compatibility, testing methods of production and general methodological issues.

The highest governing body of ISO is The General Assembly, which is held every three years. The main coordinating work conducted in 7 major committees: STACO, PLAKO, CASCO, INFCO, DEVCO, COPOLCO, REMCO.

STACO is the *Committee for the Study of the scientific principles of standardization.* STACO provides the methodical assistance and information to the ISO Council on the principles and methodology of the development of international standards.

INFCO is the *Committee for Scientific and Technical Information. It* coordinates and harmonizes ISO activities as well as its members in the field of information services, databases, marketing and sale of standards and technical regulations.

REMCO is the *Committee on standard samples.* REMCO provides the methodological assistance through the development of relevant ISO documents on issues related to standard materials (etalons).

PLAKO is the *Technical bureau.* PLAKO prepares proposals for planning the work of ISO to organize and coordinate technical aspects of the work.

PLAKO considers the proposals for the establishment and dissolution of technical committees, defines the area of standardization, which should be considered by the Committee.

CASCO is the *Committee on conformity assessment*. CASCO considers the evidence of conformity of products, services, processes, and quality systems to requirements of standards by studying the practice of this activity and analyzing information.

The Committee develops documents of testing and conformity assessment (certification) of products, services, quality systems, evidence of competence of testing laboratories and certification bodies.

DEVCO is the *Committee on aid to developing countries.*

The main functions of DEVCO are:

- organization of discussion on a wide scale of all aspects of standardization in developing countries, creating the conditions for the exchange of experience with developed countries;
- training of standardization experts on the basis of various training centers;
- preparation of textbooks on standardization for developing countries;
- encourage the development of bilateral cooperation of industrialized countries and developing countries in the field of standardization and metrology.

COPOLCO is the *Committee for the protection of consumers' interests.*

COPOLCO is responsible for promoting the interests of consumers in the field of standardization.

Main functions:

- to study issues of consumer interests and opportunities to promote this through standardization;
- to summarize the experience of consumers participating in the creation of standards;
- to develop programs for consumer education in the field of standardization and bringing to them necessary information on international standards.

Direct management of ISO is provided by *ISO Council, Executive Bureau and Central secretariat.*

Currently, ISO includes more than 164 countries and more than 200 committees.

Direct work on international standards is done by technical committees and subcommittees, which may establish working groups.

ISO members are National Standards Bodies that represent the interests of their country in ISO, as well as ISO in their country.

Membership categories:

- *full-fledged members* affect the content of standards developed by ISO and the strategy by participating in the vote and international meetings;

- *members - correspondents* are observing for the development of ISO standards and strategy by reviewing the results of voting, so they do not have voting rights, and means of participation in international meetings as an observer;

- *members - subscribers* receive up to date information about the works carried out in ISO, but can't participate in the work.

The Republic of Kazakhstan has been a member of ISO since 1994.

In ISO Kazakhstan is represented by Committee of Technical Regulation and Metrology (State Standard of Kazakhstan) of the Ministry at Investment and Development of the Republic of Kazakhstan.

Today, Kazakhstan is a full-fledged member of 16 ISO Technical Committees (P-Member). Kazakhstan is an observer- member of 13 ISO Technical Committees (O-Member).

8.2 The International Electrotechnical Commission (IEC)

The International Electrotechnical Commission (IEC) was established in 1904 at a conference of 13 countries. The date of beginning of cooperation between these countries is 1881. IEC is the first sectoral international organization for standardization. It deals with standardization in the field of electrical engineering, electronics, radio, telecommunications and instrumentation. Since 1946, IEC is an autonomous organization within ISO.

IEC in cooperation with ISO develops ISO/IEC Guide and ISO/IEC Directives on standardization, certification, accreditation of testing laboratories and methodological issues.

IEC Standards can be divided into two types - general engineering, being of intersectional nature, and technical ones, including requirements for specific products. Each year, IEC considers more than 500 topics on international standardization. IEC adopted more than 2000 standards. These standards are more specific than ISO standards.

The National Committees of all participating countries form the Council - the highest governing body of IEC.

The main coordinating body of IEC is Action Committee. It identifies the need to develop new areas of work, develops methodical documents, participates in the decision of issues on cooperation with other organizations, performs the Council tasks.

IEC members are National Committees one of each country.

Individual participation in the work of the IEC is conducted only through the National Committees.

There are two levels of IEC Membership:

- *full members* - National committees have access to all technical and management activities and functions at all levels of IEC, including the right to vote in the Council;

- *associate members* have full access to all working documents, but limited IEC members.

8.2.1 IEC and Kazakhstan.

Today, Kazakhstan is a full member in the following technical committees of IEC:

- TC 18 "Electrical equipment of ships, mobile and stationary marine facilities";
- TC 46 "Cables, wires, waveguides, RF connectors and microwave passive components and accessories";
- TC 77 "Electromagnetic compatibility";
- ISO/IECJTC1/SC25"Information Technology".

8.3 Interstate Council for Standardization, Metrology and Certification (ISC) of the Commonwealth of Independent States (CIS)

Interstate Council for Standardization, Metrology and Certification (ISC) of the Commonwealth of Independent States (CIS) is an intergovernmental body of CIS on formation and carrying out coordinated policy on standardization, metrology and certification.

"Agreement on coordinated policy in the field of standardization", which is the base of interstate standardization system, was signed on March 13, 1992 by representatives of the states of the former USSR.

The following documents (standards) have been recognized according to this agreement:

- acting GOST USSR as interstate standards;
- standard (etalon) base of the former USSR as a joint property;
- the need for bilateral agreements for mutual recognition of systems for standardization, metrology and certification.

The Interstate Council for Standardization, Metrology and Certification (ISC) was established at the intergovernmental level.

In 1995, ISC - Regional Organization for Standardization was recognized by the International Organization for Standardization (ISO) as *the Eurasian Council for Standardization, Metrology and Certification (EASC).*

The highest body of the ISC is a meeting of members of ISC, which is held twice a year, alternately in the states - members of the Agreement. Between sessions, the leadership of the Council's work is carried out by the Chairman. Functions of ISC Chairman alternately performed the heads of national bodies for standardization, metrology and certification.

ISC working body is the Bureau on standards in the group of experts and regional information center. More than 270 interstate technical committees for standardization were created in the Council.

8.4 European Union System for Standardization

The basic principles of *the European standardization system* is the independence and co-operation with the authorities. Unlike the USA, the European standardization system is characterized by orderliness and organization.

There are three standardization organizations in Europe: ETSI, CEN and CENELEC, all of them are private. CEN has existed since 1961. Its members are 18 countries in Europe.

The European system is based on the requirements of the new approach to standardization and technical regulation, adopted in 1985 by the Council of the European Union. In accordance with it the state's activity in the field of standardization is to monitor the implementation of basic requirements for health and safety in the supply of industrial products to the market. The role of voluntary standards is to solve technical problems to ensure compliance with these requirements. For this, the European Commission has signed the Memorandum of Understanding (1984) with the European organizations on standardization. According to it, the European Commission must not develop its own technical requirements.

Also, the European system performs external functions, contributing to the elimination of technical barriers in the European trade. The European system is characterized by providing preferential position of European standardization in comparison with the national one. In accordance with this principle, the national organization shall refrain from developing its own standard, if the work is being carried out in this area on the European level. Also, all the national organizations in Europe accept European standards and cancel its own developments in identifying differences with the European ones.

8.5 American System for Standardization

A special feature of the American system for standardization is the range of coverage, taking into account industry specifics.

The American system is distributed within the industry and supported by numerous standards organizations, both private and public. American standards were developed for individual sectors in response to specific requests of the industrial enterprises and public authorities.

For over a hundred years, the US standardization has developed by the initiative of the private sector without a governmental interference. The main task of the introduction of standards has been and remains the development of technical requirements for products, processes and systems.

In 1918, private organizations for standardization have established federation of partners - *American National Standards Institute (ANSI),* whose main objective was to coordinate activities in the field of standardization. ANSI - a non-governmental organization comprised of 700 companies, 30 government bodies, 20 institutes and 260 professional, technical, commercial, and industrial organizations. ANSI activities funded through membership fees and revenues from the sale of documents.

About 600 organizations develop standards in the USA. The standardization system is voluntary and compliance with standards is not mandatory.

The Federal government of the USA does not fund and does not manage the activities of standards organizations, but with the support of a private sector is involved in voluntary standardization as a buyer and an active participant in the development of technical standards. Also, the federal government watches to it that the standardization process reflects national interests.

Despite some complexity of the American system of standardization, it continues to prove its effectiveness, helping manufacturers to design, produce and sell products, timely meet the needs of industry, government and consumers. Currently, the United States produces about 25% of the world industrial output. This country is a leader in the production of such high forms as computer hardware, aeronautics, automotive, railway transport, space technology, etc.

