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Development and Research of the Influence on Accuracy of the Main Sources of Uncertainty in the Measurement of Humidity and Other Physicochemical Measured Values

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ABSTRACT: The article considers the issues of accounting for influencing factors on the accuracy of measurements. The compilation of sources of uncertainty of measurement results is analyzed. We know that any measurement process can be represented as a sequence of operations. Therefore, to describe the measured value and identify sources of uncertainty, it is advisable to present the chain of conversion of the measured quantity in the form of a diagram showing the sequence of the measurement process. Some indicators of the quality of measurements obtained in an interlaboratory study can be directly used in assessing uncertainty, while some may require verification in order to identify sources of uncertainty that are beyond the scope of this interlaboratory experiment.

KEYWORDS: measurement accuracy, uncertainty, measurements, factor, source, experiment, measurement result, measured value, diagram, normal distribution law, measurement quality, interlaboratory comparisons, estimation of measurement uncertainty

I. INTRODUCTION

At the first stage of the assessment, determine what and how going to measure, and then go to the second stage - identification of sources of uncertainty. When compiling a list of sources uncertainties are usually convenient to start with the main expression used to calculate the result of intermediate values. All parameters in this expression may be sources of uncertainty. Moreover, there may be parameters that are not explicitly included in expression used to find the value measurable quantity, but which, nevertheless, affect result. You can also consider the measurement procedure in the form sequences of individual operations, defining the uncertainty of each such operation. In practice, the correspondence used for routine analysis of analytical methods for a specific goal most often establish in the course of research to evaluate them suitability. The results of such studies give information, both by general characteristics, and by individual influencing factors, and this information can be use in estimating uncertainty.

General metrological characteristics of the method set in the process of developing the method and its interlaboratory research or following the program intralaboratory research. In routine analysis, when there is data on metrological characteristics of the method, others evaluate

possible contributions to uncertainty for verification only their significance. The emphasis is more on identifying and elimination of significant effects, rather than on the introduction relevant amendments to the analysis result.

Below we consider typical sources uncertainties. Sampling. In cases where operations sampling performed in the laboratory or directly at the object of analysis, are part analytical techniques, effects such as random differences between samples and any possibilities for the appearance of bias in the sampling procedure, form components of the uncertainty of the final product. When determining organ phosphorus pesticides in bread, the distribution of pesticide residues is most likely will take place according to one of three options:

- the substance is distributed only on the upper part surface (implemented in the case of decorative additives, e.g. whole grains);
- the substance is evenly distributed in surface layer;

- the substance is evenly distributed throughout the sample, but its concentration decreases near the surface due to losses due to evaporation or decomposition.

II. LITERATURE SURVEY

Sampling should be carried out depending on Moreover, according to which variant the pesticide residues are distributed.

Storage conditions. When analyzed samples stored for some period of time until execution analysis, storage conditions may affect the result. Therefore, the duration of storage, as well as the conditions storage should be considered as sources uncertainties.

Hardware effects. These effects may include, for example, analytical error limits weights; the presence of a temperature controller that can keep the average temperature different (inspecified limits) from the registered; auto analyzer that may be subject to effects overload.

The scales manufacturer's documentation indicates three source of uncertainty when weighing in containers: precision, readability (digital scale resolution) and contribution due scale uncertainty (scale nonlinearity weights). The latter is caused by sensitivity changes. weights and calibration function. Permissible limit error of the scales specified in the documentation, $\pm 0,0002$ g.

Even if the starting reagent tested, concentration of titration solution cannot be installed with absolute accuracy since there remains some uncertainty associated with the methodology this check. Many reagents, such as organic dyes are not pure and may contain impurities, for example, isomers or inorganic salts. Purity of such substances are usually indicated by the manufacturer, at least such and such a level. Any suggestions regarding degrees of purity, introduce an element of uncertainty.

