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Humidity Control During Hydrothermal Treatment of Grain and Their Processed Products

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Abstract. The article deals with the problems of controlling the moisture content of grain and products of their industrial processing in industrial conditions, describes various electrical systems, a dielcometric method for measuring the humidity of various classes of products, and the construction of moisture control devices on its basis, and also analyzes the measuring transducer, as well as the measuring schemes of the humidity control devices under consideration. A sample of an emocostal moisture meter for determining the dielectric constant of grain products, both in laboratory and production conditions, and its metrological characteristics are shown, as well as a number of factors are noted, the dielectric constant for grain, which considers the temperature, material, which makes it possible to assess the degree and nature of the influence of each factor on the total error of measuring it. Humidity. The obtained results are relevant in the development of moisture control devices for such specific twerk and bulk materials of the agro-industrial complex, grain, and products of their processing.

Keywords: Grain · Humidity · Control · Device · Transducer · High-frequency · Measurement

1 Introduction

Grain and grain-derived food products are the most popular and affordable compared to other products. According to the Organization for Economic Cooperation and Development (OECD), world wheat production in 2020 was at the level of 750,0 million tons. In the next 10 years, a slowdown in the growth of world wheat production is predicted. By 2024, wheat production will grow by 7,9%, which is 59,7 million tons more than in 2014. In the world, special attention is paid to both the quantity of grain grown and their quality. In this regard, it is advisable to increase the volume of high-quality grain crops on a national and world scale.

To solve the problem of agricultural development, a comprehensive intensification of agricultural production is necessary. In Uzbekistan, grain production is one of the

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most popular food products. Wheat cultivation in the country is about 7,5 million tons per year.

Wheat cultivation is carried out in all regions of the republic.

The moisture content of the grain is a decisive economic factor for production. Humidity greatly affects the duration of their storage, as well as the quality and cost of most products, and humidity underlies some technological processes for the production and processing of products. Depending on the persistence of grain during storage, as well as the possibility of its processing, four states of moisture are established in state standards for grain, they are in the range of 14–18% and flow from the forms of connection of moisture with grain.

Humidity significantly affects the modes of storage and processing of grain, the moisture content in the grain exceeds the established norm, the grain begins to deteriorate, as a result, the nutrients in it decrease. At all stages, starting with harvesting in the field, transportation, admission to the enterprise, its storage, as well as in the technological processes of grain processing, special humidity control is provided, and in the process of its hydrothermal humidification, it is necessary to regulate humidity, so that at subsequent stages of abstraction the humidity stabilizes.

AT JSC "G'ALLA-ALTEG" the Republic of Uzbekistan, batches of wheat grain with different quality are received, each batch of grain in its composition is also heterogeneous in structure. One of the problematic issues at G'ALLA-ALTEG JSC, as well as enterprises of the flour milling industry of the Republic of Uzbekistan, is the lack of instrumental methods for determining the properties of grain, which leads to incomplete use of the technological properties of local grain varieties, as a result of which it does not allow to establish optimal modes of preparation and grinding of grain, this, in turn, requires effective operation of the enterprise in the current market conditions, First of all, the creation of an increase in the efficiency of technological processes at the enterprise, the organization of perfect control and management of production.

To provide moisture control devices for the entire cycle of grain processing throughout the entire technological chain, an integrated, systematic approach is required that would consider all stages of the life cycle of grain as a single whole - from harvesting to postharvest processing, storage, and processing.

The solution of this problem requires in-depth theoretical and experimental research in order to develop conceptual issues of the theory and practice of express moisture meters in the technological processes of the agro-industrial complex, the creation of scientifically based principles for the construction and implementation of modern methods of engineering calculation and hardware design of humidity control devices.

The purpose of the study is to further improve the practice of high-frequency moisture meters, substantiate the system methodology for studying the electrophysical parameters of grain as objects of moisture measurement, and create on this basis humidity control devices, a wide class of products of processing of the agroindustrial complex.

Achieving this goal involves the solution of the following specific and little-studied research tasks in the field of grain moisture measurement:

- Critical analysis of the current state of the theory and practice of measuring electrophysical characteristics and identification of trends in their further development and improvement;

- Development and implementation of grain moisture control devices in accordance with the requirements of the latest generation of electrical analysis devices;
- Research and selection of the method, as well as on its basis the implementation of the device that performs the functions of control, including humidity.