8.6 Russian Federation System for Standardization

Now the main objective of standardization in Russia is to develop and maintain the normative framework which would ensure the development, production and consumption of high-quality, safe and competitive products.

In 1998, the State Standard of Russia adopted a new Concept of national standardization system. Based on this concept, the function of standards provides such level of quality and safety of products, that meets modern requirements of sanitation, hygiene, ensures the protection of the environment and safety of people, as well as their property.

The legal status of Russian State Standard (Russian Federation Committee for Standardization, Metrology and Certification) is fixed by the Law "On Standardization".

Also, the State Standard of Russia establishes common, i.e. uniform for the whole country of organizational and technical rules for all kinds of works on standardization. The territorial bodies of the State Standard of Russia are created on the territory of all subjects and in large industrial centers by State Standard of Russian Federation (Centers of Standardization, Certification and Metrology): Rustest - in Moscow, Test – in St. Petersburg and others.

8.7 RK State Standardization

Republic of Kazakhstan is a member of:

- International Organization for Standardization (ISO);
- International Organization of Legal Metrology (IOLM);
- Interregional Association for Standardization (IAS);
- Eurasian Council for Standardization, Metrology and Certification (EASC).

RK State standards fund contains about 32 000 normative documents, of which 19 000 are interstate standards, about 3 000 – international standards and about 10 000 - national standards of foreign countries.

The Republic of Kazakhstan signed an intergovernmental agreement on cooperation in the field of standardization, metrology and certification:

- with *the Commonwealth of Independent States (CIS)* countries;

- with the Institute of Standards and Industrial Research of Iran (ISIRI);
- German Institute for standards DIN - (Deutsches lnstitute fur Normung);
- Turkish Standards Institute (TSE);
- with the following countries: China, Bulgaria, Iran, Russia, Kyrgyzstan, Azerbaijan, Ukraine, Georgia, Moldova, Belarus, Poland and prepare agreements with other countries.

More information on the topic can be obtained in [2-5,8,9].

9 Lecture №9. Bases of the Confirmation of Conformity

Lecture content: essence and content of certification, the basic terms and concepts, mandatory and voluntary certification, forms of participation in the certification and agreements on the recognition.

Lecture objective: learn the basic definitions, purposes and tasks of the certification, the main provisions of the Law "On Technical Regulation"; principles, rules and procedure of certification of products.

Certification in Latin means *"Made true"*. In order to make sure that the product is "made right", it is necessary to know what requirements it must conform, and how it is possible to obtain reliable proof of *conformity.*

ISO / IEC offer the term "*conformity*" indicating that this procedure, in result of which the application may be made, giving the assurance that the products (processes, services) satisfy the specified requirements. It may be:

a) *a declaration of conformity*, i.e. written manufacturer's warranty that the product satisfies the specified requirements;

b) *a certification* is a procedure by which a third party gives written warranty that a product, process, service conforms to specified requirements.

The Declaration of Conformity includes the following information: the address of the manufacturer, who submitted the declaration; the designation of the product, and additional information about it; name of a normative legal act in the field of technical regulation, to meet the requirements which the products are confirmed; an indication of the manufacturer of personal responsibility for the contents of the statement, and others. The information provided should be based on the test results. The declaration of conformity is adopted for a period specified by the manufacturer (executor) of product, based on the planned date of the production, but not more than one year.

The confirmation of conformity through *Certification* requires a mandatory participation *of a third party.* Such a confirmation of conformity is independent, giving the assurance of conformity to specified requirements, carried out by the rules of a certain procedure. *A certification* is considered to be the main reliable proof of conformity of product (process, service) to specified requirements.

The proof of conformity is carried out by this or that *certification system.* It is a system that provides certification by their own rules concerning both procedure and management.

A certification system consists of:

- *a central authority* that controls the system, carries out its oversight and may transfer the right to other certification bodies;
- *rules and procedure of certification*;
- *regulatory documents* by which the certification is carried out;
- *procedure (scheme) of certification*;
- *a procedure of inspection control.*

Certification systems may operate at national, regional and international levels.

Certification in the Republic of Kazakhstan is organized and conducted in accordance with national laws of the Republic of Kazakhstan: the Law "On Consumers' Rights Protection ", "On Technical Regulation", and with the RK laws related with certain industries: "On veterinary", "On Fire" "On the sanitary-epidemiological welfare of population", other legal acts of the Republic of Kazakhstan.

Law "On Consumers' Rights Protection", adopted in 1991 (with changes as of 29.12.2014), established a number of fundamentally new provisions. It consolidated consumer rights recognized in the civilized world:

- the right to security of goods, works, services for life and health;
- the right to proper quality of the got goods, works and services;
- the right to reparation and judicial protection of rights and interests of consumers.

It provided the consumer protection mechanism whose rights are violated in the sale of substandard goods or for improper performance of works and provision of services.

The law does not consider individual entrepreneurs as consumers if they buy goods for their activities related to the extraction of profit.

The Law "On Technical Regulation" was adopted in 2004 (with amendments as of 31.01.2006). The Law established the goal of certification, the national certification body - RK authorized body - and the directions of its activity, nature of mandatory and voluntary confirmation of conformity, rights of certification bodies, sources of financing for various areas of certification activities, etc.

Certification can be mandatory and voluntary.

A mandatory certification is carried out on the basis of laws and regulations and provides the proof of product (process, service) conformity to the requirements of technical regulations, mandatory standards. Since the mandatory requirements of normative documents related to safety, health and environmental protection, the main aspect of mandatory certification is the safety and environmental friendliness.

In Kazakhstan the mandatory certification was introduced by the Law "On Consumers' Rights Protection". The products subjected to mandatory conformity confirmation are determined by normative legal acts in the field of technical regulation.

A voluntary certification is carried out by the initiative of individuals or legal entities on contractual terms between the applicant and certification body in the voluntary certification systems. The voluntary certification is allowed in the system of mandatory certification by bodies on mandatory certification. A normative document on the basis of which tests are carried out by voluntary certification, is selected, as a rule, by the applicant. The applicant may be the manufacturer, supplier, vendor, consumer of product. Voluntary certification systems often consolidate manufacturers and consumers interested in the development of trade on the basis of long-term partnerships.

The participation in certification systems may be in three forms:

- admission to the certification system;
- participation in the certification system;
- membership in the certification system.

An admission means the possibility for the applicant to carry out the certification in accordance with the rules of the system. A membership and participation are set at the level of the certification body. The first form of participation (admission) refers to the enterprises - manufacturers, suppliers of products that certify their products in the selected system (for example, voluntary certification) or obliged to carry out the certification on a given system, for example, under the provisions for mandatory certification. Two other forms of activity are related to the certification authority in the national, regional and international certification systems.

The certification is intended to promote the development of international trade. However, the certification system may be a technical barrier. Mutual recognition of agreements (*agreement on the recognition* - in the terminology of the Guide 2 of ISO / IEC) help to eliminate technical barriers to trade. They are unilateral, bilateral, multilateral. It depends on the number of countries recognizing the results of another (other) party.

In systems of conformity confirmation by a third party two ways are used to specify conformity with standards: *certificate of conformity and mark of conformity*.

A certificate of conformity is a document certifying the conformity of products, service to requirements established by normative legal acts in the field of technical regulations, standards or other documents. The certificate may refer to all the requirements of the standard, as well as to its individual sections or specific characteristics of the product that is stipulated clearly in the document.

A conformity mark is a designation is intended to inform consumers that the products, services underwent the procedure of confirmation of conformity to the requirements established by normative legal acts in the field of technical regulations, standards and other documents. A permit (license) to use the mark of conformity is issued by the certification body.

The standards intended for certification usage, in the "Application area" should indicate their application for certification purposes. The standards include only those characteristics that can be objectively verified. The standard should establish a sequence of tests, if that affects their results. Methods of non-destructive testing are preferred.

The order of conformation of products conformity is set in relation to the mandatory certification (including imported products), but can also be used with the voluntary certification. General principles of the order of certification of products correspond to Guide 2 of ISO / IEC. Work management on conformation of conformity is carried out in the framework of the state system of technical regulation. Direct work on certification is carried out by certification bodies and testing laboratories.

The certification procedure is:

a) *application for product certification* to the body of confirmation of conformity; that authority considers the application within a month and informs about the decision: which bodies and testing laboratories may be selected by the applicant for the certification of its products;

b) *selection, identification of specimens and its tests*, which are carried out by the testing laboratory; the test reports are issued one by one for applicant and body of confirmation of conformity; the shelf life of the protocol equals to the term of certificate;

c) *evaluation of production;* analysis of production, certification of production or quality control system are carried out; the method of evaluation of the production is specified in the certificate of conformity;

d) *issuance of the certificate of conformity*; the expert opinion is drawn up according to the results of b) and c); it is the main document on the basis of which the body for confirmation of conformity shall make a decision to issue of the certificate of conformity; the expert also makes a certificate indicating the reason for its issuance and registration number, without which it is invalid.