Measured Glassware can be used, for example, at a temperature different from the one at which it was calibrated. Large temperature effects must be considered. the introduction of amendments, however, in this case, any uncertainty in fluid temperature and glass to be considered. Similarly may have humidity value if the materials used are sensitive to its possible changes.

The resulting diagram is presented in fig. 1.

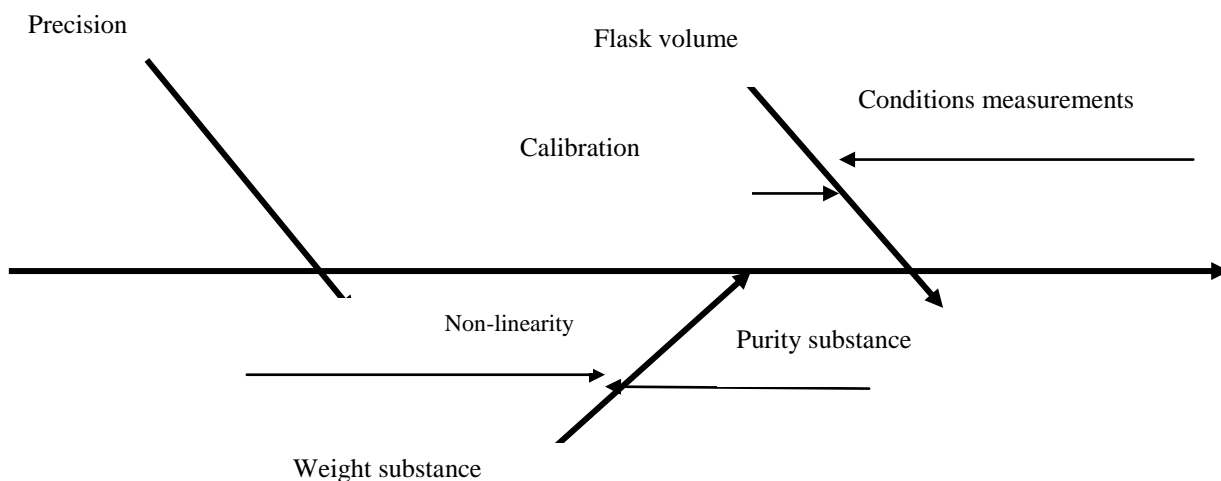


Fig. 1. Chart of sources of uncertainty when preparing a standard solution

III.METHODOLOGY

A variety of sources of measurement uncertainty include:

- a) Incomplete determination of the measurand;

- b) imperfect implementation of the definition of a measured;
- c) non-representativeness of the sample (measurements are carried out on a sample that does not represent the measured value);
- d) inaccurate knowledge of the influence of environmental conditions on the measurement result or inaccurate measurement of quantities characterizing these conditions;
- e) subjective systematic error (introduced by the operator when taking readings of analog instruments);
- f) the final resolution or sensitivity threshold of the instrument;
- g) inaccurate values attributed to standards and reference materials;
- h) inaccurate knowledge of physical constants and other parameters obtained from third-party sources and used in data processing;
- i) approximations and assumptions used in the measurement method and procedure (measurement procedure);
- j) variability in repeated observations under seemingly unchanged measurement conditions.

These sources are not necessarily independent, for example, some of the sources listed in a) to i) may contribute to the source indicated in j). If any systematic effect has not been identified, then it cannot be taken into account in assessing the uncertainty of the measurement result, although it contributes to the measurement error.

To assess the correct operation of the measuring system, the standard standard deviation of the measurement results obtained with its help is often compared with the standard deviation estimate obtained by summing the uncertainty components from different sources. In this case, it is necessary to take into account the components of the uncertainty (regardless of how their estimate was obtained - according to type A or B) only from those sources that determine the variability of the measured value during the experiment.