2 Hydrothermal Properties of Grain

State wheat standards set limits for harvested and supplied wheat. One of the main processes of preparing grain for grinding, which qualitatively improves its food use, is its hydrothermal treatment (GTO). The use of hydrothermal grain treatment gives a complex production effect, which includes three groups of indicators: technological, energy, and economic.

In the literature, there is little information about the features of the process of moistening the grain of these crops, so it is interesting to study the distribution of moisture in the grain of wheat, rice, barley during moisture.

With proper moistening, the grinding qualities of the grain are improved, due to the moistening of the endosperm, it is easily separated from the shells, the ash content of the flour decreases, the whiteness and yield of flour of the highest grades increases, the load on the technological equipment decreases, and the consumption of electricity is reduced. To achieve these benefits, it is necessary to stabilize the moisture content of the grain as accurately as possible.

The process of agitation is carried out statically. After many years of research for local grain in enterprises, it is advisable to use a static method of abstraction, as this will allow you to regulate the water consumption for the second stage. The advantage of this method is that the variation in the moisture content of the grain in the stream will be less than with the dynamic method. The water consumption after the first separation of 45 tons of grain is about 1200–1400 L. With the dynamic method, the water consumption is about 1600–1800 L. The results of the studies showed that water consumption can be saved within 1 m^3 per 100 tons of grain. After 12 h of downtime, the grain must be remoistened to increase the moisture content of the grain. Recommended indicators should be within the following limits: for local grain not less than 15,5%, but not more than 16,8%. Between the first and second humidification, it is necessary to systematically check the moisture content of the grain by the laboratory method. These traditional methods are very time-consuming and time-consuming. A drying oven is traditionally used to determine the moisture content of the grain.

This method is energy-consuming and time-consuming since it requires considerable time for analysis. In addition to the cabinet itself, the traditional method requires some laboratory supplies, in particular, buxes, a desiccator, and analytical balances. For technological processes, this stage is more responsible, because it is forbidden to make errors of the human factor, due to the impossibility of its further correction. To eliminate the time-consuming process, it is necessary to automate the system between the first and second humidification, the discrepancy of variation can be eliminated only with the help of an automatic method and the use of automatic humidity controls.

In grain processing enterprises of the country, there are practically no automatic devices for monitoring the moisture content of local grain. This requires scientific

research indicating the scientifically based advantages and disadvantages of the recommended methods, as well as the creation of moisture control devices based on them in both discrete and technological modes (for local grain).

In the process of GTO grain in mills, the separation of shells is facilitated, in the ripping process the yield of cereals increases. As a result, the yield of flour increases, its ash content decreases, and the quality of finished products improves.

During processing, the grain parameters for varietal grinding of wheat moisture supplied to industrial enterprises should be no more than 14,0%. In the studied wheat samples, the moisture content of the grain fluctuates within normal limits. At flour milling enterprises of the republic, automated control systems for the fermentation process often do not provide the required moisture accuracy, due to the moral and physical deterioration of the system and the impossibility of accurately predicting the final moisture content of the grain.

Currently, there is no reliable and accurate method of controlling humidity in the process of agitation, as a result of which it is difficult to control the process with existing methods. The time of separation is determined in enterprises by laboratory measurements. These leads, in particular, to the purposeful overexposure of grain in the bins of the fermentation to complete the process of moisture redistribution, which adversely affects both the technological properties of the flour and the productivity of the preparatory department of the mill. This, in turn, once again confirms the need to create an automated control system for the cold air conditioning process, considering the initial hydrothermal indicators of grain in the bins.

The introduction of modern automation systems of grain storage and processing enterprises allows to qualitatively prepare grain for grinding and automatically (optimally) determine the moisture content of grain. The time of agitation in the "cold" method of conditioning should be set no less than required by the conditions for the redistribution of moisture and loosening of the endosperm, which, according to the review of the literature, is within 8–20 h. Wheat grain of highly vitreous and durum varieties takes even longer. When determining the moisture content of the grain, as well as in the technological process, it is important to consider the physical and mechanical qualities of the grain.

