Application of model ZH-128 grain state detection and control system to storehouse

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Abstract

Model ZH-128 grain state detection and control system was developed, supported by the key scientific and technological projects of the Seventh Five-Year Plan of Ministry of Internal Trade. With the application of the First Grain Depot and the Third Grain Depot of Guangdong Provincial Grain and Cooking Oil Distribution Activities Company and further joint development, its application has been expanded from detecting temperature of packed grain to calculating preserved grain varieties and number of various storehouses, barns and heaps. It brings great convenience for grain preservation and have shown that it is economical and practical in the application of past two years. Its technical specifications have fully fulfilled the demands in design. It detects temperature rapidly and accurately, and its characteristics are especially stable. Not only the toil in manual temperature measurement, but also the phosphine corrosion for the cable and detectors have been solved. The grain temperature detection can be carried out as usual under the condition of pesticide fumigation. Since the computer communication between the company and various storehouses has been realized, the grain state exchange among various storehouses can be implemented. The company can also check the grain preserving state of its subordinate storehouses and provide the firsthand data of the preserved grain to the various leading bodies in real time.

General

Model ZH-128 Grain State Detection and Control System is a measure and control equipment which is suitable for the large and medium-sized grain depots. The technique used for the equipment once won the second prize of the scientific and technological achievements of Ministry of Internal Trade. In 1993 it won the first place in the lectotype appraisal in comparison with the same kind of products of the whole nation, and was rated as the first popularising equipment by State Grain Storage Administration. In 1995 the equipment won the first place once again in the national check. In the same year the product was ranked among the Torch Plan in Tianjin. In 1996 it was rated as a national grade product by State Science and Technology Commission. In 1997 it was selected and used by the loan project of the World Bank and at present it has been used by more than 200 national grain storage storehouses.

System composition

Model ZH-128 grain state detection and control system is a “collecting-distributing” constitution. The system consists of a PC microcomputer as central management equipment and single-chip microcomputers as sub-system equipment for field detection and fan control. Its composition is shown in Fig. 1. The main detection and control system are connected with various sub-systems. One detection and control system can be connected with 40 sub-systems and each sub-system can detect 244 sampling points.

The grain stored by Guangdong Provincial Grain and Cooking Oil Distributing Company is packed grain and it is stacked in piles. Each pile weighs about 100 tons. The sampling points are distributed at 9 points in 3 layers of each pile. A connection box is used in each pile and a sub-system is used in each storehouse.

System performances

Main functions

The system has functions of regular and automatic survey detection, automatic analysing for grain state and automatic control for mechanical ventilation.
Main specifications

Operating environment:
- Temperature: -30°C to +50°C
- Humidity: 15% rh to 95% rh

Temperature detection:
- Range: -30°C to +50°C
- Detection error: ±0.3°C (not including detector error)
- Repeatability error: ±0.3°C
- Resolution: 0.1°C

Humidity detection:
- Range: 20% to 95% rh
- Detection error: ±5% rh
- Repeatability error: ±1% rh
- Resolution: 1% rh

Detection speed: 40 points/second

Communication range: 4 km

System principle

The operator interacts with microcomputer through keyboard. The main detection and control system for grain state calls the sub-system in a roll call way and assigns a mission to the appointed sub-system. During detection the sub-system sends out selecting point pulse to the connection box and continuous samples. The sampling signal is converted into data through A/D conversion. The data will be sent back to the control microcomputer with data block, and the data block will be processed, displayed and printed by the microcomputer. In ventilation control the sub-system will sample various parameters every two minutes. The various parameters, such as absolute balanced humidity and
so on, will be obtained according to the different grain varieties and the different ventilation purposes, and the ventilation conclusion for ventilator control will be obtained according to "Regulations of the Mechanical Ventilation for stored Grain" issued by the Ministry. During the whole ventilation process, the detection and control system automatically monitors the grain temperature and the environmental conditions, captures the ventilation opportunity. The connection box is a controlled analog switch used to simplify the wiring within the storehouse. The connection box number of each sub-system is determined by the following equation:

\[ N = \frac{240}{P} \quad (P \text{ is sampling point number of each sub-system}) \]

In order to reduce the wiring within the storehouse, the serial way is adopted for selecting point pulse sent to the connection box by the sub-system, thus the number of selecting point will not be limited by the data line number.