Measuring instruments must pass the state metrological control and verification before obtain a certificate of conformity.

The certificate of conformity is issued for a period specified by the scheme of conformity, but not more than three years.

The inspection control over certified products is carried out throughout the term of the certificate and license to use the conformity mark, but at least once a year.

More information on the term can be obtained in [2-5, 8,9].

10 Lecture №10. Quality Management (Basis of Qualimetry)

Lecture content: qualimetry, types of quality indicators, methods for determining of quality indicators.

Lecture objective: to study the properties, rules of formation and methods of evaluation of quality indicators.

10.1 Measurement and Estimation of Quality

The set of product properties that lead to its suitability to satisfy certain requirements in accordance with its purpose, is called *a quality*. To control the quality, primarily it is necessary to estimate the quality, and in the ideal case - to measure it.

Qualimetry studies questions of *quality estimation*. A generalized property Itself called quality, is not a physical value and can't be measured in metrological sense, because *legal measure* does not exist for this property. However, practical recommendations to evaluate the quality were obtained based on analogies with measurement of physical values in qualimetry, including its quantitative evaluation.

To identify or measure a value one can only compare it to another known value, taken as a unit of comparison - *a measure*. In metrology such measures are units of physical values. In qualimetry *the quality indicators* are the analog of physical values. The terms "physical value" and "quality indicator" are close, but not identical. The physical value reflects *the objective properties of nature*, and quality indicator - *the social need in specific conditions*. Thus, *the mass* is a physical value and *mass of the product* is an indicator of its transportability; *lighting* is a physical value, and *lighting at the workplace* is an ergonomic indicator.

The quality is a complex, *multi-dimensional property* of a product, *generalized characteristic* of the set of its consumer properties. For the purposes of estimation, the quality appears to be *a simplified model*, which includes only a small number of the components determining the quality. As required**,** the quality model can be improved and new product features may be taken in to consideration, more fully characterizing the quality. The way back is not excluded – the way to simplify the model.

E x a m p l e: Cake model can be selected from model, including four properties: taste, structure, color and shape. We can simplify the model to the limit, leaving only two components of the quality - taste and shape. Estimating the quality of the cake in four quality indicators is to characterize the quality of the product more fully.

10.2 Properties and Rules of Formation of Quality Indicators

Depending on whether the quality indicators are the physical values or values of non-physical (economic, humanitarian, social, etc.), quality indicators are expressed in units of physical values or in units designated by an agreement (for example, in points/grades, on a scoring scale).

Quality indicators are divided into *single* and *complex*. *Single indicators* refer to one of the properties that determine the quality; *complex indicators* are formed from several single indicators.

Complex quality indicators may be formed from single ones based on known functional relationships between them, and can be a combination of single indicators, made by mutual agreement. So, choosing as single indicators of a radio quality the supply voltage U and the current consumed I, you can get a complex indicator – power consumption P, using a functional dependence P = UI.

In the absence of an objective functional dependence for the formation of *complex quality indicators*, *a subjective method* is used it is a calculation of complex indicator on the principle of weighted average, using one of the formulas:

- *weighted arithmetic mean*

$$\overline{Q} = \sum_{i=1}^{n} g_i Q_i \quad ; \tag{10.1}$$

- *weighted harmonic mean*

$$\widetilde{Q} = \frac{\sum_{i=1}^{n} g_i}{\sum_{i=1}^{n} \frac{Q_i}{g_i}} \quad ; \tag{10.2}$$

- *weighted geometric mean*

$$\breve{Q} = \left(\prod_{i=1}^{n} Q_i^{g_i} \right)^{\frac{1}{\sum_{i=1}^{n} g_i}} \quad . \tag{10.3}$$

By *weighting coefficients* g_i the importance or value (weight) of each single quality indicator Q_i is taken into account. The problem of determining the weights of indicators of quality is usually solved by the condition:

$$\sum_{i=1}^{n} g_i = 1 \quad . \tag{10.4}$$

Practice recommendations:

- *the weighted arithmetic mean* is used to calculate a complex quality indicator when homogeneous indicators having little variation are combined;

- with a significant variation of indicators it is recommended to use *the weighted harmonic mean;*

- the most universal methods of formation of the complex indicator is considered on *the principle of weighted geometric mean.* By this scheme, combined single quality indicators when they are heterogeneous (refer to the diverse products and different conditions of its application) and have a significant variation.

If a complex indicator includes heterogeneous single indicators they will need to be expressed in relative form.

When estimating the properties of the product by the complex quality indicator, the low values of some single indicators can be compensated by the unreasonably high others. To eliminate such possibility, the complex quality indicator is multiplied by *the coefficient of veto*. This coefficient is equal to *zero*, when any of the most important single indicator has gone beyond the permissible ranges, and equal to *one* in all other cases. Due to this, a complex quality indicator falls to zero, if at least one of the important properties of the product is too little.

Complex quality indicators obtained from single indicators can be combined into complex indicators of a higher level. Thus, the structure of quality indicators is a multi-level. In the transition to a higher level of indicators, the quality model of production becomes more rude, till this model is not reduced to the description of the quality of one indicator – *a generalized indicator*.

Complex quality indicators can be formed in relation to a particular group of product properties. Such indicators are called *group indicators*. So, for the industrial products the group quality indicators are *indicators of purpose, reliability, security,* *and others.*

A kind of a complex indicator, estimating the quality from the economic perspective, is *an integral indicator of quality*. It is defined as the ratio of the total useful effect from the use of products to the value of the cost on its creation and operation.

E x a m p l e: the integral indicator of quality is the unit cost of 1 km of run

$$K_y = \frac{Z_C + Z_E}{L},$$

where Z_C and Z_E - respectively, the cost and the expenses for operation of vehicle before overhaul;

L - vehicle mileage to overhauls.

10.3 Methods for Determining Quality Indicators

Instrumental and expert methods can be used to determine the values of quality indicators.

Instrumental methods are used in limited cases where the quality indicators are physical values and there are measuring instruments (measuring devices), having normalized metrological characteristics. Instrumental determination of quality indicators is reduced to the solution of the usual measurement objectives of metrology.

Expert methods are used when the use of measuring instruments is impossible or not economically justified. Expert methods are used, for example, for the estimation of ergonomic and aesthetic indicators, in sport, in humanities sciences.

The kinds of expert method are organoleptic and sociological methods.

Organoleptic method is based on determining the properties of an object using the human senses: eye sight, hearing, touch, smell and taste. For example, to estimate the quality of tea by tasters.

Sociological methods are based on the population polls when each individual acts as an expert.

The general to all expert methods is the view of *the human- expert* as some "non-technical" measuring instrument. It is believed that the measure of relevant properties the human creates in his imagination. Being based on this methodological approach, expert estimations of the quality indicators are often referred to as the result of the measurement, and estimation process itself - the quality measurement.

Expert estimations are the result of a rude estimation but not of measurement! And, nevertheless, expert estimations of consumer properties of production, yet inaccessible for measurement, have great practical role, open up the possibility of comparison, classification of objects on the intensity of estimated properties.

Expert estimation of the quality of products can be given by one person, but to improve the reliability of the estimation the preference is given *to the group method of estimation.* To be effective, estimates must be carefully selected and attestated by an expert commission.

The basis for the selection of candidates for an expert commission is a check of their competency through testing. When forming a group, significant difficulties are associated with the problem of ensuring consistency and independence of expert assessments. Therefore, at the final stage of formation of the commission it is advisable to carry out self-assessment and mutual assessment of experts. The experience shows that expert groups with high self-assessments rarely mistaken in estimation of the quality of facilities.

More information on the topic can be obtained in [2-4].