In the process of grain processing, due to excessive humidity, undesirable physical and chemical processes are activated, which leads to negative results. At the same time, it is necessary to study the properties of the behavior of grain during hydrothermal treatment, which is mandatory in the technology of flour, cereals, and mixed fodder to optimize process properties.

Hydrothermal properties describe the behavior of grain during hydrothermal treatment, which is mandatory in the technology of flour, cereals, and feed to optimize process properties, especially in the temperature range during hydrothermal treatment, the higher the temperature, the more intense the absorption of moisture.

The process of hydrothermal processing of grain is characterized by a technological scheme regulating the sequence, the installation of appropriate technical means by a set of parameters of their operation: the degree and frequency of moisture, the type of moisture carrier (steam, water), its temperature or pressure. Figure 1, a technological scheme of the cold method of hydrothermal processing of grain is presented.

3 Method and Materials

The moisture cntent of the grain in its degree is distinguished as dry, medium-dry, wet and raw. The moisture content of grain (wheat) is always above average. Monitoring the moisture content of wheat at metering stations is mandatory since any deviation from the specifications agreed by the supplier and the consumer entails serious fines.

Therefore, wheat moisture control devices at metering units must meet the following requirements:

- Fast response required to avoid the extraction of a large volume of the on-conditioned product;
- Low accuracy and reproducibility of measurement results to ensure compliance with the requirements of the commercial grain specification.

Based on the requirements of the consumer of JSC "G' ALLA-ALTEG", to the choice of method and design of humidity control devices, we have provided high measurement accuracy, as well as the ability to carry out measurements in a continuous technological flow, both in small and large volumes based on the dielcometric method and a prototype of the device with metrological characteristics of satisfying operational services.

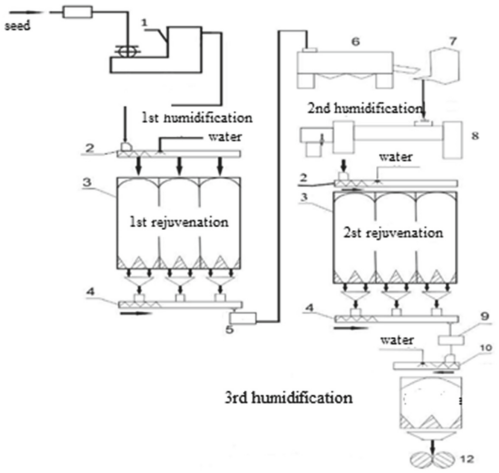

Fig. 1. Technological scheme of hydrothermal processing of grain in JSC "GALLA-ALTEK" Where, 1 - grain washing; 2 - distribution screw; 3 - tank hopper; 4 - au-ger-mixer; 5 - a device for humidity control; 6 - horizontal wallpaper machine; 7 - pneumatic separating channel; 8 - humidification apparatus; 9 - weighing dosage; 10 - screw mixer; 11- capacitive hopper; 12 - chopper;

The scientific novelty of our results is as follows: as a result of theoretical analysis, and experimental studies, as well as engineering calculations, the most promising areas of automation of moisture control of technological processes of flour production based on excitation sensors based on the dielcometric method, are substantiated.

The methodological foundations for creating an automated moisture control system, which is determined by the quality indicator of flour in the grinding process, have been developed.

A mathematical model of the grain moisture process and the interaction of the HF field with the studied medium have been developed, (the functions of converting HF energy into a humidity signal have been derived), it has been established that in the range from 8 to 18,5% of the mass ratio of humidity, the nominal conversion function is close to linear, and above nonlinear. The scientific novelty of the methods and devices proposed for automated technological control of humidity is confirmed by patents and computer programs of the country.

Based on the analysis of the physical and mechanical properties of grain, recommendations have been developed and the tasks of constructive and circuit development of the HF moisture meter that meet the requirements of industrial operation have been formulated.

4 Measuring Equipment

The material in question is multicomponent, and, in addition, is heterogeneous in its composition and properties. The listed features of the material under consideration must be considered when choosing a measurement method and developing moisture control devices, in particular on determining the various electrical properties of the grain mass - electrical conductivity and electrical capacitance [1].

