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THE STATE OF AUTOMATION IN GRAIN STORAGE: AN IN-DEPTH ANALYSIS

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Abstract

The article discusses the issues of automation of grain storage in silos and elevators, the use of this system will make it "transparent", ensure the stability of the process and the profitability of the agricultural enterprise, plan resources and budget, organize the coordinated work of structural and functional divisions, create a single information field for contractors and customers. The article analyzes the automation system taking into account the control of technological parameters, including temperature, humidity using modern measuring instruments. Options for controlling humidity and temperature parameters with the use of various structural automation schemes are discussed, appropriate recommendations are given for the further use of automation tools for full automation of the grain storage process.

Key words: *grain, storage, temperature, humidity, control, thermal suspension, thermometry, automation.*

Introduction. The agro-industrial complex (AIC) is one of the most unstable industries, constantly exposed to difficulties and risks. Due to the complexity of technologies and dependence on external factors (reliability of suppliers, quality of raw materials, technologies used, weather, seasonality), the level of development of the agricultural sector is much lower than in other industries (logistics, retail).

To solve these problems, the agro-industrial complex needs effective tools for "end-to-end" monitoring and automation of each process, management of technical compliance, planning of the work of each employee and management of work execution for quick response and making the right management decisions by agricultural producers.

Automation means access to new end-to-end monitoring and management capabilities covering the entire production, processing and storage cycle in the agricultural sector – from attracting investment to shipping products to customers. The program simplifies organizational issues, prevents mistakes and omissions of important moments, minimizes losses and establishes interaction with internal and external organizations.

The process of automation of elevators is carried out in parallel in two directions:

- technological processes of storage, drying, logistics, automation of equipment, equipping with sensors and monitoring devices, indicators;
- scope of accounting, management and control over the activities of the elevator. Automation of this area includes external logistics processes, accounting, financial services, accounting of finished products, and warehouse operation.

These two areas are interrelated with each other at the level of data exchange: for example, the accounting system collects data on the real costs of fuel spent on drying the volume of grain, which will later be taken into account in the total amount of costs for the formation of a batch of agricultural products, its storage to determine the cost of shipped grain [1].

The elevator automation system should be based on the philosophy of the "Automated Workplace" and a unified system for storing and accessing information. This means that each employee performing a certain function has his or her own workplace in the elevator automation system [2].

Material and methods.

The methods used in grain storage in silos and elevators are mostly used by automatic systems of leveling robots, which are an alternative to traditional grain storage systems using metal silos and conventional floor warehouses. In general, the use of automatic leveling machines provides safer working conditions for personnel (there is no need to work inside the warehouse), aeration, more careful handling of grain and control over it with the possibility of mixing or recirculating it.

Analysis of many sources confirms that the operations carried out on robotic granaries are aimed at the following:

- Levelling system with automatic leveller.
- Grain aeration system.
- Fully automatic loading, unloading and transfer of grain or other bulk product.
- Portion filling with different crops or products.

The main equipment that is used to automate the floor grain storage warehouse:

- Robotic leveler (level leveler) of grain.
- Aeration system.
- Conveyor elevator equipment (bucket elevators, conveyors, etc.).

The leveler is the heart of the automated floor grain storage warehouse.

This is a device that is "suspended" at the top of the warehouse and allows you to move grain from one place to another.

- A conventional floor grain warehouse is filled by loading from above. At the same time, cone-shaped "hills" of grain are formed, which do not allow you to fill the warehouse to the very top. In order to fill the warehouse to the maximum, the leveler levels the grain across the entire width of the warehouse.
- The leveler moves the grain towards the grain unloading system. In this way, the floor storage warehouse can be completely emptied without the need for a front loader.

A grain leveler (level leveler) allows you to fill the warehouse to the maximum and provide fully automatic unloading of the warehouse without additional mechanisms (for example, front bucket loaders).

Outcomes

The Department of Automation and Control of Technological Processes of the National Research

University conducts research aimed at developing automation systems for storing grain in silos. The research is aimed at developing smart and safe grain storage, which should ensure that grain is preserved for long periods without spoilage or loss of quality. Stored grain can change both physically and chemically. Freshly harvested grain generates (especially at high temperature and humidity) hot spots, mold, mycotoxins, and additional temperature and humidity that cause spoilage. Dry, cool, and clean grains can be safely stored for longer periods of time thanks to careful moisture and temperature monitoring, as well as proper grain management procedures, and this can be done with the right conditioning facilities.

The purpose of the study is to improve the accuracy of determining the grain grade of agricultural products and to develop an automatic device for determining the grain grade in the process of storage, processing it in silo elevators and acceptance and transfer to other enterprises.

The goal is achieved by the fact that five main parameters are used to determine the grade of grain: gluten, hardness (glassiness) of the grain structure, weediness, moisture content of grain, grain temperature, and the grade of grain supplied for storage to silo elevators is determined after the processes of cleaning the grain from contamination and drying it, which are carried out with the grain prior to storage [3].

A typical elevator (Figure 1) consists of grain acceptance units (dump pit, weight control, railway acceptance); grain cleaning (pre-cleaning machines, pre-sale cleaning machines, seed cleaning machines); grain drying (accumulating cone silo, grain dryer); grain storage and shipment (flat-bottomed silos with thermometry, shipping bins, railway shipment).The thermometry system consists of thermal suspensions installed in grain silos, switching, distribution and interface cabinets, and an operator's station (computer with SCADA system) (Fig. 1).