Appendix A

Automated Process Control System

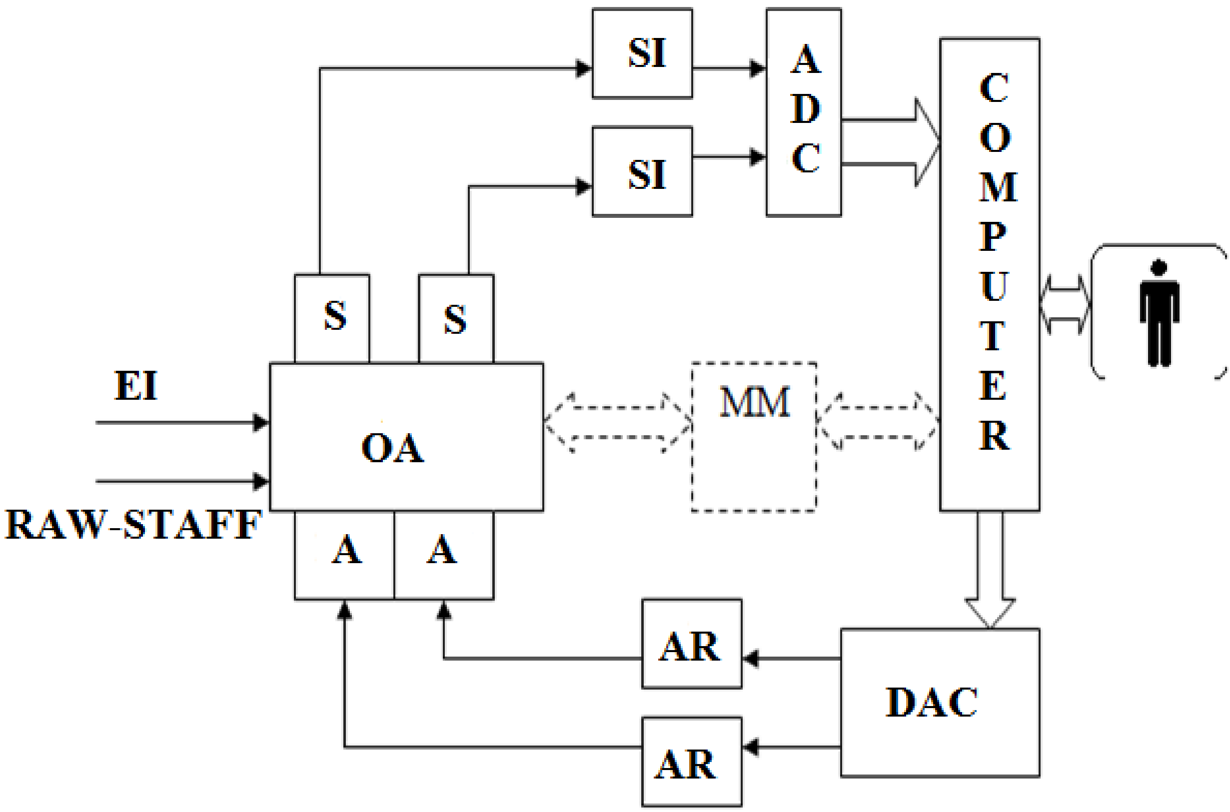

Figure A.1 – Block diagram of APCS

Appendix B

Classification of Measurements

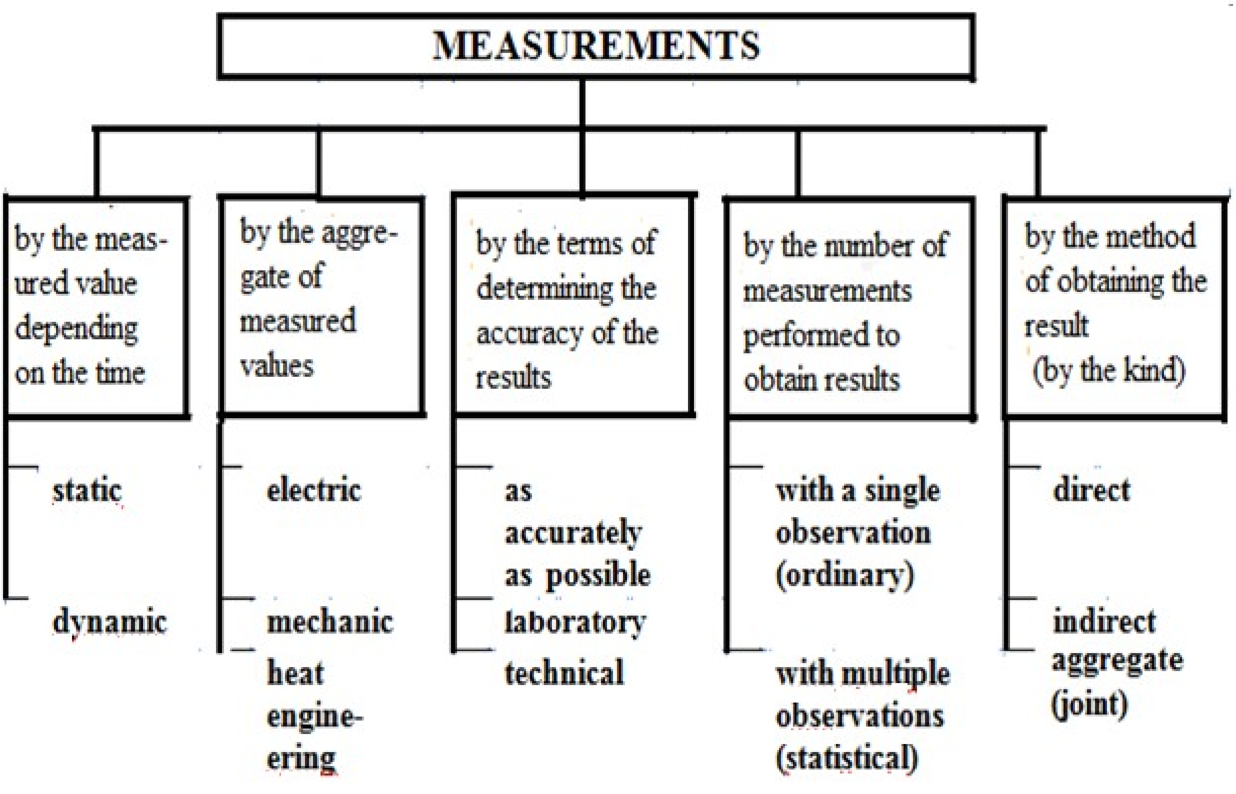

Figure B.1 –Classification of measurements

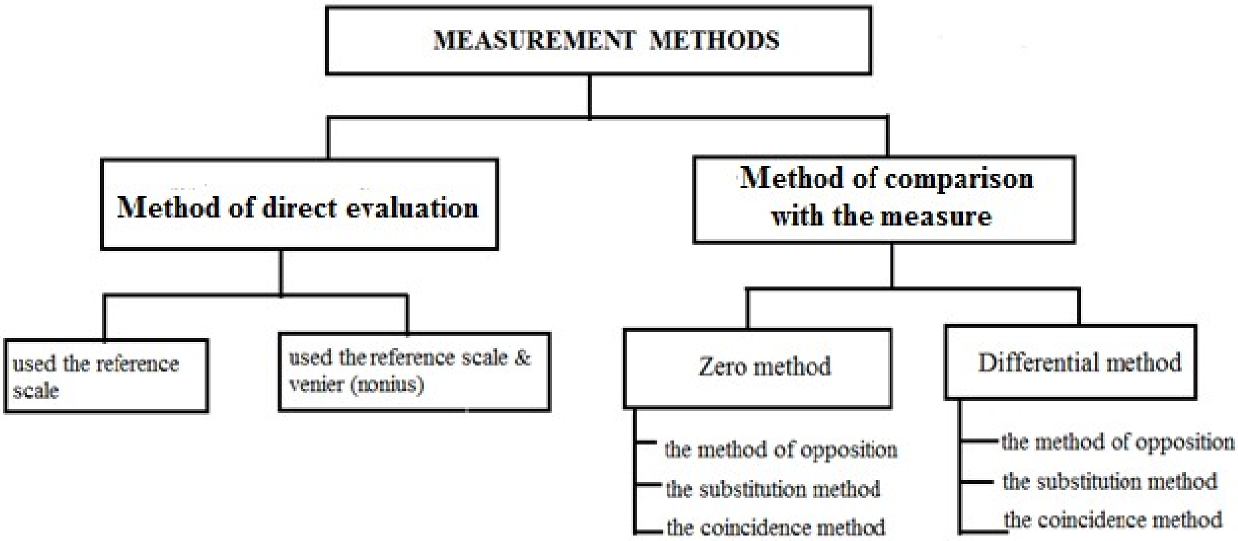

Figure B.2 – Classification of measurement methods

Appendix C

Classification of Measuring Errors

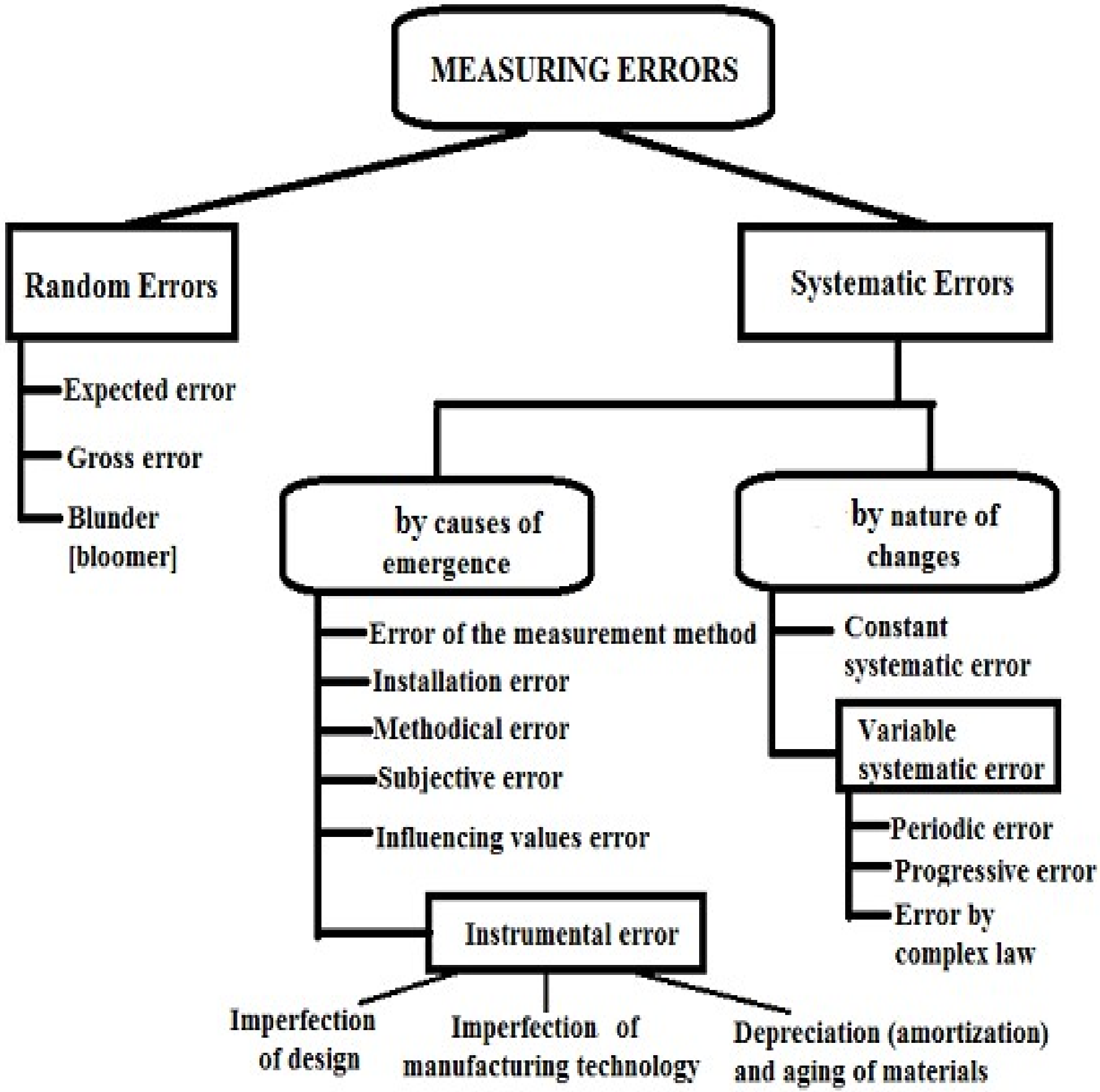

Figure C.1 - Classification of Measuring Errors

Appendix D

Classification of Measuring Instruments

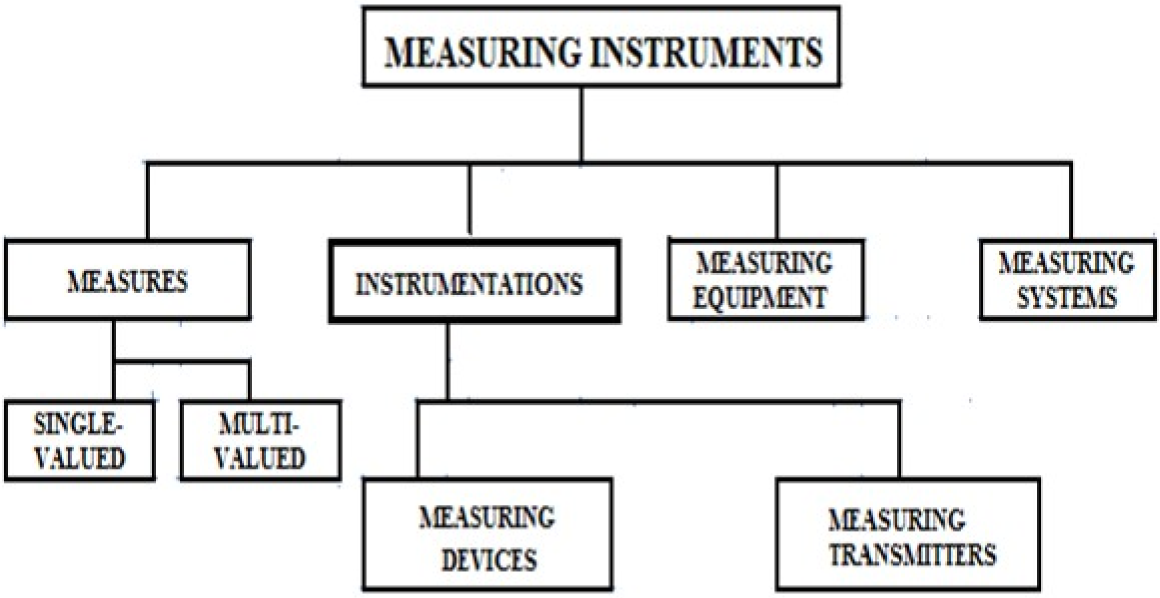

Figure D.1 – Classification of measuring instruments

Appendix E

Classification of Errors of Measuring Instruments

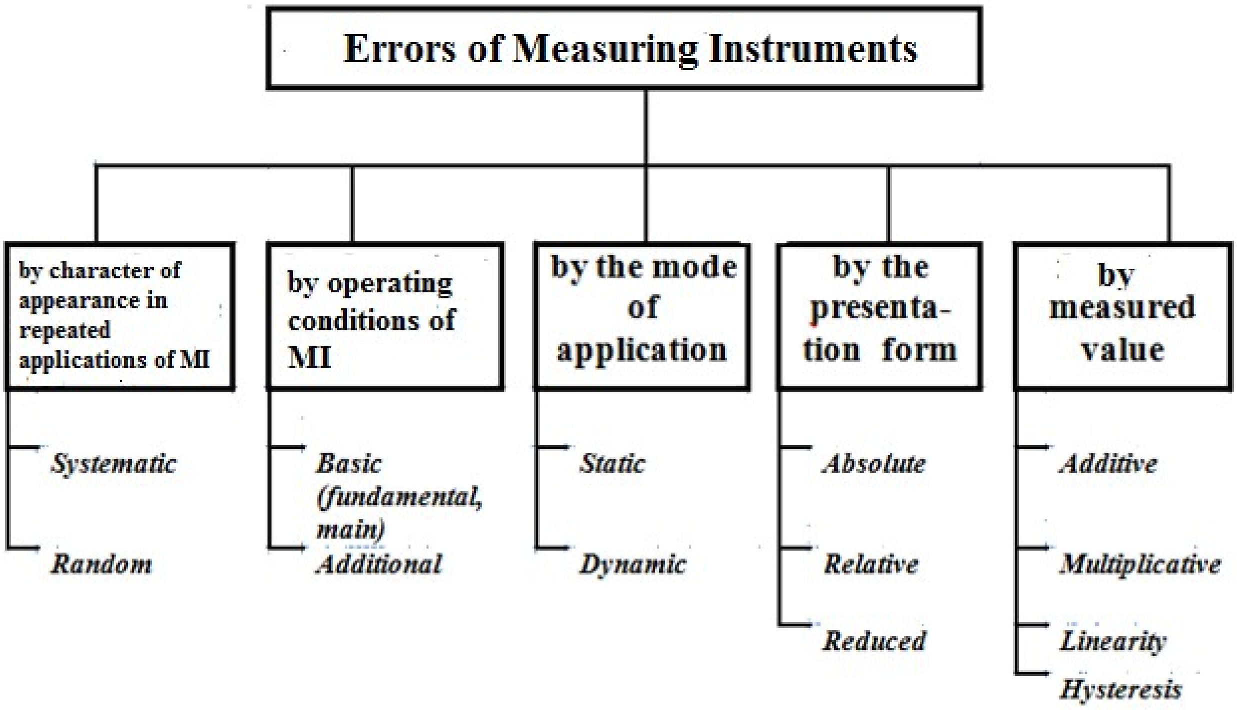

Figure E.1 – Classification of errors of measuring instruments

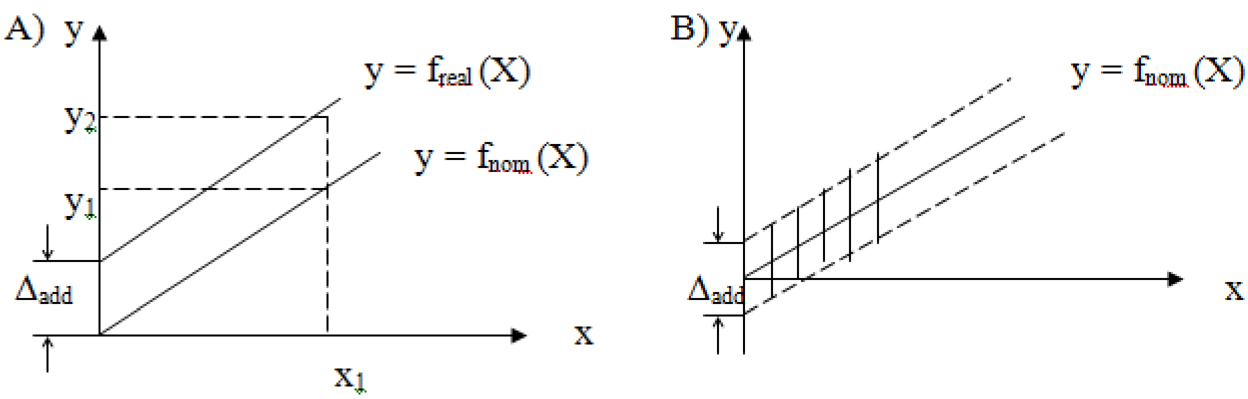

Figure E.2 – Graph of additive errors of MI
(A - systematic error, B – random error)

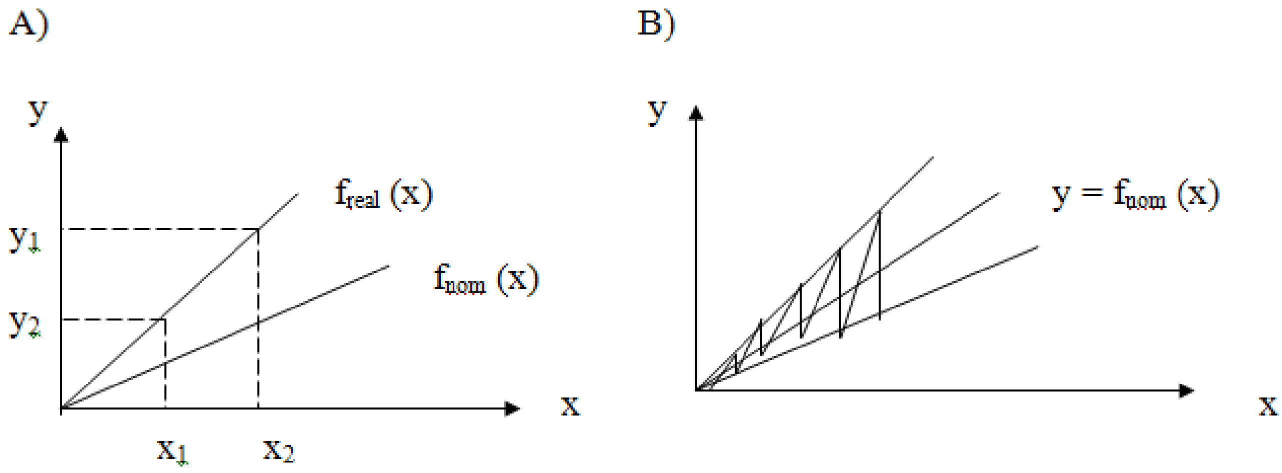

Figure E.3 – Graph of multiplicative errors of MI
(A - systematic error, B – random error)

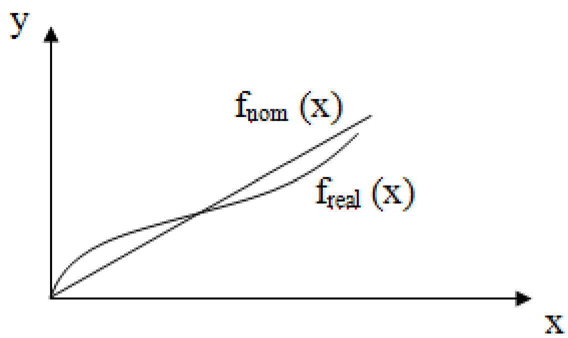

Figure E.4 – Graph of linearity errors of MI

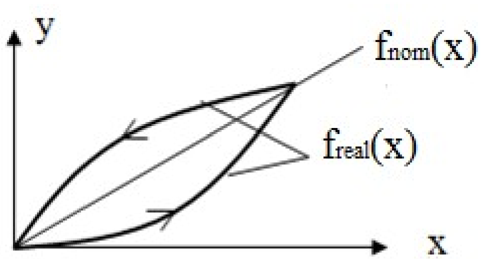

Figure E.5 – Graph of hysteresis errors of MI

VOCABULARY

Lecture 1

actuator (A) – исполнительный механизм
ambient temperature – температура окружающей среды
analog-to-digital converter (ADC) –АЦП
arshin - аршин
Automated Process Control System (APCS) – Автоматизированная система управления технологическими процессами (АСУ ТП)
Automatic Control System (SAC) - Система автоматического управления (САУ)
automatic controller (AC), regulator – автоматический регулятор
correspond to feasibility of measurement by "improvised" ways **-** соответствовали возможности осуществления измерений «подручными» способами
cubit – локоть
derivative units - производные единицы
digital-to-analog converter (DAC) –ЦАП
ensuring the uniformity of measurements – обеспечение единства измерений
external influences (EI) – внешние влияющие величины