When designing humidity control devices, especially their sensors of both domestic and foreign production, it is necessary to view the effective development aimed at the development of innovative moisture-sensitive compositions, i.e. have high reliability, minimum dimensions, and weight, in addition, the technical implementation of means of measuring grain moisture in the stream, should provide for the possibility of direct measurement methods. At present, and for the last at least half a century, methods based on changes in the physical characteristics of the grain with a change in its moisture content have been and are being used for such measurements [2, 3].

The analysis shows that the majority of metrologists prefer dielcometric, in particular, high-frequency (HF) and ultrahigh-frequency (microwave) methods based on the physics of grain properties in high-frequency electromagnetic fields (HF), where the frequency range is from 5·103 to 5·107 Hz, and ultra-high frequency (microwave), the frequency range is in the range from 5·107 up to 5·1010 Hz [4].

However, at present, the control and regulation of the moisture content of grain and processed products are practically not automated due to the lack of effective devices for monitoring the moisture content of grain products in the technological flow [5].

HF methods can be successfully applied to control the humidity in the flow from the outlet of the drying chamber, which allows you to control the quality of the finished product, but does not provide effective control of the drying process [6].

The measuring device is designed on a dielcometric basis for measuring humidity, with an initial capacitance of the measuring cell of 0,5 MHz, and a final capacity of 10 MHz, which corresponds to wavelengths. Structurally, it consists of a sensor and two electronic blocks of the measuring and transducer path. The continuous sensor

is a metal structure. The electrodes of the sensor are coaxially pressed into electric ceramics, as well as the sole is made of titanium alloy, which allows you to use the sensor on the conveyor belt for a long time without deterioration of its parameters. The measuring device with such a sensor has been tested and soon it is scheduled to conduct metrological certification as a measuring device for grain and granular materials with a measurement error not exceeding 1,0% humidity in the range of 10–18% humidity.

An example of a parametric capacitive primary converter is a variable capacitance included in the generator circuit (Fig. 2). Here, when the rotation angle of the rotor axis changes, the capacitance of the sensor changes, and the frequency of the generator, which is the output value, changes.

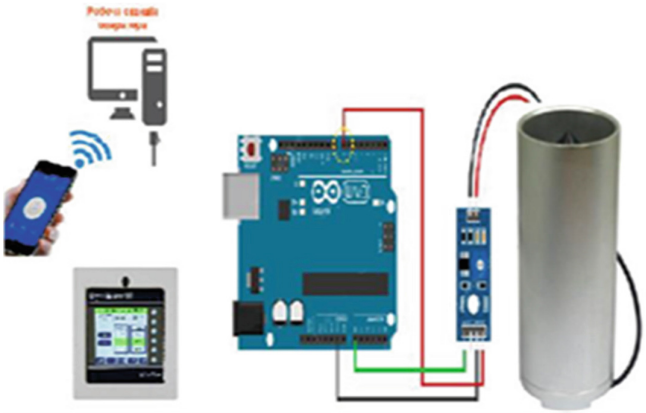

Fig. 2. A device for monitoring grain moisture in real-time using a capacitive primary converter.

$$C = \varepsilon_a(s/a) \tag{1}$$

Cylindrical – like

$$C = \varepsilon_a \left[\frac{2\pi L}{\ln\left(\frac{R_2}{R_1}\right)} \right] \tag{2}$$

where ε - a is the absolute dielectric permittivity of the interelectrode space f/m; S - the area of the electrodes, m^2; a is the distance between the electrodes, m; L - length of the cylindrical electrodes, m; R_2 is the radius of the internal electrode, m; R_1 is the radius of the outer electrode, m.

Formulas (1) and (2) shows that at constant geometrical sizes of the following functional dependence:

$$C = (\varepsilon) \tag{3}$$

In this regard, experimental studies in the field of the high frequency of dielectric properties of the materials under consideration need to solve the following problems:

- Determination and analysis of the transformation function and the influence function of the primary measuring high-frequency transducer. To do this, it is necessary to investigate experimentally the dependence of the dielectric properties of the materials under study on humidity and the most important influencing factors;
- Construction on the basis of the obtained experimental data of electrical models of the primary converter with the material, the optimal approximation of the real characteristics of the materials under study;
- Based on the data obtained, the development of specialized high-frequency moisture meters for grain and products of their processing, and the testing of these devices in laboratory and production conditions.

