UDC 621.317.39

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SYNTHESIS OF TEST ACTIONS FOR CAPACITIVE MOISTURE METER THAT IS INVARIANT TO SUBSTANCE TYPE CHANGE

Проведено дослідження різних тестових впливів з метою забезпечення інваріантності діелькометричних вологомірів до зміни сорту речовини. Проаналізовано способи зменшення сортової невизначеності. Виявлено найперспективніший напрям досліджень – тестові методи. Вибрано алгоритм тестового методу і структурну схему вимірювальної системи для адитивного та мультиплікативного тестів. В ході розрахунків отримано вираз для визначення вологості речовини, що є інваріантним до зміни діелектричної проникності.

Ключові слова: діелькометричний вологомір, сортова невизначеність, тестовий метод, адитивний тест, мультиплікативний тест.

In the article the research of various test actions to ensure invariance of capacitive moisture meters to change of substance type is carried out. The analysis of ways to reduce uncertainty of substance type is carried out. The most perspective direction of researches – test methods is chosen. The algorithm of a test method and the block diagram of measuring system for additive and multiplicative tests are chosen. During calculations the expression for determination of substance moisture that is invariant to change of dielectric permeability is obtained.

Key words: capacitive moisture meter, uncertainty of substance type, test method, additive test, multiplicative test.

Problem statement

Product quality improvement, decrease in power consumption at production and storage of ready-made product is one of actual tasks both modern science and its various appendices in national economy. The solution of this task is impossible without development of devices for measurement of product-quality indexes. One of the most widespread product-quality indexes is moisture [1]. Moisture is an important factor at control of parameters and control of technological processes in industry and in production of various materials [2]. For example, water that is contained in hydraulic and lubricating liquids can cause serious damages of details needing greasing [3]. Moisture control is extremely important also for agricultural production. For many types of agricultural production (grain and fodders) moisture is the factor that shows a share of nutrients in production and duration of its storage [4 – 6]. In industry it is often necessary to analyze moisture of petroleum products, bulks, building materials and other substances directly in technological process without using bulky samplers. For the solution of an objective and some other tasks the capacitive method for moisture measurement has gained the most widespread.

Advantages of capacitive moisture meters are first of all the possibility to control a moisture in wide range with high accuracy, efficiency of measurements and no damages on the measured sample [7].The main disadvantage is presence so-called uncertainty of substance type associated with the fact that the dielectric permeability values significantly differ not only for various substances but also and for various brands of the same substance [8].

Thus the most important direction of researches in the field of capacitive moisture meters is reduction of substance type uncertainty that will allow to use these moisture meters for measuring of substances moisture because they have a number of advantages.

Analysis of the last researches and publications

Today there are some ways to solve the uncertainty of substance type for substances moisture measuring using capacitive moisture meters. One of such ways is input of calibration curves in memory of moisture meters. These curves have information about substances dielectric permeability that can be used in the measurement process. However, it is obvious that the amount of substances and types of these substances is so great that to consider all possible dielectric permeabilities isn't possible.

Another way is providing of moisture meters with a calibration tables (moisture meters of Kett, IV3-M1, IV3-M1T, WILE-55, Sinar AP 6060, Kaplia, Grain Master, VSN-100, VSP-6P, Mu1ti Grain, FAUNA, Farmpoint, GAC500, HE-50, Superpoint types) [9]. These tables are created on the basis of experimental data about dielectric characteristics of moisture containing materials. The disadvantage of the most experimental works is that they cover measurements of only one or several materials in the limited frequency range and therefore don't give the chance to receive enough general conclusions about dielectric permeability [7]. One of the ways is carrying out of moisture meters calibration for the specified structure of substance. Thus the moisture meter ceases to be universal as the measurements of moisture are possible only for that structure of substance for which a calibration was carried out. Moreover, the most important is the fact that accuracy of analytical methods of moisture meters calibrations in many cases not more than accuracy of calibrated device [7].