hyperfine structure of the ground state **-** сверхтонкой структуры основного состояния
infinite length - бесконечная длина
interrelated and interdependent common rules - взаимосвязанные и взаимообусловленные общие правила
kosaya sazhen - косая сажень
legislative provisions **-** законодательные положения
mathematical Model (MM) – математическая модель
measurand, measured value (quantity) – измеряемая величина
measurer, meter; gauge; counter – измеритель, прибор
measuring instrument – средство измерения
metrology, standardization, certification and quality management - *метрология*, стандартизация, сертификация и управление качеством
negligible circular cross-section **-** ничтожно малое круговое сечение
physical value (quantity) PV – физическая величина
raw-staff - сырье
sazhen – сажень
searches shifted – поиски переместились
secondary device **(***SD***)** – вторичный прибор
sensor (S*), transmitter* – датчик, преобразователь
span (single inch) – пядь
subject of automation (SA) – объект автоматизации
thermistor, Thermal Resistance – термосопротивление
thermocouple – термопара

thermoelectric converter (TEC) – термоэлектрический преобразователь
transmitter, Transducer - измерительный преобразователь
triple point of water **-** тройная точка воды
units of physical values – единицы физических величин

Lecture 2

accuracy of measurement - точность измерения
actual physical value - действительное значение физической величины
adopted units – общепринятые единицы
aggregate (joint) **–** совокупный (совместный)
an ammeter - амперметр
an arrow on the scale of the device – стрелка на шкале прибора
by the aggregate of the measured values - по совокупности измеренных величин
by the measured value depending on the time - по зависимости измеряемой величины от времени
by the method of obtaining the result (by the kind) **-** по способу получения результата (по виду)
by the number of measurements performed to obtain results - по числу измерений, выполняемых для получения результатов
by the terms, determining the accuracy of results - по условиям, определяющим точности результатов