For these purposes, all sources of uncertainty are divided into two groups: those that determine the variability of the measured value during the experiment, and those that do not influence the changes in the values of the measured value during this experiment. Figure 2 shows a conceptual comparison of accuracy and measurement uncertainty. Theoretical research confirms that the true value of the measured physical quantity changes its value in time and it is impossible to obtain in real conditions.

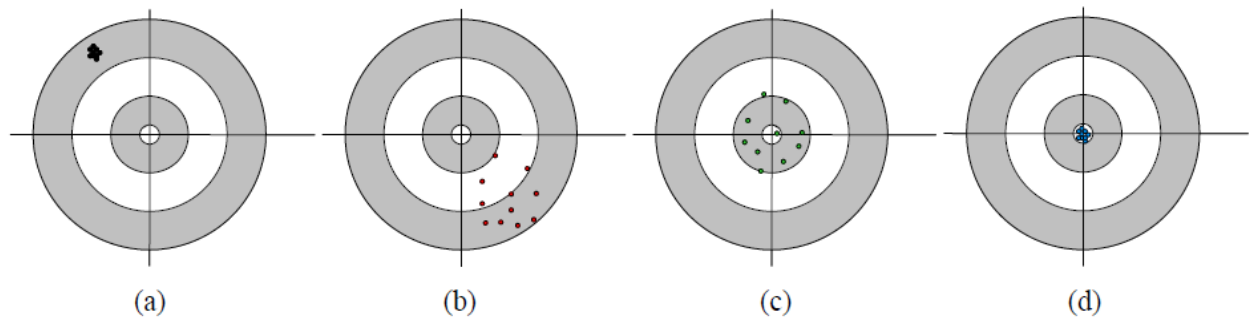


Fig. 2. Illustration of accuracy and uncertainty in the measurement of physical quantities

a) low accuracy but low uncertainty of the measurement results; (b) low accuracy and large uncertainty of the measurement results; (c) high accuracy but large uncertainty of the measurement results; (d) high accuracy and low uncertainty of measurement results.

For example, in Fig. 3, a classification is proposed consisting of 9 main groups and sources of the total uncertainty of capacitive measuring systems for humidity control according to the results of experiments and studies.