One of the perspective directions is use so-called "test methods" that allow to reduce influence of substance type on the moisture value [10, 11]. The essence of these methods consists in generation of test actions by means of injection a known amount of water or dielectric substance with the set dielectric permeability in initial substance. Thus the result of measurement is determined by change of dielectric permeability of initial sample after test actions with use of test methods.

With a research objective of this direction in early works [8, 12, 13] synthesis and tests of effective ways of test algorithms formation were carried out. These test algorithms would allow the compensating of substance type uncertainty of studied substances in conditions close to real polarizing processes in dielectrics and with a minimum of restrictions. Thus in [12] it is presented a method for formation and research of invariant test algorithm with the use of least-squares method (LSM), and in [13] – with the use of an interpolation Lagrange's polynomial. The theoretical researches conducted in these works proved that compensation of change of dielectric permeability of dehydrated substances is unsatisfactory. Thus application of test methods for the solution of objectives requires more careful research.

Goal setting article

The aim of the article is the study and application of test methods as the most effective way of substance type uncertainty compensation for capacitive moisture meters. The main requirements for the selected method are the possibility of its application both in the laboratory and in production conditions and the possibility of substances moisture determining which is in a continuous stream.

Choice of test method algorithm

Generally at test methods the measuring process consists of several steps. In the first step (the main) the measured value is defined and in others steps an additional tests are carried out each of which is some function of the measured value [11].

Concerning moisture measurements by capacitive method the test approach is the following. So let we have the studied substance that dielectric permeability is unknown. For an exception of this value at moisture determining it is necessary to carry out some additional tests. In the previous works [8, 12, 13] such tests were formed by addition of some in advance known amount of water in studied substance. Thus dielectric permeability of initial sample of substance was equaled. In the first test dielectric permeability of the same sample after addition of a known amount of water was received ( ). The second test was formed by adding to the sample of the first test still the same amount of water. However, as the results of calculations showed such approach didn't allow to get rid completely of the problem of substance type uncertainty. For the solution of objective the algorithms of test method are analyzed by authors. As a perspective the algorithm consisting in carrying out of independent additive and multiplicative tests is chosen.

There are some ways of measuring systems (MS) construction for realization of chosen algorithm. Block diagrams of such MS are presented in fig. 1-3.

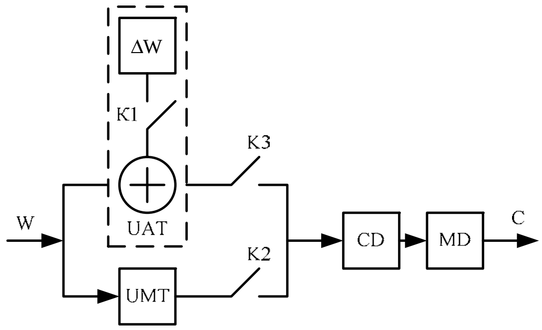

Fig. 1. Block diagram of measuring system for additive and multiplicative tests with three keys: UAT – unit of additive test; UMT – unit of multiplicative test; CD – computing device; MD – measuring device

For this diagram the measurement process consists of three steps. In the first step keys K1 and K2 are disconnected, and key K3 is closed and on input of measuring device (MD) the measured value – moisture W is directly supplied. In the second step K1 is closed and on input of MD the additive test is supplied. In the third step K3 is disconnected, and K2 is closed connecting the output value $k \cdot W$ of unit of multiplicative test (UMD) on input of MD. Results C_1, C_2, C_3 of transformations are transferred from output of MD in computing device (CD).

Thus independent additive tests can be presented in the form of the sum:

$$W_{ad} = W + \Delta W,$$

where W_{ad} – value of substance moisture received after carrying out of additive test; W – measured value of moisture; ΔW – constant component of additive test which is uniform and independent value from W, and is a water addition.

Independent multiplicative tests can be presented in the form of product:

$$W_{mult} = k \cdot W,$$

where W_{mult} – value of substance moisture received after carrying out of multiplicative test; k – coefficient of transformation which is independent from W and represent a certain multiplier.