coincidence method - метод совпадений
coincidence of scale marks - совпадение отметок шкал
common in quality – общее в качественном отношении
classification feature - квалификационный признак
denominated number – именованное число
density – плотность
directly measured values - непосредственно измеряемые величины
dissimilar values – разноименные величины
equal-shoulders balance – равноплечие весы
high-precision measure – высокоточная мера
humidity – влажность
individual in quantity – индивидуальное в количественном отношении
influencing physical value (IPV) – влияющая физическая величина
measure – мера
measurement – измерение
measurement object (MO) - объект измерения
measuring error – погрешность измерения
measuring instrument (MI) (device, tool) – средство измерения
method of comparison with the measure (MCM) – метод сравнения с мерой
method of direct evaluation (MDE) - метод непосредственной оценки
method of opposition – метод противопоставления

numerical value of a measured quantity – числовое значение измеряемой величины
qualitatively - качественно
quantitative content – количественное содержание
quantitatively- количественно
reference scale – отсчет по шкале
search value – искомое значение
simultaneously affect **-** одновременно воздействуют
size of a physical unit (the size of a unit) - размер единицы физической величины (единицы измерения) = *dimension* - размерность
specific weight (gravity) - удельный вес
standard (etalon) - эталон
substitution method – метод замещения
to get closer to –приблизиться к = *approaching*
to have an impact on – иметь влияние на
to measure – измерять, мерить
true physical value – истинное значение физической величины
unit of measurement – единица измерения
value directly reproduced by the measure – величина, непосредственной воспроизводимая мерой
value taken per unit of comparison – величина, принятая за единицу сравнения
vernier (nonius) (auxiliary scale) – нониус (дополнительная шкала)
weighing a load (cargo) on the spring balance – взвешивание груза на пружинных весах

