Grain Handling Automation and Controls

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Introduction

Grain handling and storage has undergone changes due to great advancements in automation and computer technology during the past three or four decades. Changes will rapidly continue in the years ahead with innovations in electronics. Safety, the cost of employees and training, the need to move product more efficiently and faster and insurance costs have impacted grain handling and management. These challenges have encouraged the use of automatic controllers, variable frequency drives and monitors to track inventory, move grain, control atmospheres within grain storage facilities and make grain facilities more productive, safer and more profitable.

An Example of Automation in an Elevator

The following scenario is an overview of what happens in an automated system when a truck delivers grain to an elevator from the field or other grain facility.

Step 1: Truck entry at the scales of an elevator

There is no need for the driver to exit the truck cab except to open truck gates at the receiving pit. The truck and its contents can be identified with bar codes or by intercom communication with the driver. After the loaded truck is weighed, the information is sent ahead remotely to the outbound scale and to the grain accounting system in the main office.

After weighing the incoming grain, a remote sampler collects grain and sends it pneumatically to the control room for inspection. Upon testing, the information is entered into software that calculates the USDA grade and records everything about the sample in the grain accounting system. All data files go to the general accounting system, which maintains inventory information and has the ability to handle split accounts for payment if appropriate.

Step 2: Grain Receiving

The operator of the receiving pit can review the grade and test information via network access to the grain accounting system. The destination bin can be selected by the operator and information about grain level and accessibility of the targeted bin is displayed on a computer screen or smart phone. Mistakes in bin selection are alerted and blocked by the software, so errors of dumping one type of grain in with another are prevented. If the current load is a different type of grain than the previous load, a time delay allows the legs and conveyors to clear out before the grain change is made.

Step 3: Truck Exit

The truck driver receives a printout when he weighs his empty truck at the outbound scale. The main accounting system has all of the records about the load delivered integrated with the grain owner's records for payment and with the grain company's inventory and accounting records.

Behind-the-scenes Tasks of Automation at an Elevator

Grain Handling

As grain enters a storage facility, the first example of automated tasks is most likely weighing and sampling. Many commercial facilities use electronic scales and robotic sampling equipment (Figure 1) to draw samples of grain from the truck beds and dump the samples into quality and moisture content sampling equipment. The grain in the truck is then unloaded at the dump pit and automatic controls send the grain to the proper bin for storage as designated by the control room in the company's offices or by applications on smartphones or tablets. Empty trucks exit via the outgoing scale, where truck weight is recorded into the grain management and accounting system, the truck driver receives a ticket, then the truck exits the facility.

Figure 1. Automatic sampler ready to gather a sample from an incoming grain truck.

Dryers

While dryers may not be commonplace in Oklahoma, they certainly can make good use of automatic controllers when used. Automatic controllers can be used to adjust and record temperature, air movement, heating times and moisture content as the grain passes through the dryer. Moisture content data before and after drying can be retained in a database for inventory control and traceability of the product through the handling system. As the controller monitors both grain and ambient conditions, the grain is more accurately dried to specifications because the controller is dedicated to the purpose and does not require as much manpower, attention or knowledge of moisture relationships to achieve the desired moisture content.

Storage

One of the key advantages that electronics and automation have given to the management of grain quality is the monitoring of temperature with temperature cables throughout bins. An increase in temperature may indicate deterioration of grain, insect presence and/or microbial activity in the area around the cable. Detection of this temperature increase gives managers an early warning sign, and the decision to remedy the problem or move the grain, can then be made before the problem grows larger and disaster strikes. Many grain bin incidents can be attributed to grain deterioration. Loss of grain quality may also result in lower prices when grain is sold.

Temperature Monitoring

Temperature data from cables can be read manually with a handheld monitor, or the cable data can be read automatically at set intervals by a computer system and recorded to a database. Wireless transmission capabilities can simplify installation and maintenance in larger facilities (Figure 2). Some controllers can be integrated into the fan control system. When relative humidity and temperature conditions meet preset control levels, the aeration fans turn on and off when the conditions in the grain have met the desired levels or the air outside has become unfavorable (too humid or too dry, too warm or too cool) for proper grain aeration. Some cable systems can gather humidity data to help estimate grain moisture content. CO_2 sensors have also been integrated in some storage automation systems for early detection of microbial activity or grain condition deterioration.