Figure 3 presents the recommended block diagram of the prototype of a high-frequency moisture meter, based on the dielcometric (high-frequency) method of measuring grain moisture during hydrothermal treatment in the process of abstraction in the conditions of JSC "GALLA-ALTEG".

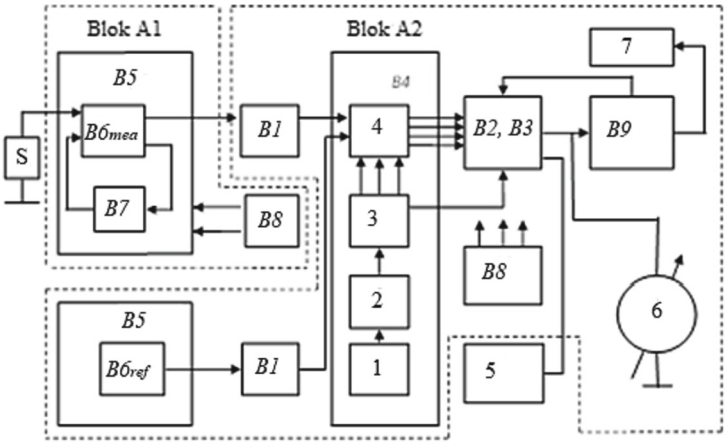

Fig.3. Functional diagram of high-frequency moisture meter for grain.

The high-frequency moisture meter is designed to control the humidity of finely dispersed bulk materials and is a digital F-meter of cyclic action with alternate processing of information of the measuring and reference channels. Structurally, it consists of a sensor and two electronic blocks of the measuring and converter path. In this regard, the task of developing a scientifically based methodology and designing measuring instruments, and creating a humidity control system based on technical, structural, and algorithmic methods aimed at reducing errors in the technological processes of using the HF method is of particular relevance.

5 Outcomes

The results of the study are aimed at identifying and disclosing the principles in the design of similar express humidity control devices for the materials under consideration. The

leading method to investigate this problem is the choice of a method based on which it will be necessary to synthesize a device that allows to comprehensively measure the moisture content of the material at all stages of their humidity control.

The presented materials will allow engineering calculation and selection of the operating frequency and capacitance of the measuring parameters of the primary capacitive type converter and synthesize an express humidity control device for the materials under consideration. The materials are of practical value for food, cotton-cleaning, grain-processing flour mills, where grain moisture is one of the most important technological parameters, which requires monitoring at all stages of material production.

To achieve this goal, we have solved the following specific and little-studied studies in the field of grain moisture measurement:

- A grain moisture control device has been developed and implemented in accordance with the requirements of the latest generation of electrical analysis devices;

To solve the problem, the following experimental characteristics have been identified, describing the dependencies respectively of the actual (ε') and imaginary part (ε'') of the dielectric constant of the moisture-containing material on humidity and parameters characterizing the composition and properties of the grain, and the frequency of the electric field, while humidity characteristics.

ε(W) when stabilizing the frequency of the field, the temperature of the material, its density and other parameters affecting the dielectric properties. Frequency-humidity characteristics of ε(W) functions at different humidity values at T = const, ρ = const, and stabilization of other quantities affecting dielectric properties [7].

Humidity and frequency-humidity characteristics have been studied, which made it possible to determine the function of transforming the first link of the generalized scheme of the moisture meter, i.e. conversion "humidity-dielectric properties" of the materials under consideration in the studied frequency range, the choice of the optimal operating frequency for the development of measuring converter circuits [8].

The basis for the use of the HF method of measuring humidity is the dependence of the parameters of the electromagnetic wave interacting with the controlled material, on its dielectric characteristics. At the same time, the most influential values in measuring humidity are the density and temperature of the material in question. Density determines the amount of dry material and moisture in the controlled volume, so the dielectric parameters of the sample depend on it.

The influence of the temperature of the material on its dielectric properties is due to the fact that temperature fluctuations lead to a change in the binding energy of moisture with the material and the redistribution of moisture between the components of the material.