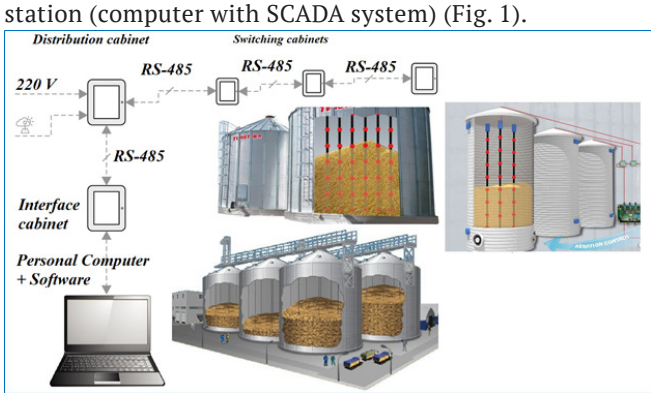

Fig.1.Temperature control system in silos

Thermometry systems are used to control the temperature in elevators. Elevator thermometry is an automated system for monitoring the storage temperature of a grain mound. It is used in the food, feed, grain processing industry and agriculture to preserve the quality of bulk products and prevent its self-heating [4]. A diagram of such a system is shown in Fig. 2.

The thermal suspension consists of a smooth and flexible tube with a small diameter, which reduces the effects of traction on the roof of the silo. Calibrated sensors installed in the cable measure the temperature at various levels. The easy removal and reinstallation of the sensor cable (even when the silo is full) makes it easy to repair, verify and calibrate.

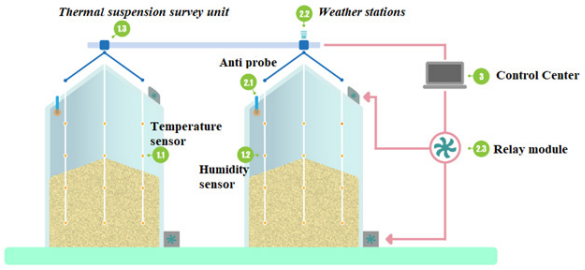

Fig.2. Composition of the elevator thermometry system

Thermal suspension with humidity sensors

They consist of a smooth and flexible tube with calibrated sensors that measure the temperature and humidity of the stored grain. They are manufactured with an unlimited number of sensors at the distance from each other that the customer needs.

Thermal suspension polling unit. Polling units are electronic panels, usually located in the center of the silo and accessible from the gallery. Simple connection and exchange, allow you to carry out any type of repair.

Automatic Silo Ventilation System

Humidity Sensor

Measures the relative humidity and temperature of the air between the grain and the roof of the silo. Controls the start and stop of roof extractors, preventing condensation from forming on the walls and ceiling of the silo.

Weather Station. Measures the relative humidity and temperature of the outside air. Allows the fan to be connected only when the ambient conditions are favorable for the ventilation of the silos.

Relay Module

Electronic cabinet with free voltage contacts, where the fan signals are connected for automatic start / or automatic stop, according to the selected parameters. It can also be used to transmit an alarm signal to the PLC or SCADA system being used.

Handheld Reader

The reader is designed for small and medium-sized installations where it is not advisable to use a PC. It consists of a unit, with an LCD display and a numeric keypad to select the desired thermal suspension and silo. It is possible to connect a printer.

Software

Designed for those who focus on the high quality of their grain preservation. Allows monitoring from several computers, I/O and a complete overview of the entire system in relation to the current temperature and the history of recorded values.

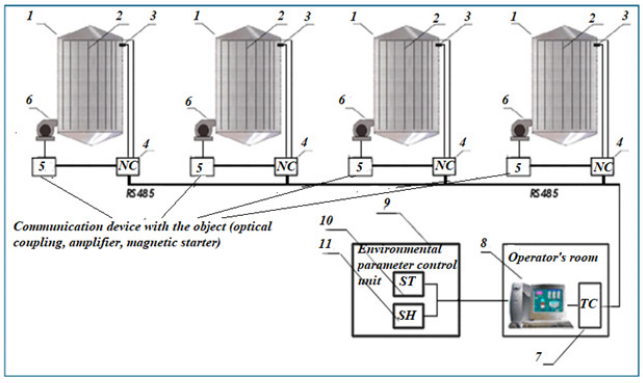

Fig.3. Structural diagram of the granary:
1 - Granary Building, 2 - Thermal Suspensions, 3 - Level

Sensor, 4 - Network Controller, 5 - Object Communication Device (Optoisolation, Amplifier, Magnetic Starter), 6 - Fan, 7 - Process Controller, 8 - Computer, 9 - Environmental Parameters Control Unit, 10 - Temperature Sensor, 11 - Humidity Sensor

Findings

The application and use of smart and safe grain storage will ensure that the grain is preserved for long periods without spoilage or loss of quality. Stored grain can change both physically and chemically. Freshly harvested grain generates (especially at high temperature and humidity) hot spots, mold, mycotoxins, and additional temperature and humidity that cause spoilage. Considered options for controlling process parameters, grain can be safely stored for a longer time thanks to careful monitoring of humidity and temperature, as well as proper grain management procedures, and this can be done with the correct application of automation tools

[5-7]. The considered schemes and the algorithm for temperature control in elevators use thermometry systems. This will provide an automated system for monitoring the storage temperature of the grain mound.

In order to fully realize the automation of grain storage in silos and elevators, it is necessary to simulate condensation systems and analyze real-time temperature and humidity data in order to make the right decision about conditioning methods and develop models and algorithms in grain storage systems.

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