The sub-system is applied to the field detection and control. During ventilation control, the microcomputer and the main system can be switched off. The ventilation control can be independently performed by the sub-system.

The main system is applied to increase the communication range between the central equipment and the sub-system equipment and it is possessed of the functions of timing and saving data at power-off. The microcomputer can be switched off in the regular automatic survey detection and the sub-system equipment can be started by the main system in the timing way, thus a long-term operating state of the microcomputer can be avoided.

**Main problems in designing and solution**

**Detection accuracy and stability**

The system uses thermistors as sensors for detecting grain temperature. The long-term usages in many grain depots of the whole nation have demonstrated that the element has the advantages of stable properties, good consistence, small noise, and it would not be damaged by the induced high voltage of thunder and lightning. In order to obtain higher detecting accuracy, a 10bit A/D circuit is adopted by the system and an A/D conversion accuracy can be as high as 1/1000.

The detection error will be influenced by drift of DC amplifier, lead resistance, breakover resistance and so on. The detection stability will be influenced by surge of power supply, variation of environmental temperature and various electromagnetic interference. In order to obtain a higher accuracy and stability, the following measures have been adopted for the hardware of the system:

A. Secondary voltage-stabilisation is adopted in DC power supply of analog circuit.

B. Grain temperature sensor is driven by micropower and the conduction time is reduced, thus the error induced by sensor temperature ranging can be avoided.

C. Automatic error correction circuit is designed. Once the system detects composite error, the detected data will be corrected automatically.

D. Thermistor is a nonlinear resistor and its resolution is low in a high temperature state. The linear circuit is adopted to the system, thus its resolutions at high temperature and low temperature are the same.

While we adopt measures for hardware, the system software detects each sampling point repeatedly. The averaged value is obtained after accidental values have been eliminated, then the readings can be corrected through checking table. The usage in First and Third Grain Depots, Guangdong Provincial Grain and Cooking Oil Distribution Company proves that the detected data of the system are accurate and stable.

**Anti-interference problem**

Some grain depots are situated near airport or broadcasting station. The strong electromagnetic wave interference often results in unstable data or the detected values which do not correspond with the sampling points. In order to overcome this phenomenon, the following measures have been adopted for the hardware of the system:

A. Two-line balance transmission is used between main system and sub-system, thus the difference-mode interference can be avoided.

B. Increasing amplitude of the transmission signal.

C. Selecting suitable baud rate.

D. Using shielding line as communication line.

E. Selecting sampling points with redundancy for sub-system.

Shaking-hands mode is applied to the communication software between the micro-computer and the main system. Odd-even check and check both ends are adopted in the communication between sub-systems and the main system. Since various grain depots of Guangdong Provincial Grain and Cooking Oil Distribution Company are situated near airports and docks, both electromagnetic wave interference and heavy-current interference are strong. During the usage, the system does not have any abnormal phenomenon caused by interference.

**Anti-thunder and lightning**

Anti-thunder is a key property of the detection system. In the course of usage, the past detection system was often damaged by thunder and lightning. Thunder and lightning induction mainly invade in the following four ways:

- 220V AC power network;
- Overhead signal transmission line;
- Grounding device;
Space induction.
When thundercloud discharges to ground, voltage $U$ (kV) induced at the wire can be calculated in the following equation:

$$U = 25 \left( \frac{IH}{S} \right)$$

Where, $I$ is thundercloud discharge current (kA) against ground, $H$ is the height of the overhead line from the earth, $S$ means vertical distance between thunder stroke point and the wire.

According to the above equation, if a 50kA lightning striking occurs at a place beyond 2km, then 2,500V voltage can be induced at 4m overhead line, it is enough to damage various electronic devices. The anti-lightning measures adopted in the system circuit are mainly blocking-up, shunting and isolation. A voltage induced by thunder and lightning is shunted into ground by resistors, inductance and discharge devices placed at the lead-in end of the exterior line. There are many kinds of discharge devices with different response times. The system selects different discharge devices according to the different cases and adopts multi-stage shunting. A photoelectric coupler isolation or transformer isolation is used between communication circuit and digital circuit. When the system is not working, the input line will be switched off or shorted to ground. We once took a roundabout course in ground lead arrangement. The whole system can only be grounded at one point, thus the counterattack induced by potential to ground can be avoided in the period of thunder and lightning. Thunder and lightning are frequent in Guangzhou District in summer and the system operates as usual.