6 Energy Saving

One of the main tasks of the processing industry enterprises at present is to save electric power resources. If the electricity consumption for the production of a ton of grain in the republic is 2–3 times higher than in European countries, and its costs for flour production

exceed their level in developed countries by 1,2–1,5, this once again confirms that the results of the analysis of the process of producing varietal flour revealed a number of shortcomings, focused on technological aspects and practically did not associate them with the equipment used. The development of an effective system that allows linking all the numerous processes and their parameters into a single whole, determining their mutual influence, and finding optimal flour production modes with maximum equipment productivity and minimum power consumption is an important task.

The amount of energy consumption is determined by the structural and mechanical properties of raw materials, the design and quality of manufacturing of technological equipment, in addition, the technical condition of grinding rollers, the technology feature, and the type of in-shop transport of grain, intermediate and final products.

As an object of research, grain and its processed products are considered, which we use in the technology of flour, cereals as a mandatory and highly efficient technological operation of preparing grain for processing. At the same time, GTO of grain makes it possible to obtain products of predetermined humidity and provides longer periods of safe storage.

In order to reduce energy consumption, it is necessary to rationally organize the technological process and to change the structural and mechanical properties of grain using hydrothermal treatment, while technological processes must be carried out at optimal specific loads and modes. To select the method, we use the well-known cold conditioning method, in which the grain is moistened with water at a temperature of 15…20 °C, and then it's cooling - isothermal exposure for a certain time. During rejuvenation, moisture is distributed over the anatomical parts of the grain, accompanied by the following structural, mechanical, and technological transformations:

- Swelling with the release of hydration heat;
- Loosening of the endosperm due to an increase in specific volume;
- The development of microcracks in the endosperm;
- Weakening of the connection of the shells and the aleurone layer with the starch part of the endosperm due to the difference in the change in specific volumes during swelling.

Automation of the grain humidification process has become particularly important in today's conditions when the number of grain producers has increased, and the size of grain shipments delivered to the mill has decreased. The moisture content of the grain entering the grain cleaning during one shift varies significantly. Manual regulation of the humidification process with laboratory humidity control does not ensure the supply of grain with a given humidity to the first dry system.

As a result, the uncertainty or error reaches large values, which requires constant adjustment of the grain grinding process.

In this regard, the use of humidity control devices and their operation as part of automation and production processes that will allow us to neglect unnecessary losses of electricity, and in our opinion, it is one of the urgent tasks of grain processing enterprises of the Republic of Uzbekistan.

If necessary (according to the requirements of the supervisory authorities for the efficient use of energy resources), confirmation of compliance of the energy efficiency indicators of energy-consuming industrial and technical products in operation (use) with

the values set in the technical documentation is carried out by testing products (at the user) under regulated conditions, as well as on the basis of processing statistical data on energy consumption (energy efficiency) obtained during the operation of products, including according to energy surveys of enterprises (organizations) - consumers of energy resources.

The main energy-intensive processes are the grinding of grain and intermediate products. To solve this problem, it is necessary to regulate the humidification system. For this purpose, it is recommended to use an automated system complex, which should consist of the following main blocks: grain moisture measurement, grain flow measurement unit, as well as a microprocessor control and control device. It also needs to include a water control and monitoring unit. As a result, we will get an automatic monitoring and control system, which will allow us to apply an automated humidification system using high-precision grain moisture meters, water, and grain consumption, in general, it will make it possible to stabilize the output moisture of grain.

In turn, this approach to the automated process control system will allow the rational use of grain and increase the efficiency and energy saving of flour milling production, as well as obtaining maximum profit while meeting the demand for the company's products.

The distribution of electricity will lead to a decrease in both energy intensity and gross domestic product.

7 Discussion

Technological processes and a number of other systems used at flour milling enterprises often do not provide the required accuracy of grain moisture due to their moral and physical deterioration, the impossibility of accurately predicting the final humidity, the lack of control over the dynamics of changes in its humidity in the hoppers, etc.

To date, there are various methods for determining humidity. However, there is no consensus on the superiority of one or another method. In this regard, many well-known manufacturers of moisture meters in the world market during the development try to cover in their production several combined measurement methods. This is due to the presence of a large number of heterogeneous materials, the humidity of which must be controlled with the required accuracy and speed, as well as with a convenient design.