Block diagram of MS differing by presence of adder is presented in fig. 2.

This diagram is used in case it is impossible to include a key K3 in a chain of the measured value. Thus the additive test will be the same as in the first case: $W_{ad} = W + \Delta W$. The result of multiplicative test can be presented as a sum: $W_{mult} = k \cdot W + W$.

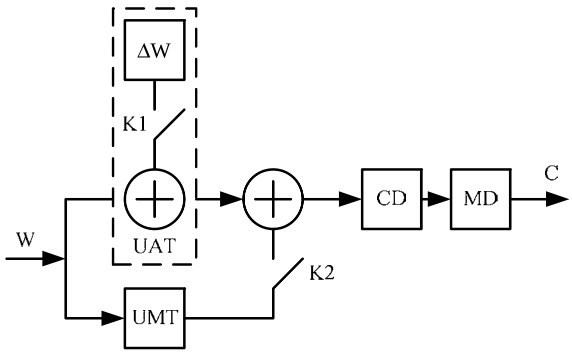

Fig. 2. Block diagram of measuring system for additive and multiplicative tests with two keys and adder

The advantage of the block diagram presented in fig. 3 is the possibility of an exception of influence of transformation coefficient of UMT on the result of measurement.

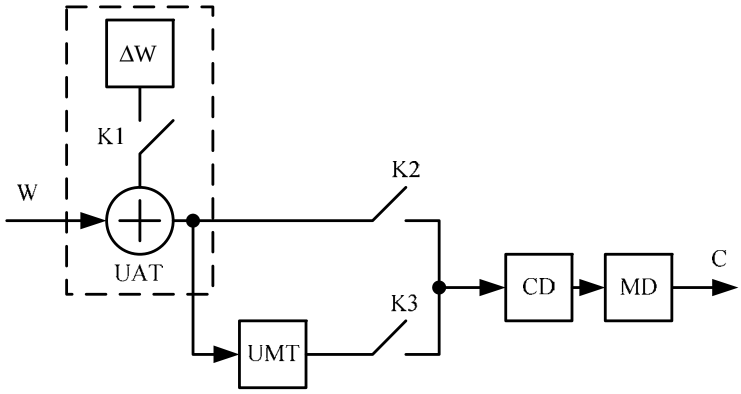

Fig. 3. Block diagram of measuring system for additive and multiplicative tests with two keys and adder without influence of transformation coefficient

In this case process of measurement consists of four steps: measurement of moisture value W, additive test $W_{ad} = W + \Delta W$, multiplicative test $W_{mult} = k \cdot W$ and test of $k \cdot W + k \cdot \Delta W$ type.

For realization of the test method chosen by authors the most suitable diagram is the block diagram presented in fig. 1 as it allows to receive a necessary number of tests of a certain type.

Synthesis of test methods and search of optimum mathematical model for determination of moisture

For the purpose of implementation of possibility of application of test method for capacitive moisture meters at this stage we will consider tests creation for liquid dielectrics (for example petroleum).

Taking into account that test conditions have to be at least two during researches we will receive: capacity of primary measuring transducer (PMT) with initial sample of substance (C_1), capacity of PMT with the same sample after addition of the set amount of water (C_2) (additive test) and capacity of PMT with initial sample of substance at carrying out of measurements k times (C_3) (multiplicative test). This is sufficient for the formation of a system with three equations solving which we will receive expression for determination of substance moisture. Thus using a linear dependence given in [8] we will receive:

$$\begin{cases} C_1 = \varepsilon(1+3W)g; \\ C_2 = \varepsilon(1+3(W+\Delta W))g; \\ C_3 = k \cdot \varepsilon(1+3W)g, \end{cases} \tag{1}$$

where C_1, C_2, C_3 – capacity of PMT with initial sample of substance and at formation of additive and multiplicative tests respectively, pF; ε – dielectric permeability of studied substance; g – spatial characteristic of a field of the gap created by a form of electrodes chosen by PMT, equal 10 m; ΔW – addition of water for additive test, equal 0,1 (10 %); k – coefficient for multiplicative test, equal 2.