Lecture 3

arithmetic mean of the results of individual observations **–** среднее арифметическое результатов наблюдений
blunder [bloomer] – промах
by complex law – по сложному закону
causes of emergence – причины возникновения
constant systematic error – постоянная систематическая погрешность
correction at the end of the measurement – поправка по окончании измерения
dispersion of a set of observations – дисперсия ряда наблюдений
distribution law of random values – закон распределения случайных величин
error of measurement method – погрешность метода
evaluations of basic characteristics – оценка основных характеристик
expected error- ожидаемая погрешность
gross error- грубая погрешность
imperfection of design – несовершенство конструкции
imperfection of manufacturing technology of measuring instruments – несовершенство технологии изготовления СИ
imperfection of the measurement method – несовершенство метода измерения

influencing values error – погрешность от влияющих величин
installation error- погрешность установки
instrumental error – инструментальная погрешность
insufficient knowledge of the phenomenon – недостаточная изученность явления
mathematical expectation – математическое ожидание
mean square deviation – среднее квадратическое отклонение
methodical error – методическая погрешность
nature of appearence - характер проявления
nature of changes – характер изменений
normal distribution law (Gauss) – нормальный закон распределения (Гаусса)
periodic systematic error - периодическая систематическая погрешность
probability density of the distribution law – плотность вероятности закона распределения
progressive systematic error – прогрессивная систематическая погрешность
random error – случайная погрешность
really distort – явно искажает
running out (amortization) and material aging - постепенный износ (амортизация) и старение материала
scatter - разброс
square root of the dispersion – квадратный корень из дисперсии
standard deviation of a series of observations (S) – стандартное отклонение ряда наблюдений
subjective error – субъективная погрешность
systematic error – систематическая погрешность
uniform distribution law – равномерный закон распределения
variable systematic error – переменная систематическая погрешность

Lecture 4

additional error - дополнительная погрешность
as small as desired - сколь угодно малой
axiom of distribution – аксиома распределения
axiom of randomness – аксиома случайности
basic error – основная погрешность
confidence borders – доверительные границы
confidence interval – доверительный интервал
correction, adjustment – поправка
elimination - устранение
exclusion of sources - исключение источников
given confidence probability – заданная доверительная вероятность
handle together – обрабатывать вместе
limits of admissible additional error - пределы допускаемой дополнительной погрешности
limits of admissible basic error – пределы допускаемой основной погрешности

make a correction - внести поправку
method of multi-channel measurements - метод многоканальных измерений
method of multiple repeated measurements - метод многократных измерений
method of parametric stabilization - метод параметрической стабилизации
normal conditions – NC – нормальные условия
probabilistic estimation (evaluation) – вероятностная оценка
reliability - надежность
several MI - несколько СИ
structural methods – структурные методы

Lecture 5

accessible - доступной
alternating current – переменный ток
auxiliary devices - вспомогательные устройства
bit standards – разрядные эталоны
block-modular principle – блочно-модульный принцип
conversion (transfer) function - функция преобразования,
designed - предназначенное
direct action devices and devices of comparison - приборы прямого действия и приборы сравнения
direct current – постоянный ток
exemplary working measures - образцовые рабочие меры
final and initial values of the scale - конечное и начальное значения шкалы
full-scale range - диапазон показаний по шкале прибора
functional feature - функциональный признак
improve the reliability - повышать надежность
instrumentation (I) – измерительное устройство
interchangeability –взаимозаменяемость
kettlebell - гиря
measuring device (MD) – измерительный прибор
measuring equipment (ME)– измерительная установка
measuring instrument (MI) – Средство Измерений
measuring systems - измерительные системы
measuring transmitter (T), transducer – измерительный преобразователь
national metrology agency – национальный орган по метрологии
nearby scale marks – соседние отметки шкалы
normalized metrological characteristics (NMC) - нормированные метрологические характеристики
normalized permissible error – нормированная допустимая погрешность
operation mode – режим работы
provide broad prospects - давать широкие перспективы
ruler – линейка
scale spacing – цена деления

sensitivity - чувствительность,
showing and recording devices - показывающие и самопишущие приборы
slope of the tangent - тангенс угла наклона касательной
SSI (the State System of industrial Instrumentation and automation) - ГСП (Государственная система промышленных приборов и средств автоматизации)
storage – хранение
suitable for transmission – удобной для передачи
technical means – технические средства
threshold of sensitivity - порог чувствительности
unified MI – унифицированные СИ
verification (testing) and calibration – поверка и градуировка

Lecture 6

absolute, relative and reduced error – абсолютная, относительная и приведенная погрешность
accuracy class - класс точности
additional error – дополнительная погрешность
additive error - аддитивная погрешность
basic (fundamental, main) – основная погрешность
by measured value – от значения измеряемой величины
by character of appearance in repeated applications of MI – от характера проявления при повторных применениях СИ
by mode of MI application – от режима применения СИ
by operating conditions of MI - от условий эксплуатации СИ
by the presentation form – от формы представления
can be found fit and approved for use - может быть признан годным и допущен к эксплуатации.
conversion factor – коэффициент преобразования
conversion function – функция преобразования
dimensionless quantity - безразмерная величина
dry friction in mechanical transmission elements - сухое трение в механических передающих элементах
errors of a transducer at the input and output - погрешности измерительного преобразователя по входу и по выходу
extended range of values (ERV) – расширенная область значений (РОЗ)
flyback error (lag error) - погрешность обратного хода (погрешность запаздывания)
forward stroke – прямой ход
friction in bearings – трение в опорах
gap, clearance - люфт
generalized metrological characteristic (MC) – обобщенная метрологическая характеристика
hysteresis error – погрешность гистерезиса

imperfection of technology of schemes production - несовершенство технологии производства схем
inner friction in springs materials - внутреннее трение в материалах пружин
linearity error - погрешность линейности
mismatch – несовпадение
multiplicative error – мультипликативная погрешность
nominal and real conversion function – номинальная и реальная функции преобразования
nonlinear distortion - нелинейные искажения
normalized value of the measured value – нормированное значение измеряемой величины
normalizing value of the measured value – нормирующее значение измеряемой величины
operating mode of application **-** режим применения
permissible (admissible) error – допускаемая погрешность
relative error of the measuring device –относительная погрешность измерительного прибора
reverse conversion function – обратная функция преобразования
set noise – собственный шум прибора
to shift with respect to - смещается по отношению к
zero drift – дрейф нуля

Lecture 7

advisability of standard - целесообразность стандарта
authority – орган власти
bodies and services of standardization - органы и службы стандартизации
Bodies and Services of Standardization **-** Органы и службы стандартизации
cancellation - отмена
classifiers of technical and economic information – классификатор технико-экономической информации
Committee of Technical Regulation and Metrology – Комитет технического регулирования и метрологии
compatibility and interchangeability of products – совместимость и взаимозаменяемость продукции
confirmation of conformity – подтверждение соответствия
consumer – потребитель
defense capability - обороноспособность
disasters and emergencies - катастрофы и чрезвычайные ситуации
documents of technical specifications **-** документы технических условий
exhaustive list of products – исчерпывающий перечень продукции
fulfillment of requirements - выполнение требований
fundamentals **–** общие положения
general purposes (goals) – общие цели

Guide – Руководство
implementation of requirements – выполнение требований
Law «On ensuring the uniformity of measurements» – Закон «Об обеспечении единства измерений»
Law «On technical regulation» – Закон «О техническом регулировании»
Law «On Consumer Rights Protection» – Закон «О защите прав потребителей»
maintenance - техническое обслуживание
mandatory to implement - обязательная для реализации
marking or labeling - маркировка или этикетирование
mobilization readiness - мобилизационная готовность
national authorized body - национальный уполномоченный орган (УО)
nature of standardization - сущность стандартизации
normative documents – нормативные документы
normative legal acts – нормативно-правовые акты
objects and areas of standardization - объекты и области стандартизации
optimum benefit to society - оптимальная выгода для общества
participants - участники
particular purposes – конкретные цели
permanent working body – постоянный рабочий орган
preliminary (temporary) standards - промежуточный (временный) стандарт
property – имущество
provision – положение
publicly available – общедоступные
reasonable prices – приемлемые (умеренные) цены
regulation - регулирование
«Regulation on the Committee of Standardization, Metrology and Certification of the Ministry of Industry and Trade RK» – «Положение о Комитете по стандартизации, метрологии и сертификации министерства индустрии и торговли РК»
regulations - регламент (нормативный документ)
right to safety and comfortable working - право на безопасность и комфортность труда
rule books – своды правил
rules of sampling – правила отбора проб
self-contained standard - самостоятельный стандарт
standardization body - орган по стандартизации
technical -regulations (TR) – технический регламент
to purchase products – приобретать товары