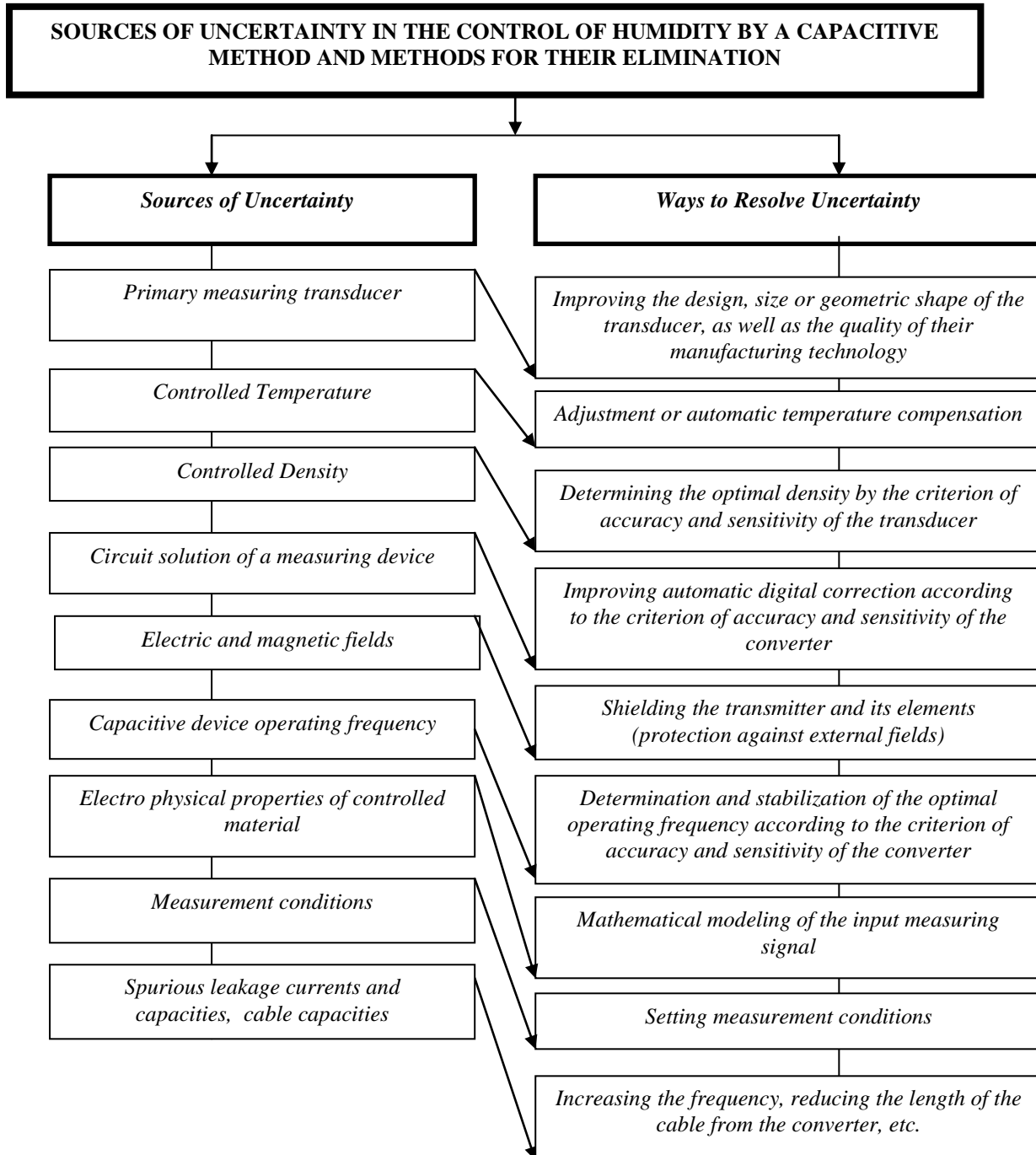


Fig.3. Classification of sources of uncertainty and methods for their elimination when controlling the humidity of materials by the capacitive method

Fig. 4.graphically shows the estimate of the value of the input quantity X_i and the uncertainty estimate of this estimate for the sample (repeated observation) from the general population with the known distribution law. Figure 4 shows the results when the input quantity X_i is temperature t , and the unknown distribution is the normal distribution

with the expected value $m_t=194,689^{\circ}C$ and standard deviation $\sigma=1,5711$, with the probability density described by the formula (1).

$$P(t) = \frac{1}{\sigma \cdot \sqrt{2\pi}} \cdot \exp \left[-\frac{1}{2} \left(\frac{t - m_t}{\sigma} \right)^2 \right] \tag{1}$$

The distribution function has the form (2):

$$F(t) = \frac{1}{\sigma \cdot \sqrt{2\pi}} \int_{-\infty}^t \left[-\frac{1}{2} \left(\frac{t - m_t}{\sigma} \right)^2 \right] dt \tag{2}$$

Figure 5 shows the histogram $n=20$ of repeated observations t_k of temperature t , presumably from the general population, which is described by the distribution shown in Figure 4. To insure the histogram of observation, the values of which are given in Table 1. The results obtained are as follows, $^{\circ}C$: 194, 23; 197.50; 194, 70; 196, 12; 194, 81; 196, 92; 191.65 ;; 195, 96; 194, 56; 195.33; 195, 82; 195, 64; 194, 05; 194, 36; 193, 94; 193, 09; 193.64; 192.77; 192.15; 196, 54. Figure 6 shows the scatter of the results obtained and the deviation of each measurement from the reference value.

Table 1. Twenty repeated observations of temperature t grouped in a class $1^{\circ}C$.wide.