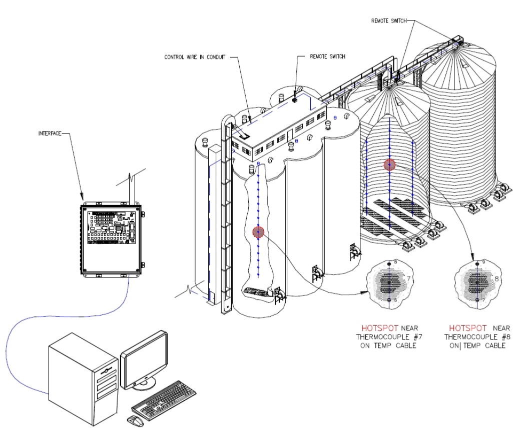

Figure 2. Example of bin temperature cable and wireless monitoring system.

Figure 3 shows a monitor display that represents the temperature cables within one bin. There are eight cables located at different places within the bin. Cable one has 18 thermocouples, cables two through six have 16 thermocouples and cables seven and eight have 15 thermocouples. A manager could determine three important things from this screen. The grain level is at the height between thermocouple 15 and 16 on cable one and one thermocouple lower on the remainder of the bin. That is where the headspace temperature is different than the grain temperature. The manager can determine this from the screen because the colors are different. The grain is in the green area and the headspace temperature shows in the gold area. The screen also shows a "hotspot" or trouble area (Figure 3) where the temperature is higher in the area around cables four and five at the height of thermocouples seven and eight and radiating around that area for a little

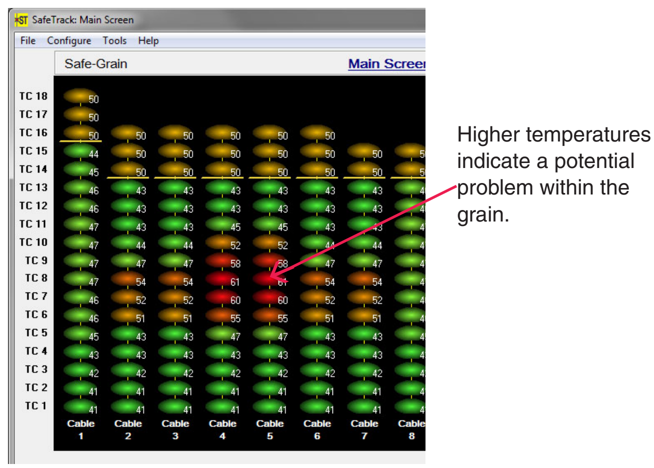

Figure 3. Thermocouples on temperature cables indicating a possible trouble spot in the grain bulk.

distance. The remainder of the bin has been stabilized at a temperatures between 41 C and 47 C. The manager can set alarms at a temperature that would indicate a problem area. Some systems like the one in Figure 3 can generate reports and graphs of the temperature history of the bin. This controller system could be connected to the aeration fan system to turn the fans on and off at preset temperatures. If connected to a humidistat system, relative humidity can also be considered in the aeration fan system controls. Working with a reputable dealer or contractor will provide assistance in selecting and implementing these controller and reporting systems.

Content Management

Bin level sensors help estimate how much grain is contained in each pit, bin or silo (Figure 4). They assist managers in determining where to put new product being received or move product between bins. Some level sensors use ultrasound, some are capacitive sensors and some have mechanical moving parts much like trip switches or rotator switches. These level sensors also help to prevent mistakes in selection of bins when placing the grain in storage. If a bin level sensor indicates a bin is already full, an automatic "lock out" will not

