Wireless system for remote monitoring of temperature and humidity in the grain storage and grain dryer

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Abstract. Monitoring the temperature and humidity of the air in the premises of granaries and in containers with grain allows you to create automatic systems to maintain the storage conditions of grain, which is necessary to preserve its grade. This article proposes a system for wireless monitoring of temperature and humidity, reducing the cost of laying and operating cable thermometers in the infrastructure of the storage facilities, monitoring the temperature and humidity of air at different levels of grain mounds, and monitoring the temperature and moisture of the spent drying agent in silage.

1 Introduction

Biological objects can comfortably exist in a fairly narrow range of changes in environmental factors [1]. When exposed to adverse conditions, stress develops, there is damage to cell structures and individual biological macromolecules [2-4], and the result is the death of the object. For experiencing adverse environmental conditions, there are a number of life forms, such as cysts, spores, seeds, etc. Such life forms are much more tolerant to changing environmental factors; however, they can also die with a significant change in intensity. Among environmental factors that can cause suppression and death of living beings, it is usually distinguished: temperature [5], light exposure [6], humidity [7], radiation background [8], etc. [9]. In grain storage conditions, the most variable factors are temperature and humidity. Monitoring the temperature and humidity of the air in the premises of granaries and in containers with grain allows you to create automatic systems to maintain the storage conditions of grain, which is necessary to preserve its grade. No less relevant is the rapid measurement of temperature and humidity in the process of drying the grain in silage when preparing its laying in elevators and other granaries. If during the drying of the grain it is too dry, then the grain grade may dramatically deteriorate, and in insufficiently dried grain sent for long-term storage, rotting processes may develop.

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2 Methods

Measurement of the temperature of the grain during the drying process in silage is carried out using thermal suspensions, for example, thermal suspensions manufactured by Ukrmashprom (Fig. 1a), hanging in the drying column on thick cables that experience enormous mechanical stresses when the grain is poured into the dryer. Cables going to thermocouples or digital sensors used to measure temperature hang on these cables, which of course makes the design expensive and difficult to maintain during operation.

Measuring the temperature and humidity of the grain in the granaries is important for the rapid determination of possible point of rotting. Such measurements at the different levels of the grain mound are carried out manually using rods, such as rods, manufactured by Kolb company (Fig. 1b) with a thermometer at the end of the rod, which are stuck into the grain mound at a predetermined depth and then recorded in the measurement log.

Fig. 1a. Schematic view of the thermal column

Fig. 1b. Manual temperature measuring rod.

Measuring the moisture content of the grain both during the drying process and during storage is also carried out by a very outdated method of sampling grain and laboratory measuring the weight of samples before and after they are completely dried.

Such “manual” measurements cannot be called operational, nor can they be used to automate the processes of drying and storing grain.
The premises (column) for drying grain (silage) are equipped with systems for layering or vertical blowing of grain with hot gas (a mixture of air and a drying agent (Fig. 2), and grain moisture in appropriate layers and can be promptly used by the silage master during the drying process.

This present article describes the QCONTROL wireless system for monitoring the temperature and humidity of air in grain stores, as well as in grain silage.

The QCONTROL monitoring system (Fig. 3) includes a computer-server, Eth-AP radio hubs, autonomous radio temperature/humidity sensors and software that allow processing digital packets from autonomous wireless sensors, display this data on the monitor, and if necessary carry out automatic control of the ventilation processes during storage or drying of grain.

The Eth-AP radio hubs (Figure 4) are designed to process digital radio packets from autonomous wireless sensors and transfer them to the computer-server using TCP/IP. Radio hubs are similar to cellular stations in cellular communication systems. They are placed on the premises or on its external borders, so that all autonomous sensors can be "heard" by the computer-server. QCONTROL radio hubs operate at a frequency of 433.92 MHz and can listen to radio packs from autonomous sensors at a distance of up to 500 meters (in open areas). In the premises, the distance to which autonomous sensors can be spaced usually does not exceed a hundred meters, which is determined by the thickness of the walls and partitions, however this may be quite enough for one radio hub to serve the
A radio hub is a “transparent” device, so the number of autonomous radio sensors that it processes is formally unlimited.

![QCONTROL Eth-AP Radio Hub](image)

**Fig. 4.** QCONTROL Eth-AP Radio Hub

A standalone wireless temperature sensor (Fig. 5) is built on the basis of microelectronic sensitive elements with a digital output, such as, for example, DS1820 or MAX31725. In some cases, it is effective to use analog sensors, such as thermistors with a negative temperature coefficient of resistance, but the nonlinearity of such sensors complicates the digitization and calibration of data from the sensor. Standalone sensor powered by a lithium battery. In order to increase the battery life, the sensor is programmed so that most of the time it sleeps and does not consume battery power, and only for a few milliseconds, the sensor measures temperature, forms a digital packet and goes on the air to transmit this packet to the radio hub receiver. If you program the period for the autonomous sensor to go on air, for example, once every 30 minutes or once an hour, such a sensor will work on one battery for about 10 years.