Manual regulation of the humidification process in conjunction with laboratory humidity control does not allow to ensure the supply of the required moisture to the first grain system. As a result, the absolute error reaches about 2% humidity, which requires constant adjustment of the grain grinding process.

Practice shows that modern methods of measuring grain moisture by express devices are effective and intensive in determining humidity in any conditions, namely:

- Field (at harvest);
- warehouse (in granaries, on grain currents, etc.);
- during transportation;
- before grinding.

Our analysis of the moisture meters sold allowed us to identify a group of methods that have become most common for measuring the moisture content of grain and grain

materials. Among them are conductometric, dielcometric high-frequency (HF), infrared methods for analyzing the spectrum in the infrared range, as well as the ultrahigh-frequency (microwave) method.

The results of our research when choosing a method more optimal that the use of an automated humidification system using high-precision grain moisture meters, based on the electric dielcometric method, provide prompt monitoring of the moisture state of the grain (in the fermentation hopper). This allows you to stabilize the output moisture content of the grain, therefore, achieving optimal grinding properties of the batch gives a significant economic effect and a quick return on investment.

Based on the above, in order to create an HF humidity control device, it is important to choose a converter, its principle of operation, and design. The study of the humidity and frequency-humidity characteristics of the measuring transducer makes it possible to determine the functions of converting the circuit of a high-frequency device in the range from 5•103 to 5•107 Hz frequencies [9].

Critically assessing the shortcomings of the design of primary converters, it should be noted that developers and designers do not have a unified approach, both to the choice of operating frequency, converter and to the method of control.

In the works of a number of authors, there is a significant discrepancy and contradiction in the technical data of the devices under consideration. The difference in the values of the results of experimental studies and the frequency range indicates the insufficient study of this issue and shortcomings in the methodological solutions of the studies conducted [10].

When choosing the operating frequency and capacity of the primary converter, many developers miss the question of the need to consider the parameters and characteristics of the circuit of the working generator. With an increase in frequency, the implementation of the mechanisms of relatively lower frequency types of polarization gradually and smoothly ceases, which is accompanied by a decrease in the dielectric constant. The frequency-humidity characteristics of the material in question indicate that there is a dependence between the dielectric constant and humidity, the nature of which is influenced by the frequency, with increasing frequency, the sensitivity to humidity decreases [11]. We took these shortcomings into account when developing humidity control devices based on the high-frequency method.

Based on the results of our research [12] and a number of other researchers, when conducting similar studies on the choice of method and on their basis the synthesis of moisture devices, in the field of high-frequency dielectric properties for materials such as grain and products of their industrial processing [13], it is necessary to consider the following emerging problems, first:

- Determination and analysis of the transformation functions of the primary measuring high-frequency converter (for this it is necessary to experimentally investigate the dependences of the dielectric properties of the studied products on the humidity of the most important influencing factors);
- Construction on the basis of the obtained experimental data of the electrical model of the primary transducer, with an optimal approximation of the real characteristics of the materials under study;

- Implementation of the obtained data by developing high-frequency moisture control devices for dispersed and inhomogeneous materials and their testing in laboratory and production conditions.

Secondly, the grain in the first approximation is a three-phase composition consisting of fiber, moisture, and air, having different electrophysical properties. The electrophysical parameters of wet granular materials as composite macro and micro-inhomogeneous systems are described mainly by the processes of migratory polarization, the role of which increases significantly with a decrease in frequency. The physical basis of migration polarization is the movement of weakly bound ions in the volume of the dielectric over a considerable distance commensurate with the thickness of the entire dielectric [14]. These movements lead to the formation of spatial charges at the interfaces of the dielectric, so this polarization is called interlayer polarization. The time spent on such movements is long, so there is a delay.

Thirdly, as noted above, the researchers do not pay enough attention to the development of universal analytical models of the dielectric properties of heterogeneous systems in general and dispersed moisture-containing bodies in particular. One of the main reasons for the unsatisfactory nature of the known formulas of the mixture when used by wet material is the lack of consideration of the influence of types and forms of moisture binding on the electrophysical properties of the material.