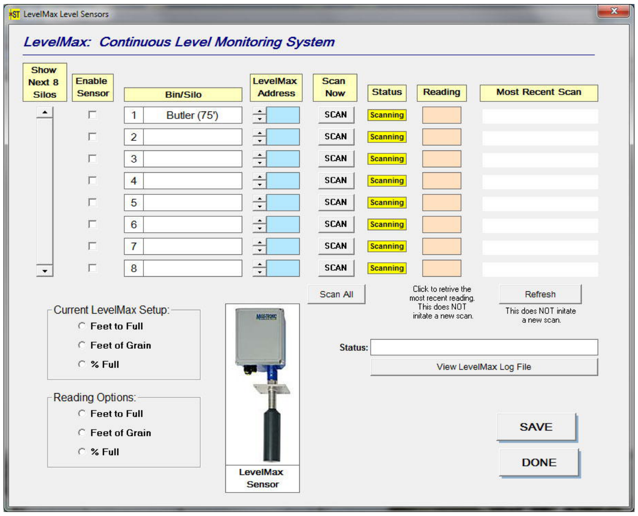

Figure 4. Example of bin level sensing system monitoring screen.

allow more grain to enter the bin, preventing a catastrophic overflow or grain backup in a leg. A grain "mismatch" will also send an alarm to the operator and prevent mixing grain by mistake. Knowing the level of grain in a bin may help estimate inventory levels as well.

Control Room

The superintendent or manager can monitor the entire grain complex in real time, including all alarms for bearings, belts and level switches. If there is a malfunction or alert, a message is sent directly to supervisor and maintenance personnel cell phones as well as to the control room. In some systems, all equipment involved and the feeding conveyors for that equipment go through a shutdown sequence to prevent devastating damage. All reports can be generated automatically and accounts are updated automatically. Traceability is in place from receipt of the grain until the grain leaves the facility. Information about aeration and moisture control is recorded along with any other modifications to the grain or bin structure.

Some automated control systems provide real-time monitoring of all equipment by the maintenance personnel through direct and immediate access electronically to reports of repairs, trouble alarms, and routine maintenance operations. This real-time knowledge allows for better response to problem areas before the problems grow into catastrophic events. It also allows maintenance departments to predict and prepare for repairs by knowing the frequency that equipment requires repairs. Management would also be able to tell if a piece of equipment needs to be replaced by reviewing the maintenance record through the record-keeping system.

Grain Load Out

Each rail car or truck has a radio frequency identification (RFID) tag or other automated identification system. The grain accounting system knows the amount of grain that can be loaded in that type of car or truck. The system also determines the correct mixing and sourcing of the grain. The automated system controls the loading of the grain into the railcar or truck. Trucks and railcars can be loaded quickly and accurately with less risk to workers having to "walk the line" of rail cars checking to see the status at different points.

Safety

Automation and control systems can be used to improve worker safety. Heat and motion sensors installed on bearings and belts can alert maintenance personnel about rubbing of misaligned belts and hot bearings. This information is important so maintenance can be performed before the malfunctioning unit causes a fire or dust explosion. Also, power efficiency can be improved when belts are aligned correctly (Figures 5, 6 and 7) and bearings are not wearing beyond their service life (Figure 8). Belt speed monitors indicate slippage of belts and grain flow monitors indicate if flow of grain has stopped (Figures 9 and 10). In fact, the Occupational Safety and Health Administration's (OSHA) standard 1910.272 sets forth requirements that bucket elevators be stopped if belt speeds drop below a percentage of the normal operating speed. Of course, all enclosures and electrical systems must be rated for the dusty environment inherent to grain handling facilities and certified by a Nationally Recognized Testing Laboratory (NRTL Class 2 Division 1 Group G for inside bucket elevators or belt conveyor or Division 2, Group G for outside bucket elevators or conveyors). Figures 11 through 13 show a bearing

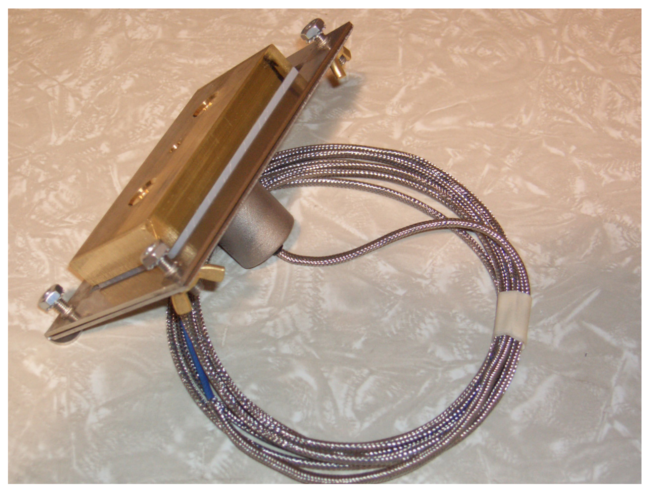

Figure 5: Belt "rub" block to detect belt misalignment.