Границы классов ($t_1 \leq t < t_2$)		Observation results, $t, ^{\circ}C$
Lower bound class $t_1, ^{\circ}C$	Upper facet class, $t_2,$ $^{\circ}C$	
189	190	–
190	191	–
191	192	191,65
192	193	192,15; 192,77
193	194	193, 09; 193,64; 193, 94
194	195	194, 05; 194, 23; 194, 36; 194, 56; 194, 70; 194, 81
195	196	195,33; 195, 64; 195, 82; 195, 96
196	197	196, 12; 196, 54; 196, 92
197	198	197,50
198	199	–
199	200	–

The arithmetic average \bar{t} of $n = 20$ observations is calculated by the formula (3):

$$\bar{t} = \frac{1}{n} \sum_{k=1}^{n=20} t_{20} = \frac{191,65 + 192,15 + \dots + 196,92 + 197,50}{20} = 19 \tag{3}$$

It is assumed that it ($\bar{t} = 194,689$) is the best estimate of the mathematical expectation m_t of the quantity t (temperature, measurable quantity).

The scatter of values in the observations of t_{20} is due to random changes in the influencing quantities. Sample standard deviation $S(t_{20})$ is calculated by the formula (4):

$$S(t_{20}) = \sqrt{\frac{1}{n-1} \sum_{k=1}^{n=20} (t_k - \bar{t})^2} = \sqrt{\frac{1}{20-1} \cdot [(191,65 - 194,689)^2 + \dots + (197,50 - 194,689)^2]} = \tag{4}$$

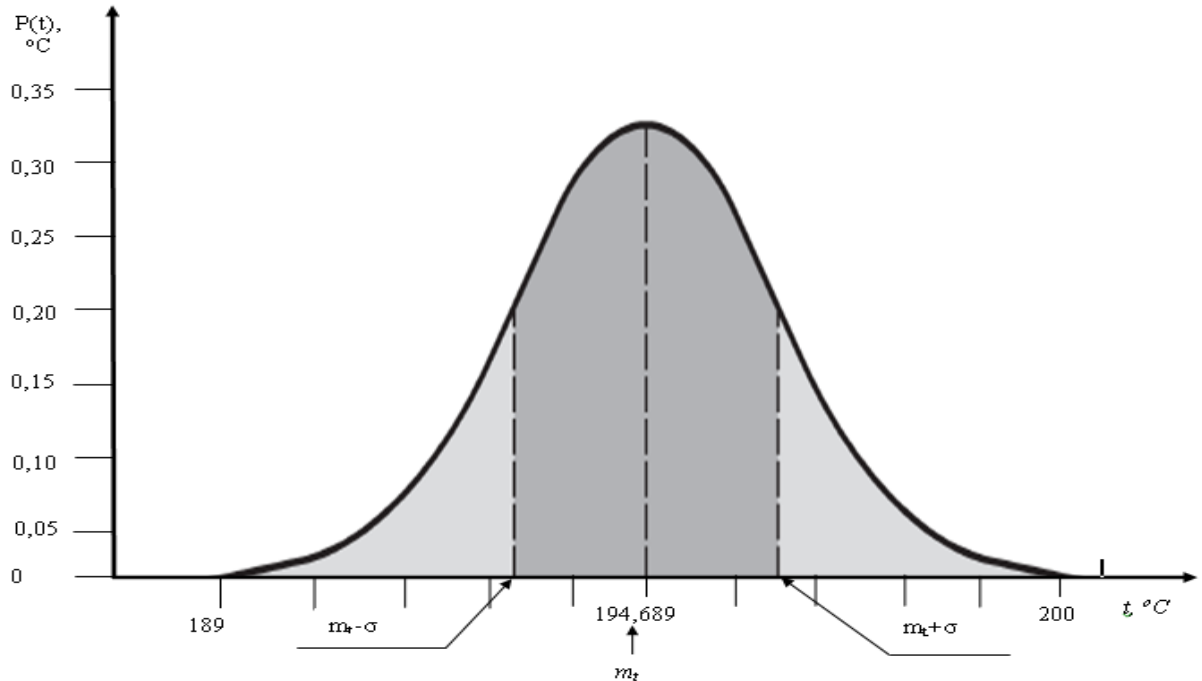


Fig. 4. Graphic illustration of the estimation of the standard uncertainty of the input quantity by repeated observation (graph of the probability density of random processes, measured value - temperature in units of Celsius scale, °C)