For the solution of the system (1) the differential method offered in [14] is used:

$$C_2 - C_1 = 3\varepsilon g \Delta W;$$

$$C_3 - C_1 = \varepsilon g(k-1)(1+3W);$$

$$\frac{C_3 - C_1}{C_2 - C_1} = \frac{(k-1)(1+3W)}{3\Delta W},$$

from which

$$W_{calc1} = \frac{\Delta W(C_3 - C_1)}{(k-1)(C_2 - C_1)} - \frac{1}{3}. \tag{2}$$

Thus from the equation (2) it is visible that substance moisture doesn't depend on dielectric permeability at using the offered test algorithm.

Check of the equation (2) on invariance is carried out with the use of formulas:

$$C_1 = g \cdot \varepsilon_1; \tag{3}$$

$$C_2 = g \cdot \varepsilon_2; \tag{4}$$

$$C_3 = g \cdot \varepsilon_1 \cdot k, \tag{5}$$

where ε_1 – dielectric permeability of initial substance; ε_2 – dielectric permeability of substance with addition of water ΔW, equal 0,1 (10 %).

As change of dielectric permeabilities ε_1 and ε_2 in range of humidity from 0 % to 15 % is nonlinear as mathematical dependence we use Winer's formula allowing rather adequately to describe polarizing processes for a wide class of binary dielectric systems [15].

$$\varepsilon_1 = \varepsilon\left(1 + \frac{3W}{\dfrac{\varepsilon_w + 2\varepsilon}{\varepsilon_w - \varepsilon} - W}\right); \; \varepsilon_2 = \varepsilon\left(1 + \frac{3(W + \Delta W)}{\dfrac{\varepsilon_w + 2\varepsilon}{\varepsilon_w - \varepsilon} - (W + \Delta W)}\right),$$

where ε_w – dielectric permeability of water, equal 80.

So let dielectric permeabilities of some virtual group of substances equal 2,0; 2,1; 2,5; 3,0 and 3,5. We will change moisture of these substances by addition of water into them from 0 (0 %) to 0,3 (30 %) with a step of 0,1 (10 %). The calculated values of dielectric permeabilities are given in table 1.

Table 1

Calculated values of dielectric permeabilities

Moisture (W)	Dielectric permeability (ε)				
	for $\varepsilon = 2$	for $\varepsilon = 2{,}1$	for $\varepsilon = 2{,}5$	for $\varepsilon = 3$	for $\varepsilon = 3{,}5$
0	2,0	2,1	2,5	3,0	3,5
0,1	2,614	2,742	3,252	3,385	4,512
0,2	3,368	3,53	4,173	4,963	5,741
0,3	4,317	4,52	5,324	6,305	7,262
0,4	5,545	5,801	6,806	8,022	9,197

Having substituted in equations (3), (4), (5) known values we will receive capacities C_1, C_2, C_3 of PMT which are necessary for determination of moisture calculated value according to the equation (2). Results of calculations of substance moisture are given in table 2.

Table 2

Results of substance moisture calculations

Moisture (W)	Moisture calculated value (W_{calc})				
	for $\varepsilon = 2$	for $\varepsilon = 2{,}1$	for $\varepsilon = 2{,}5$	for $\varepsilon = 3$	for $\varepsilon = 3{,}5$
0	-0,0076	-0,0062	-0,0009	0,0057	0,013
0,1	0,013	0,015	0,02	0,027	0,034
0,2	0,022	0,023	0,029	0,036	0,044
0,3	0,018	0,02	0,026	0,034	0,042

Obvious is that fact that with the increase of substance moisture W the moisture calculated value W_{calc} also has to increase. As evident from results presented in the table 2 the monotonous increase of moisture values is missing and invariance to change of ε isn't present.