**Anticorrosion**

When the stored grain is fumigated by phosphine, the detection equipment is easily damaged. The experiments show that the fumigating phosphine gas corrodes copper the most, but corrodes lead and tin less. The fumigating phosphine gas has a very strong penetrability. The system uses a special-designed sealed shell. Its lead and circuit board are coated with lead-tin alloy. Besides, the system uses socket connectors as less as possible, thus the anticorrosion purpose can be attained.

**Safety**

In order to avoid heavy-current introducing into warehouse, the sub-system of the system should be assembled outside the room. The connection box within the warehouse is powered by micropower and the power supply is switched on only at the operating instant. The system is at off-power state over a long period of time, thus the safety can be guaranteed.

**Operating environment**

The climate differences in various districts of our country are large and the power supply qualities are different. For this reason, a larger margin is left in designing system hardware circuit and the elements with broad operating environment range are selected. The subordinate various grain depots of Guangdong Provincial Grain and Cooking Oil Distribution Company are situated in Guangzhou District. In summer the local air temperature is high and the relative humidity is up to over 90%. In winter air temperature in Sifenhe-Harbin District, Heilongjiang Province is about -38°C and the relative humidity is about 20%. The system can operate as usual.

**System software**

Under Chinese character environment, while operator transfers operation software of the system, main menu and function key prompting will be displayed on screen. Selecting menu according to his own purpose, operator can perform operating with the prompting. The main menu contents are as follows:

A. Storehouse state setting: set stored grain property, grain variety, bag number, weight, entering time and sub-system number
B. Random detection: Operator can initiate the system and perform detection at any time.
C. Timing detection: The system starts automatically and perform detection at the specified time.
D. Ventilation control: System automatically controls mechanical ventilation
E. Grain state analysis: It automatically analyses grain state and reports the processing suggestion
F. Calculation of stored grain: It automatically calculates and tables according to the stored grain property, grain variety and number

The applied program of the central equipment of the system is compiled with C language. It can be operated under WINDOWS environment and it can be networked. Disk-stored data file can be communicated with microcomputer. The software is suitable for various storage types such as room type, silo type, bulk grain and piled packing grain. The calculation and tabling for the stored grain can also be carried out. The software of the system has been used by various subordinate grain depots of Guangdong Provincial Grain and Cooking Oil Distribution Company and good effects have been achieved.

**Application of the system**

Since the detection and control system for grain state has been applied by the First Grain Depot, the Third Grain Depot of Guangdong Provincial Grain and Cooking Oil Distribution Company and in many other regions in our country, a larger economic benefit has been achieved. It is deeply welcomed by the leaders, storekeepers and laboratory assistants.
Saving considerable labour power

The storing method of packed grain is adopted by various subordinate grain depots of Guangdong Provincial Grain and Cooking Oil Distribution Company. In the past they tested grain temperature with iron pole rice thermometer and hand-held electronic thermodetector. The former not only needs more labour to insert iron pole rice thermometers into each pile of each storehouse, but also has the disadvantages of less detection points and slow detection speed. If we detect grain temperature of a storehouse with 2,500 tons of grain (24 piles and 3 points of each pile will be detected), the work can be finished by two men in 1.5 hours. The inserted iron poles will damage the packing bags. The latter is faster than the former, but it still needs a man to finish it in 20 minutes. If the system is applied, the temperature detection for a storehouse with 40,000 tons of grain (two multistorey storehouses with 20 bins and 360 grain piles) can be finished only by one man in 45 minutes. This has increased the effectiveness by a factor of 10 than that of hand-held electronic thermo-detector and by a factor of 81 than that of iron pole thermometer. Gram temperature will be detected 3 times each month in Yutian County Grain Storehouse, Hebei Province and this work can be finished by 10 men in 3 days. With this system, the work can be finished by one man in 1.5 hours, it has increased effectiveness by a factor of 161. High-temperature season in Guangzhou District is as long as 6 ~ 7 months. High-moisture grain or heating grain is considered as semi-safe grain or dangerous grain. Their temperature should be detected every three days or every day. The temperature detection system further shows its superiority in this case. It can detect grain temperature at any time and the results can be obtained at once.