Fourthly, when designing dielcometric means of technological control of the parameters of heterogeneous systems, it is enough to cover the range from infrared to tens of megahertz, since it is in this frequency range that factors are manifested by the polarization structure. The dielectric constant model, in the hydrothermal treatment of grain and their processed products, which considers the temperature of the material, makes it possible to assess the degree and nature of the influence of the factor on the total error of measuring the moisture content of the grain and, therefore, can be used to introduce the necessary corrections to the measurement result.

Modern moisture meters for grain are characterized by high accuracy, compact size, and maximum ease of use. There are more than fifty modern grain processing plants in the country, with a total capacity of up to 4.0 million tons. It should be noted that in Uzbekistan the use of modern quality control systems for grain and grain products is insufficient. Also, the absence on the market of devices and devices of domestic production that meet the necessary requirements both in price and inaccuracy, reliability, do not allow more accurate control of humidity in real-time.

However, many enterprises of the grain processing industry still use the thermogravimetric method (drying method). This method was developed before 1990 and is standard. The error is in the redistribution of $\pm 0.3\%$. This method cannot be used for prompt obtaining results and calibration of humidity control devices.

Many years of experience and the results of our research confirm that the existing systems of the technological process itself do not fully meet modern requirements for production, and are not energy efficient. These problems require a decision on a number of little-studied studies:

1. To develop a scientific justification for the choice of a dielcometric control method, to measure the moisture content of grain in the process of agitation and control the TRP process.
2. Conduct a study on the regulation of water flow and modes of agitation.
3. To compare the results of studies of a conventional and automated moisture control system in the GTO technological process. This will make it possible to implement the stability of the mode for the grinding compartment.
4. To develop a scientific justification for increasing the efficiency of the use of raw materials and equipment in a stable mode of the working process.
5. Show the quality of the final product with the exact observance of technological parameters when using new methods and devices as part of the APCS.

8 Findings

Summing up, we can summarize the developed measuring transducer of moisture (prototype) used in grain processing, which makes it possible to carry out the periodic correction of the current calibration characteristics. Also, the advantage is its uninterrupted operation in vibration conditions, conducting a discrete-continuous mode of measuring grain moisture, ease of maintenance and convenience of verification, and data transmission in real-time.

The studies conducted were based on a high-frequency dielcometric method, which satisfied the manufacturers. Monitoring is carried out in real-time, the results are displayed on the monitor in the form of tables or graphs, access to the measurement archive allows you to analyze the dynamics of the moisture fluctuation process. However, there are a number of other methods where they can be used and recommended as an experiment to measure humidity in the technological mode.

A prototype of a device for controlling grain moisture during hydraulic processing in the technological process, with an electrical model of the primary measuring transducer, and measuring circuits providing an acceptable approximation of real frequency-humidity characteristics in the high-frequency range has been developed.

Metrological characteristics are made in accordance with the specified technique in [15].

The prototype model of the device is available for operation and measurement of humidity, in laboratory conditions, JSC “GALLA-ALTEG” [16]. With the following metrological characteristics: Humidity measurement range. Given that the company receives freshly harvested grain and its humidity is in the range of 14–17,5%, before processing its humidity is reduced to 8… 12%, then for this case the measuring range can be selected within 8… 18,5%; Measurement error: for inline measurements not to exceed 0,8%;

This technology can be successfully adapted to determine the water content, wet mass both in grain and in various agricultural products [17–20].

To solve the problems of optimal design of HF moisture meters, it is necessary to develop a methodology for assessing their quality. The evaluation should be based on a comprehensive criterion of efficiency, which includes the dominant single indicators: accuracy, reliability, and cost [21, 22].

To solve the problems of optimal design of microwave moisture meters, it is necessary to develop a methodology for assessing their quality. The assessment should be based on a complex criterion of efficiency, which includes the dominant single indicators: accuracy, reliability, and cost, of particular interest, is the study of the distribution of moisture in grain during humidification. During hydrothermal treatment, complex processes of physicochemical and biochemical nature develop under the influence of changes in humidity and temperature in the grain. Thanks to them, the technological properties of grain also change depending on its initial characteristics, method, mode of hydrothermal treatment, and other factors, as a result of which good energy-saving indicators can be achieved [23–26].

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