Thus there is a need for creation of one more test with greater addition of water. In this case the system of equations (1) will be:

$$\begin{cases} C_1 = \varepsilon(1+3W)g; \\ C_2' = \varepsilon(1+3(W+\Delta W'))g; \\ C_3' = k'\cdot\varepsilon(1+3W)g, \end{cases} \tag{6}$$

where C_1, C_2', C_3' – capacity of PMT with initial sample of substance and at creating of additive and multiplicative tests respectively, pF $\Delta W'$ – addition of water for additive test, equal 0,2 (20 %); k' – coefficient for multiplicative test, equal 4. As well as in the first case the system of equation (6) is solved using differential method. The moisture calculated value can be determined by a formula:

$$W_{calc2} = \frac{\Delta W'(C_3' - C_1)}{(k'-1)(C_2' - C_1)} - \frac{1}{3}. \tag{7}$$

Capacities of primary transducer can be determined by formulas:

$$C_1 = g\cdot\varepsilon_1;$$
$$C_2' = g\cdot\varepsilon_2';$$
$$C_3' = g\cdot\varepsilon_1\cdot k',$$

where ε_2' – dielectric permeability of substance with addition of water $\Delta W'$, equal 0,2 (20 %).

Check on invariance the various combinations of two test expressions (2) and (7). The most obvious combination is their ratio (the constant of minus 1/3 can be neglected at calculations):

$$\frac{W_{calc2}}{W_{calc1}} = \frac{\dfrac{\Delta W'(C_3' - C_1)}{(k'-1)(C_2' - C_1)}}{\dfrac{\Delta W(C_3 - C_1)}{(k-1)(C_2 - C_1)}}. \tag{8}$$

Results of substance moisture calculations for the equation (8) are given in table 3. As evident from results of calculations the invariance of moisture W_{calc} to change of substance dielectric permeability still isn't present. Monotonous increase is present along with low sensitivity of PMT to change of moisture W.

Table 3

Results of substance moisture calculations for $\frac{W_{calc2}}{W_{calc1}}$ expression

Moisture (W)	Moisture calculated value (W_{calc})				
	for $\varepsilon = 2$	for $\varepsilon = 2{,}1$	for $\varepsilon = 2{,}5$	for $\varepsilon = 3$	for $\varepsilon = 3{,}5$
0	0,898	0,898	0,899	0,902	0,903
0,1	0,885	0,886	0,889	0,891	0,894
0,2	0,872	0,872	0,874	0,877	0,88
0,3	0,852	0,853	0,857	0,861	0,865

Next, check on invariance a combination of ratio of square of moisture calculated value for test with an addition of water equal 20 % to a moisture calculated value of test with an addition of water equal 10 %:

$$\frac{W_{calc2}^{\ 2}}{W_{calc1}} = \frac{\left(\dfrac{\Delta W'(C_3' - C_1)}{(k'-1)(C_2' - C_1)}\right)^2}{\dfrac{\Delta W(C_3 - C_1)}{(k-1)(C_2 - C_1)}}.$$

Results of substance moisture calculations are given in table 4.

Table 4

Results of substance moisture calculations for $\frac{W_{calc2}^{2}}{W_{calc1}}$ expression

Moisture (W)	Moisture calculated value (W_{calc})				
	for $\varepsilon = 2$	for $\varepsilon = 2{,}1$	for $\varepsilon = 2{,}5$	for $\varepsilon = 3$	for $\varepsilon = 3{,}5$
0	0,262	0,264	0,269	0,276	0,282
0,1	0,272	0,273	0,279	0,286	0,293
0,2	0,27	0,271	0,277	0,285	0,292
0,3	0,255	0,257	0,264	0,272	0,281

By the results of table 4 it is visible that monotonous increase of moisture values is missing.

Check the combination on invariance:

$$\frac{W_{calc2}+W_{calc1}}{W_{calc2}-W_{calc1}}=\frac{\dfrac{\Delta W'(C_3'-C_1)}{(k'-1)(C_2'-C_1)}+\dfrac{\Delta W(C_3-C_1)}{(k-1)(C_2-C_1)}}{\dfrac{\Delta W(C_3-C_1)}{(k-1)(C_2-C_1)}-\dfrac{\Delta W(C_3-C_1)}{(k-1)(C_2-C_1)}}. \qquad (9)$$

Results of substance moisture calculations are given in table 5.