Operation under a non-poisonous environment

Gram fumigation can be carried out only when packed grain piles have been sealed with polyvinyl chloride than film tent. If we adopt manual temperature detection, operators will contact with poisonous gas. When iron rice thermometer is inserted into grain pile, the film tent will be damaged and the poisonous gas concentration within thin film tent will be influenced. A lot of trouble of manual grain temperature detection in fumigation period has been solved by this temperature detection and control system.

Accurate temperature detection function

As for the packed grain piles stored in subordinate grain depots of Guangdong Provincial Grain and Cooking Oil Distribution Company, each pile weighs about 100 tons and its sizes is about $10 \times 5 \times 5$ m$^3$. When we adopt manual temperature detection, only 3 sampling points of each pile can be detected. Not only the detection point is less, but also the detected temperature difference is up to $1 - 2 ^\circ C$. This cannot reflect the temperature state within the grain pile. This is caused by many factors such as inconsistency of the thermometer, position variations of the inserted thermometers and skill quality. This gram temperature detection system, since temperature detection cable is distributed into various grain piles, each time can detect the same detector situated at the same position of the grain pile, thus making the system error of the detected data constant. It is satisfactory that the random error of the system is only $0.3 ^\circ C$, so the detection accuracy is high and it can really reflect the temperature within grain piles.

Application of the timely temperature detection system to observe grain state variation at any time

The operation of the system is convenient. It can be imitated for detection and calculation at any time. High authorities can selectively examine grain temperature, variety, number and stored grain property of various storehouses and grain piles at any time. The most fast firsthand data are provided for different levels of grasping grain state. The data memory function of the system is good for inquiring about historic data as well as summing up rules and analysing grain state. The communication function of the system provides a fast means for grain state exchange among various storehouses. The statistic function of the system provides a convenient condition for inner calculation and checking of the storehouse, thus realizing accounts consistence with record and material objects.

In August 1997, Yutian Grain Storehouse, Hebei Province discovered that grain temperature at certain sampling point of No. 14 Barn was 3$^\circ C$ higher than that of the same layer and 4$^\circ C$ higher than that of the same period of last year. After the sealing layer was uncovered, they discovered that grain at that position mildewed and went bad slightly. Since the temperature detection system is applied, this phenomenon has never taken place.

Considerable reduction of power and time by means of automatic control of mechanical ventilation

Since the system can automatically determine the upper limit and lower limit of ventilation temperature and humidity, automatically select most economic ventilation conditions, thus preventing the blind ventilation can be avoided. Grain Bureau of Panshi County, Jilin Province has applied this system to control the mechanical ventilation automatically. The expected effects have been achieved in the past three years. Large quantities of grain would not be dried in air and sun. Saving a large number of power and time brings about a good economic effectiveness. According to the calculation in Panshi County of Jilin Province, Nanchong City of Sichuan Province and Xiangchen County of Henan Province, control ventilation with this system can reduce ventilation cost by 20% ~ 50%.
Training scientific and technological talent

The application of the system raises the level of science and intelligence of grain storehouse. As a large-sized storage storehouse, Guangdong Provincial Grain and Cooking Oil Distribution Company is the first company to realize temperature detection management system with microcomputer and strides forward toward scientific grain storage. Large numbers of scientific and technical personnel have been trained for the enterprises, laying a good foundation of the future scientific and technological progress.

Prospects of the system

At present, the basic functions of the system can meet the grain storage demands of storehouse. Various sensors for grain heating alarm, moisture detection, CO₂ detection and oxygen detection can be further developed according to the demands of the users. The distribution software will increase and a system can be applied to multiple applications. The serial products which are suitable for small, medium and large-sized grain depots can be constructed.