Lecture 8

Action Committee - Комитет действия
adjacent activities - смежные виды деятельности
ANSI (USA) - Американский национальный институт стандартов

associate members – ассоциированные *члены*
bilateral agreements - двусторонние соглашения
bilateral cooperation - двустороннее сотрудничество
CASCO - Committee on conformity assessment - комитет по оценке соответствия
CEN (European Union) - Comité Européen de Normalisation (франц.) – Европейский комитет по стандартизации
CENELEC - Comité Européen de Normalisation Électrotechnique (франц.) — Европейский комитет электротехнической стандартизации, отвечающий за европейские стандарты в области электротехники.
compliance with standards - соответствие стандартам
conformity assessment - оценка соответствия
consumers participating - участие потребителей
consumption of high-quality, safe and competitive products - потребление высококачественной, безопасной и конкурентоспособной продукции
COPOLCO - Committee for the protection of consumers' interests - комитет по защите интересов потребителей
DEVCO - Committee on aid to developing countries - комитет по оказанию помощи развивающимся странам
developed countries - развитые страны
developing countries - развивающиеся страны
dissolution - роспуск
EASC - the Eurasian Council for Standardization, Metrology and Certification - Евразийский Совет по стандартизации, метрологии и сертификации (EASC)
elimination of technical barriers - устранение технических барьеров
encourage - стимулирование
ETSI - European Telecommunications Standards Institute - Европейский институт по стандартизации в области телекоммуникаций
evidence of conformity -доказательство соответствия
Executive Bureau - Исполнительное бюро
first sectoral of the international organization for standardization – первая отраслевая международная организация по стандартизации
former USSR - бывший СССР
full members – действительные члены
full-fledged members –полноправные члены
general engineering - общетехнические
highest governing body - высший руководящий орган
IEC - International Electrotechnical Commission - Международная электротехническая комиссия (МЭК)
in identifying differences - при выявлении расхождений
INFCO - Committee for Scientific and Technical Information - комитет по научно- технической информации
interchangeability, technical compatibility, testing methods of production and general methodological issues - взаимозаменяемость, техническая совместимо-

сть, методы испытания продукции и общие методологические вопросы
ISC CIS - Interstate Council for Standardization, Metrology and Certification (ISC) of the Commonwealth of Independent States (CIS) - Межгосударственный совет по стандартизации, метрологии и сертификации (МГС) Содружества Независимых Государств (СНГ)
ISO - International Organization for Standardization – Международная организация по стандартизации (ИСО)
ISO Council - Совет ИСО
joint property - совместное достояние
maintain the normative framework - поддержание нормативной базы
members – correspondents – члены-корреспонденты
members – subscribers – члены-подписчики
membership fees - членские взносы
opportunities to promote - возможности содействия
orderliness and organization - упорядоченность и организованность
PLAKO - technical bureau - техническое бюро
promote - содействовать
proposals - предложения
REMCO - Committee on reference materials - комитет по стандартным образцам
responsible for promoting -занимается продвижением
revenues – доходы
Russian State Standard – Госстандарт России
sessions - заседания
STACO - Committee for the Study of the scientific principles of standardization - комитет по изучению научных принципов по стандартизации
stationary marine facilities - стационарных морских комплексов
topical issues - актуальные вопросы
waveguides – волноводы
world industrial output - мировая промышленная продукция

Lecture 9

admission to the certification system - допуск к системе сертификации
agreements on the recognition - соглашения по признанию
animals and plants – животные и растения
applicant – заявитель
assurance – уверенность
at least once a year - не реже одного раза в год
confirmation of conformity – подтверждение соответствия
environmental friendliness – экологичность
exchange or refund – обмен и возврат
forms of participation - формы участия
from the date of purchase of the goods – с даты продажи товаров

goods measured in meters, namely fabrics of fibers of all kinds, knitted and curtain fabric, artificial fur, carpets, non-woven fabrics, tapes, lace,braid, wires, cords, cables, linoleum, moldings, films, oilcloth **-** метражные товары, а именно ткани из волокон всех видов, трикотажного и гардинного полотна, меха искусственного, ковровых изделий, нетканых материалов, лент, кружева, тесьмы, проводов, шнуров, кабелей, линолеума, багета, пленки, клеенки.
hosiery products (legwear) - чулочно-носочных изделий;
improper performance of works and provision of services - ненадлежащее выполнение работ и оказание услуг
issuance of the certificate of conformity - выдача сертификата соответствия
legal entities – юридические лица
«Made true» - «Сделано верно»
mandatory certification - обязательная сертификация
manufacturer, supplier, vendor, consumer of product - производитель, поставщик, продавец, потребитель продукции.
mutual recognition agreements= agreement on the recognition - соглашения о взаимном признании =соглашение по признанию
participation in the certification systems - участие в системах сертификации
proper and improper quality – надлежащее и ненадлежащее качество
reliable proof of conformity - достоверные доказательства соответствия
reparation - возмещение ущерба
right to proper quality of the got goods, works and services **-** право на надлежащее качество приобретаемых товаров, выполняемых работ и оказываемых услуг
rights are violated - права нарушаются
shelf life - срок хранения
substandard goods - недоброкачественные товары
term of certificate - срок действия сертификата
underwear **–** нательное (нижнее) белье
voluntary certification - добровольная сертификация

Lecture 10

contradictory - противоречивый
cost and expenses for operation - себестоимость и затраты на эксплуатацию
current consumption - ток потребления
diverse products - разнородная продукция
ergonomic and aesthetic indicators - эргономические и эстетические показатели
generalized characteristic **-** обобщенная характеристика
group consistency of expert opinion - согласованность группы экспертного заключения
has gone beyond the permissible ranges – вышел за допустимые пределы
heterogeneous (inhomogeneous) indicators **–** неоднородные показатели
homogeneous indicators having little variation are combined **-** объединяются однородные показатели, имеющие незначительный разброс

legal measure (for this property) - узаконенная мера (этого свойства)
little variation **-** незначительный разброс
multi-dimensional property **-** многомерное свойство
necessary and sufficient to - необходимый и достаточный для
not economically justified - экономически не оправдано
organoleptic method- органолептический метод
overhaul - капитальный ремонт
population polls - опросы населения
power consumption - потребляемая мощность
principle of weighted average - принцип среднего взвешенного
qualimetry – квалиметрия
quality indicator - показатель качества
self-assessment and mutual assessment of experts - самооценка и взаимооценка экспертов
set of the product properties **-** совокупность свойств продукции
significance of concordance coefficient - значимость коэффициента конкордации
significant variation - значительный разброс
simplified model - упрощенная модель
supply voltage - напряжение питания
taster - дегустатор
unit cost of 1 km of run - удельные затраты на 1 км пробега
unreasonably high others - необоснованно завышением других
u*nreliability of group estimate* - недостоверность групповой оценки
value (weight) - ценность (вес)
vehicle mileage to overhaul **-** пробег автомобиля до капитального ремонта
weighted arithmetic mean - среднее арифметическое взвешенное
weighted geometric mean - среднее геометрическое взвешенное
weighted harmonic mean - среднее гармоническое взвешенное

References

1 Метрология,стандартизация и сертификация в энергетике/ под ред.А.Зайцева. –М., 2009.

2 Тартаковский Д.Ф., Ястребов А.С. Метрология, стандартизация и технические средства измерений. – М.: Высшая школа, 2008.

3 Герасимова Е.Б. Метрология, стандартизация и сертификация. – М., 2008.

4 Дубовой Н.Д. Основы метрологии, стандартизации, сертификации.- М.,2008.

5 Хан С.Г. Метрология, измерения и техническое регулирование. Учебное пособие. –Алматы: АИЭС, 2009.

6 Хан С.Г. Метрология, стандартизация, сертификация и управление качеством. Методические указания по выполнению расчетно-графических работ для студентов всех форм обучения специальности 5В070200 - Автоматизация и управление.- Алматы: АУЭС, 2015.- 43 с.

7 Хан С.Г. Метрология, стандартизация, сертификация и управление качеством. Методические указания по выполнению лабораторных работ для студентов специальности 5В070200 - Автоматизация и управление.- Алматы: АУЭС, 2015.- 66 с.

8 Батоврин В.К. Lab View: практикум по основам измерительных технологий. – ДМК пресс М., 2005.

9 Лифиц И.М. Стандартизация, метрология и сертификация. – М., 2008.

10 ГОСТ Р 54500.3-2011/Руководство ИСО/МЭК 98-3:2008. Неопределенность измерения, Часть 3. «Руководство по выражению неопределенности измерения».

11 Закон РК «Об обеспечении единства измерений». - Астана, 2000.

12 Закон РК «О техническом регулировании». - Астана, 2004.

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