Table 5

Results of substance moisture calculations for $\frac{W_{calc2}+W_{calc1}}{W_{calc2}-W_{calc1}}$ expression

Moisture (W)	Moisture calculated value (W_{calc})				
	for $\varepsilon = 2$	for $\varepsilon = 2{,}1$	for $\varepsilon = 2{,}5$	for $\varepsilon = 3$	for $\varepsilon = 3{,}5$
0	-18,543	-18,589	-18,799	-19,342	-19,654
0,1	-16,467	-16,604	-17,017	-17,338	-17,836
0,2	-14,606	-14,608	-14,909	-15,315	-15,696
0,3	-12,504	-12,619	-12,952	-13,353	-13,772

From the table 5 it is visible that the value W increases with increase of ε, therefore it is necessary to make a correction in a denominator of equation (9) for its more intensive increase with increase of ε.

Thus taking into account correction of the denominator we will receive:

$$\frac{W_{calc2}+W_{calc1}}{(W_{calc2}-W_{calc1})\cdot(1+0{,}011\cdot C_1)}. \qquad (10)$$

Results of substance moisture calculations are given in table 6.

Table 6

Results of substance moisture calculations

Moisture (W)	Moisture calculated value (W_{calc})				
	for $\varepsilon = 2$	for $\varepsilon = 2{,}1$	for $\varepsilon = 2{,}5$	for $\varepsilon = 3$	for $\varepsilon = 3{,}5$
0	-15,199	-15,101	-14,744	-14,543	-14,191
0,1	-12,789	-12,756	-12,534	-12,147	-11,92
0,2	-10,657	-10,522	-10,219	-9,906	-9,62
0,3	-8,478	-8,428	-8,168	-7,884	-7,656

Apparently from results of calculations the deviation of moisture calculated values still is significant.

Further for the purpose of receiving an optimum denominator we will change the coefficient of "0,011" in equation (10) with some chosen step h. As a result of the analysis of received new combinations the expression for which the deviation of moisture calculated values is minimum is determined. At the further change of the coefficient with specified step the deviation is increased. This expression is:

$$\frac{W_{calc2} + W_{calc1}}{(W_{calc2} - W_{calc1}) \cdot (1 + 0{,}0029 \cdot C_1)}. \qquad (11)$$

Results of substance moisture calculations are given in table 7.

Table 7

Results of substance moisture calculations

Moisture (W)	Moisture calculated value (W_{calc})				
	for $\varepsilon = 2$	for $\varepsilon = 2{,}1$	for $\varepsilon = 2{,}5$	for $\varepsilon = 3$	for $\varepsilon = 3{,}5$
0	-17,526	-17,522	-17,528	-17,794	-17,843
0,1	-15,306	-15,381	-15,551	-15,582	-15,772
0,2	-13,306	-13,252	-13,3	-13,388	-13,455
0,3	-11,112	-11,157	-11,219	-11,288	-11,376

The results of calculations received for the equation (11) have a minimum deviation and are monotonously increasing.

The values of moisture received in table 7 are nonnormalized. Normalization of values includes the following stages:

1) transformation of W_{calc} to positive values range:

$$W_{positve} = |W_{calc\,max}| + W_{calc},$$

where $|W_{calc\,max}|$ – maximum modulo value of moisture for table 7, equal 17,843;

2) combination of ranges:

$$W_{norm} = \frac{W_{positive}}{x},$$

where $x = \frac{6{,}624}{0{,}3} = 22{,}08$.

The normalized values are given in table 8.