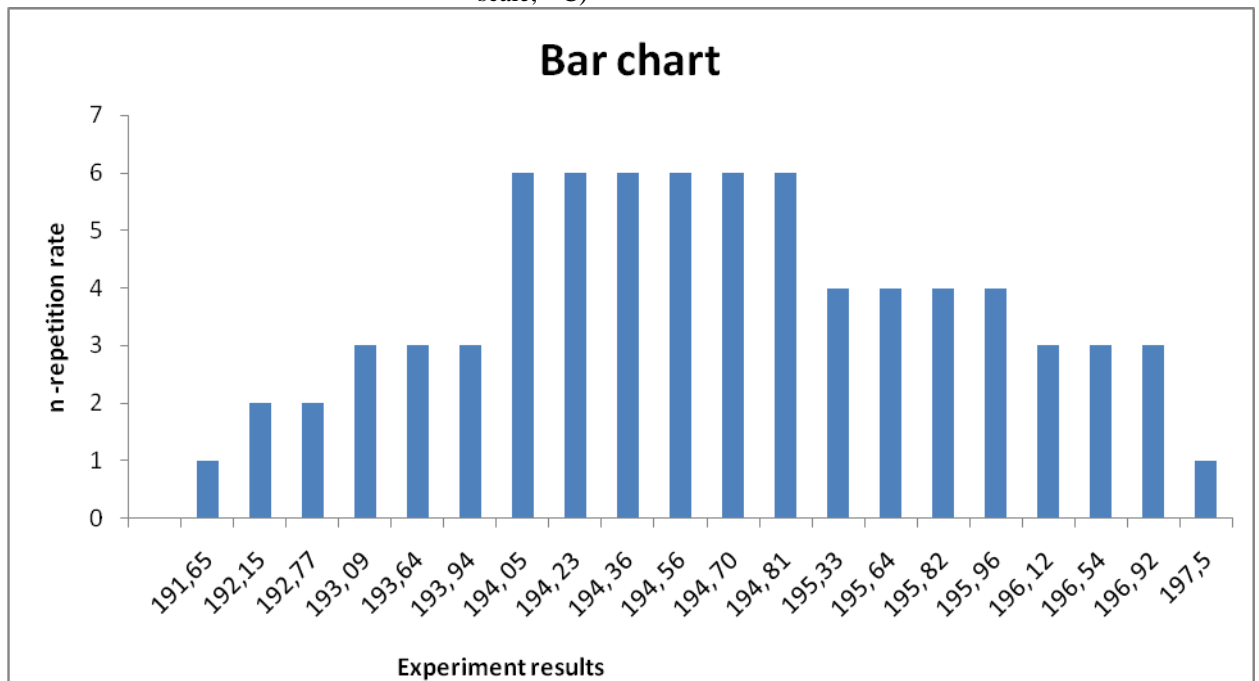


Fig. 5. The histogram of the distribution of a random variable (the histogram is compiled on the basis of experimental work which is shown in Table 1, where the measured quantity is the temperature)