Figure 6: Worn belt alignment block.

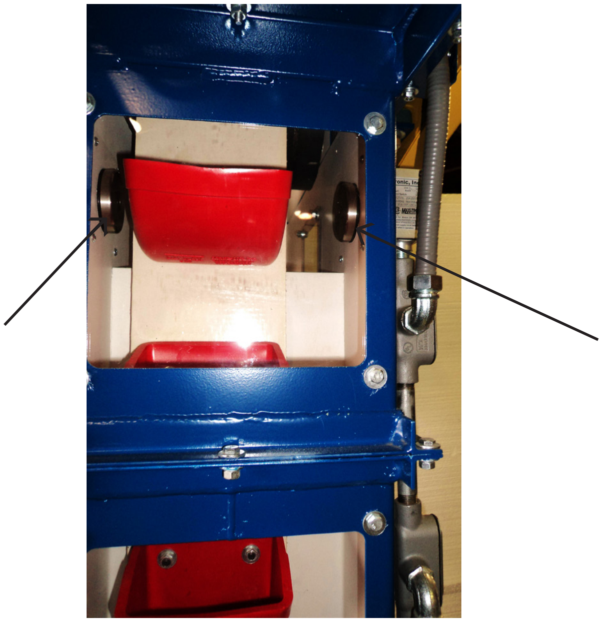

Figure 7: Belt alignment sensors. (Notice the difference in space between the bucket and the sensors on the right and left. The belt is out of alignment.)

Figure 8. Cutaway of a pillow block bearing heat sensor.

Figure 9. Bearing temperature sensor and shaft motion sensor.

Figure 10. Bearing temperature sensor and belt alignment sensor.

Figure 11. Example of a bearing temperature and belt alignment readout panel.

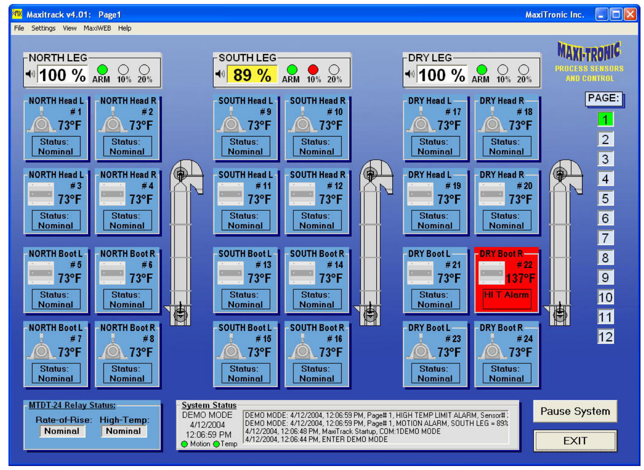

Figure 12. Monitor screen for bearing temperature sensors.

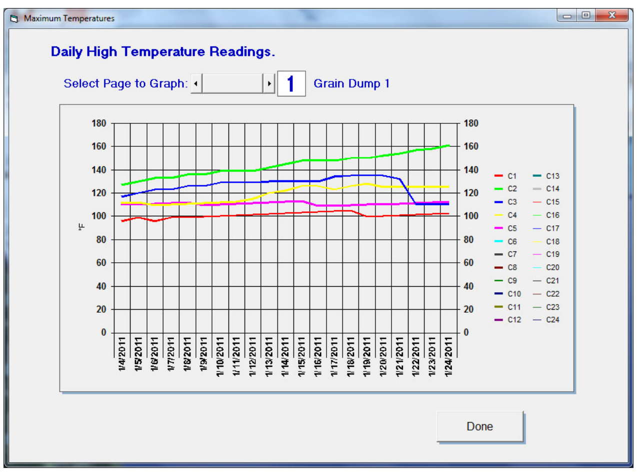

Figure 13. Historical record of bearing temperatures. The "C2" curve indicates a rise in bearing temperature, indicating a problem exists and the bearing should be inspected. All of the other bearings appear to have stable temperatures.