Table 8

Normalized values of substance moisture calculations results

Moisture (W)	Normalized values of substance moisture calculations results (W_{norm})				
	for $\varepsilon = 2$	for $\varepsilon = 2{,}1$	for $\varepsilon = 2{,}5$	for $\varepsilon = 3$	for $\varepsilon = 3{,}5$
0	0,014	0,015	0,014	0,002	0
0,1	0,115	0,112	0,104	0,111	0,094
0,2	0,205	0,208	0,206	0,202	0,199
0,3	0,305	0,303	0,3	0,297	0,293

In order to compare the results of calculations given in table 8 for the equation (11) with the results obtained in early works [8, 12, 13] in this direction of research, we will apply Pearson's criterion of consent (χ^2) [16]. This criterion allows accepting or rejecting of hypothesis about conformity of samples.

In [12] the least-squares method (LSM) was applied for creation of test influences system. The expression for substance moisture determination in this case is:

$$W_{calc} = \frac{100(0{,}17\varepsilon_1 + 0{,}17\varepsilon_3 - 0{,}33\varepsilon_2)}{\varepsilon_3 - 0{,}013\varepsilon_3^2},$$

where ε_1 – dielectric permeability of initial sample of substance; ε_2 – dielectric permeability of substance sample after addition of a known amount of water (the first test influence); ε_3 – dielectric permeability obtained after addition to the second test still of the same amount of water (the second test influence).

Results of check of this expression are given in table 9.

Table 9

Substance moisture calculations results with application of LSM

Moisture (W)	Normalized values of substance moisture calculations results (W_{norm})			
	for $\varepsilon = 2$	for $\varepsilon = 2{,}5$	for $\varepsilon = 3$	for $\varepsilon = 3{,}5$
0	0,008	0,009	0,000	0,001
0,1	0,097	0,088	0,090	0,085
0,2	0,218	0,222	0,222	0,223
0,3	0,419	0,415	0,354	0,417

In [13] Lagrange's interpolation polynomial of the second order was applied for obtaining moisture value. This polynomial is an interpolation dependence of substance moisture from dielectric permeability:

$$W_{calc} = 59{,}2 - \frac{10 \cdot \dfrac{\varepsilon_3 - \varepsilon_2}{\varepsilon_1 - \varepsilon_2} + 20 \cdot \dfrac{\varepsilon_3 - \varepsilon_1}{\varepsilon_2 - \varepsilon_1}}{100 - 90\dfrac{\varepsilon_3 - \varepsilon_2}{\varepsilon_1 - \varepsilon_2} - 70\dfrac{\varepsilon_3 - \varepsilon_1}{\varepsilon_2 - \varepsilon_1}},$$

Results of check of this expression are given in table 10.

Table 10

Substance moisture calculations results with application of the second order Lagrange's polynomial

Moisture (W)	Normalized values of substance moisture calculations results (W_{norm})			
	for $\varepsilon = 2$	for $\varepsilon = 2{,}5$	for $\varepsilon = 3$	for $\varepsilon = 3{,}5$
0	0,0	0,0	0,0	0,0
0,1	0,08	0,08	0,08	0,08
0,2	0,16	0,16	0,16	0,16
0,3	0,32	0,24	0,24	0,24

Checking the results of calculations on conformity by Pearson's criterion is carried out as follows.

Empirical value of Pearson's criterion can be determined by a formula:

$$\chi^2{}_{emp} = \sum_{i=1}^{m} \frac{(W_{norm} - W)^2}{W},$$

where W_{norm} – normalized value of moisture (it is used as empirical value) W – specified substance moisture (it is used as theoretical); m – number of intervals, equal 4.

Critical value ($\chi^2{}_{cr}$) according to Pearson is determined by the table of critical points of χ^2-distributions for the set significance value $q = 0{,}05$ ($P_{conf} = 95\ \%$) and number of degrees of freedom $k = 3$ ($k = m - 1$). Pearson's criterion calculations results are given in table 11.