![Standalone temperature/humidity sensor in the QCONTROL system](image)

**Fig. 5.** Standalone temperature/humidity sensor in the QCONTROL system.

As seen in fig. 5 An autonomous temperature sensor is quite compact and this allows it to be placed on the walls of rooms or inside grain layers, and without using wires to power the sensor or transmit its parameters. This ability of wireless systems allows you to measure and monitor the temperature in a large number of control points of the granary, including points located in the thickness of the grain mound at its different levels. To this
end, a rod has been developed (Fig. 6) for monitoring the temperature in the thickness of the grain mound, which allows both measuring temperature at several mound levels and immediately transmitting by radio a full radio packet of data about the local temperature of the grain mound layers. If you install dozens of such rods on all areas of the grain mound, this will allow you to collect on the computer-server complete operational information about the temperature distribution in the grain storage and thereby indirectly judge the physiological state of the stored grain.

![Fig. 6. Schematic view of the rod for wireless monitoring of temperature in grain mounds by QCONTROL.]

In grain dryers (silage), the most effective is the use of a QCONTROL wireless system for monitoring the humidity of the drying gas at the outlet of the drying chambers. Such exhaust pipes are located at different levels of silage (see Fig.2). Monitoring the temperature and humidity of the spent drying agent exiting from these nozzles can indirectly serve as an operational indicator of the condition of the dried grain and thus the parameter that the silage operator can use to optimally adjust the drying process.

And thanks to the QCONTROL wireless technology, the installation of autonomous temperature/humidity sensors on the exhaust silo nozzles does not require significant costs. It should be noted that the QCONTROL wireless system can also be used to control ventilation systems using wireless relays (Fig. 7). The computer-server can produce commands to enable or disable various units of ventilation or heating of the drying gas required for drying the grain, and with the reference to the level of the grain mound, which will allow more fine-tuning of the drying process.

![Fig. 7. Type of wireless electrical relay system QCONTROL.]

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3 Conclusions

The research results showed the reliability of the proposed methods. The results obtained are in good agreement with the results of studies by other scientists [11-21].

References

1. W. Gassmann, H. Appel, M. Oliver, Journal of Experimental Botany, 67 2023–2024 (2016)
2. V.E. Ivanov, A.M. Usacheva, A.V. Chernikov et al., J Photochem Photobiol B. 176 36–43 (2017)
3. M.G. Sharapov, V.I. Novoselov, S.V. Gudkov, Antioxidants (Basel), 8 E15 (2019)
4. V.I. Bruskov, O.E. Karp, S.A. Garmash et al., Free Radic Res. 46 1280-1290 (2012)
5. C. Guy, F. Kaplan, J. Kopka et al., Physiologia Plantarum 132 220-235 (2008)
6. S.V. Gudkov, S.N. Andreev, E.V. Barmina et al., Physics of Wave Phenomena, 25 207–213 (2017)
7. A. Jamiołkowska, A. Księżniak, A. Gałążka et al., Int. Agrophys. 32 133–140 (2018)
8. S.V. Gudkov, M.A. Grinberg, V. Sukhov et al., J. Environ. Radioact. 202 8-24 (2019)
9. G. Bornette, S. Puijalon, Aquatic Sciences, 73 1–14 (2011)
10. V.F. Sorochinskiy, A.L. Dogadin, J. Bread products, 3/18 49-53 (2018)
11. A.V. Moroz, V.V. Davydov, V.Yu. Rud, Yu.V. Rud, V.C. Shpunt, A.P. Glinushkin, Journal of Physics: Conference Series, 1135(1) 012060 (2018)
12. V.B. Fadeenko, V V Davydov, V Yu Rud’, A P Glinushkin, Yu V Rud’, V Ch Shpunt, Journal of Physics: Conference Series, 917(9) 092015 (2017)
13. I.A. Zharikov, R.V. Davydov, V.A. Lyapishev, V.Yu. Rud, Yu.V. Rud, A.P. Glinushkin, Journal of Physics: Conference Series, 917(5) 052011 (2017)
14. I.S. Kudryashova, V.Yu. Rud, Yu.V. Rud, V.Ch. Shpunt, A.P. Glinushkin, N.N. Bykova, Journal of Physics: Conference Series, 929(1) 012021 (2017)
15. N. Grebenikova, A. Korshunov, V. Rud, I. Savchenko, M. Marques, MATEC Web of Conference, 245 11006 (2018)
16. R. Davydov, M. Sokolov, W. Hogland, A. Glinushkin, A. Markaryan, MATEC Web of Conference, 245 11003 (2018)
17. J. Stenis, W. Hogland, M. Sokolov, V. Rud, R. Davydov, IOP Conference Series: Materials Science and Engineering, 497(1) 012061 (2019)
18. I.S. Kudryashova, V.Yu. Rud, V.Ch. Shpunt, Yu.V. Rud, A.P. Glinushkin, Journal of Physics: Conference Series, 741(1) 012106 (2016)
19. V.A. Lyapishev, V.Yu. Rud, M.S. Sokolov, A.V. Cheremisins, Proceedings of the 2018 IEEE International Conference on Electrical Engineering and Photonics, EEExPolytech 2018, 8564387 292-294 (2018)
20. N.M. Grebenikova, K.J. Smirnov, V.V. Davydov, V.Y. Rud, Journal of Physics: Conference Series, 1124(4) 041011 (2018)
21. I.A. Zharikov, V.Yu. Rud, Yu.V. Rud, E.I. Terukov, V.V. Davydov, N.N. Bykova, Journal of Physics: Conference Series, 1038(1) 012100 (2018)