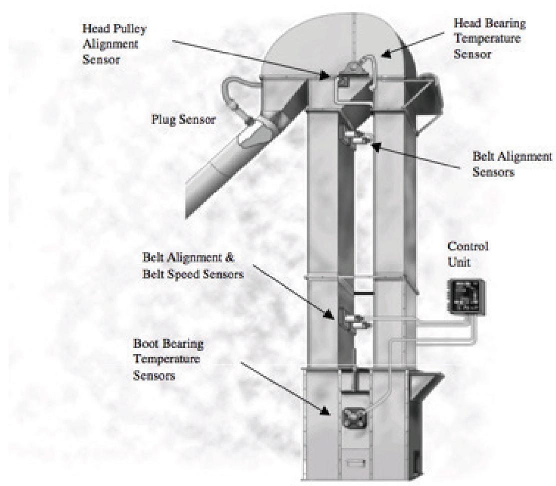

Figure 14: Drawing of a bucket elevator system with critical monitoring points identified. Photo courtesy Johnny Wheat (http://www.go4b.com/usa/technical-support/technical-papers/bucket-elevator-monitoring.pdf)

temperature readout panel, an example of a monitor that displays the temperature of bucket elevators bearings throughout a larger elevator and an example of historical bearing temperature data that can be used to diagnose problems or document maintenance improvements. The curve "C2" shows a rise in temperature in Figure 13. This would be a cause for concern and should alert maintenance personnel to check the bearing for wear.

A good example of extensive use of monitoring systems for safety is illustrated by the bucket elevator in Figure 14 with its bearing and belt alignment sensors.

Complete Management Systems

All of the controls and automated systems mentioned may be combined with a record-keeping system that provides vital information for identity preservation of product, supply chain management and product traceability. Such a system reads an identifier code when trucks deliver grain to the elevator. This identifier code can be indexed to an owner and even a specific production field. The weight, moisture content, quality inspection results, receiving dump pit and bin identification information are then automatically stored in the record-keeping system with the identifier code. Producers know how much grain came from identified fields, information about the quality of the grain and ultimately, its final destination to a customer. Information about how the grain was conditioned using fans and dryers can be recorded automatically in the database. Some systems can link the field data back to the fertilizing and planting data provided by the producer's mapping software from tractors and the yield data provided, combine monitors. This combined information provides a start for the "seed to table" traceability of a product.

Advantages of Automation

Controller and automated systems have proven to be economical by making the working environment safer and by preventing mistakes. They also help reduce the labor required to manually sample and test conditions in bins and to turn aeration fans on and off. Because the controller is dedicated to the task, the grain is kept in better condition. The storage environment is measured in real time and adjustments are made to the aeration system immediately, instead of when it fits into a worker's schedule to check and operate the systems. Equipment monitors report problems immediately and make the workplace more reliable and safer.

While labor appears to be a big point of savings, it should be noted that expertise in handling and maintaining the electronics in these systems is required. This may require using outside contractor expertise or, if the facility is large enough, hiring an electronics and/or computer technician to help maintain and update the electronics and software required for intense automation. Therefore, the labor requirement may not be less, but it most certainly will require different skill sets. Training is also necessary for maintenance personnel and workers that interface with the automated systems.

Planning is key to successful integration and future expansion throughout the facility. While automation and control systems are becoming a common part of grain handling, mistakes in planning can cause disaster. Working with an experienced sales and contracting company to establish a plan for automation has proven to be economical and a wise choice. These contractors have experts on staff who know the advantages of designing an integrated system and can give good advice that matches the size and capacity of each operation. These planning decisions will save money and time whether you are installing a new control/automation system or updating the existing system.

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