Table 11

Pearson's criterion calculations results for table 8, LSM and with application of the second order Lagrange's polynomial

Indexes	$\chi^2{}_{emp}$	$\chi^2{}_{cr}$
For table 8	0,028	0,352
For LSM	0,179	0,352
For Lagrange's polynomial of the second order	0,125	0,352

Conclusions

Apparently from results of table 8 the moisture calculated values along with high sensitivity to change of moisture are adequately invariant to change of substance dielectric permeability. During check of the results received in article on coherence by Pearson's criterion it was determined that these values have the smallest divergences (are conformed) in comparison with the results received in the previous works on this direction. Thus this expression can be used at measurement of moisture of the substance that dielectric permeability is unknown.

1. Gert J. W. Visscher. Moisture and humidity measurement / Visscher J. W. Gert. – Washington: CRC Press LLC, 1985. – 14 p. 2. Humidity and Moisture: Measurement and Control in Science and Industry. Applications. – United States: National Bureau of Standards, 1965 – Vol. 2, 634 p. 3. Mitin D. K. Monitoring of water presence in petroleum and lubricating oils is a protection of your investments / D. K. Mitin, I. M. Ozeritskyi // Terytoriia Neftegaz. – 2006. – No 2. – P. 5–10. 4. Mashoshyn P. V. Trandusers of parameters of capacitive sensors for moisture measurement of bulks / P. V. Mashoshyn // Synopsis of a thesis, 05.11.01. – Penza, 2003. – 258 p. 5. Semenova T. I. Development of electrodynamic method of SHF moisture measurements of grain in a flow / T. I. Semenova // Synopsis of a thesis, 05.18.12. – Moskov, 2003. – 130 p. 6. Soltani M., Alimardani R. Prediction of corn and lentil moisture content using dielectric properties / M. Soltani, R. Alimardani // International Journal of Agricultural Technology. – 2011. – Vol. 7, No 5. – P. 1223–1232. 7. Berliner M. A. Moisture measurements / M. A. Berliner. – Moskov: Energiia, 1973. – 400 p. 8. Zabolotnyi O. V. Compensation nuances of the "substance type" uncertainty in the test formation for adaptive moisture meters / O. V. Zabolotnyi // East European magazine of advanced technologies. – 2012. – No 2/9 (56). – P. 47–50. 9. Krushevskyi Yu. V. Influence of water mass exchange on accuracy of measurement of moisture of grain / Yu. V. Krushevskyi, Ya. A. Borodai // Scientific works of Vinnitsa national technical university. – 2007. – No 1. – P. 20–26. 10. State system for ensuring the uniformity of measurements. Ensuring the effect of measurements by the control of technological processes. Methods and ways of the measuring accuracy rise: RMG 64-2003 GSI, 2004. – Entered 01.01.1997. – Moskov: IPK Izd-vo standartov. – 13 p. 11. Bromberg E. M. Test methods of increase of measurements accuracy / E. M. Bromberg, K. L. Kulikovskyi. – Moskov: Energiia, 1978. – 176 p. 12. Zabolotnyi O. V. Providing satisfactory level of invariance of adaptive moisture meters with use of least-squares method / O. V. Zabolotnyi // Bulletin of Cherkassy state technological University. – 2012. – No 4. – P. 13–17. 13. Golub K. Yu. Providing the invariance to the change of material type for dielcometer humidity meters with the use of Lagrange polynomials / K. Yu. Golub, O. V. Zabolotnyi, M. D. Koshevoi // National Technical University of Ukraine "Kyiv Polytechnic Institute", Instrument-making: collection of scientific works. – 2013. – No 45. – P. 116–122. 14. Guselnykov V. K. To a question of application of test methods at level measurement by ultrasonic method / V. K. Guselnykov, E. A. Borysenko // "Bulletin of NTU "KhPI" Automatics and instrument making". – 2011. – No 11. – P. 7–13. 15. Krychevskyi E. S. Theory and practice of express control of moisture of bulks / E. S. Krychevskyi, V. K. Benzar, M. V. Venediktov. – Moskov: Energiia, 1980. – 240 p. 16. Greenwood P. E. A Guide to Chi-Squared Testing / P E. Greenwood, M. S. Nikulin. – New York: John Wiley & Sons, Inc., 1996. – 208 p.