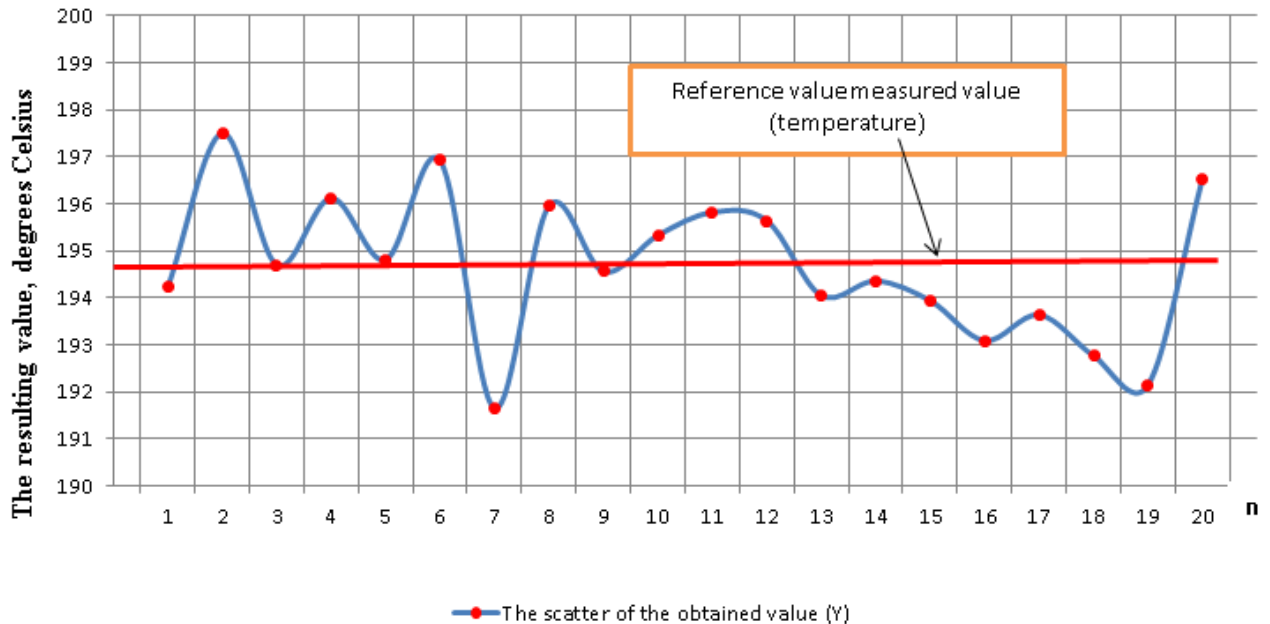


Fig. 6. Scatter of temperature measurement results and deviations of each value from the reference value

Выборочное стандартное отклонение $S(t_k)$ вычисляемое по формуле (5) являются стандартной неопределенности $u_A(t)$ среднего значения.

$$u_A(t) = S(\bar{t}) = \frac{S(t_{20})}{\sqrt{n}} = \frac{1,5711}{\sqrt{20}} = 0,3513 \tag{5}$$

III.CONCLUSION AND FUTURE WORK

Based on the research conducted on the topic: “Development and research of the influence on accuracy of the main sources of uncertainty in the measurement of humidity and other physicochemical measured values”, the following results were obtained:

- at the first stage of the assessment, a mathematical model of the measuring process is compiled. A real informational mathematical model characterizes the mathematical relationship of all the parameters that I participate in the model. After compiling the mathematical model, we proceed to the second stage - identification of sources of uncertainty;

- it should be noted that not all of constituents will make a significant contribution to expanded uncertainty. Really, in practice, only a small number constituents play a role. If the number components are small, then those that less than one third of its size a large component, you can generally exclude from consideration. Need to do preliminary assessment of each contribution component or sum of several components, and those contributions that turned out to be insignificant, can be neglected;

- based on the required accuracy of the measurement procedure, all influencing factors must be classified in advance into significant and insignificant factors. It is recommended that the proportion of each influencing factor that is involved in the mathematical model of the measurement process be calculated.

- before assessing the standard uncertainty of the measurement results (namely, uncertainty of type A), the initial data eliminate the normality of the distribution law (for example, the rules of three sigma) eliminates the effects of systematic and random effects.



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