Bucket Elevator
Monitoring Systems

By
Johnny Wheat

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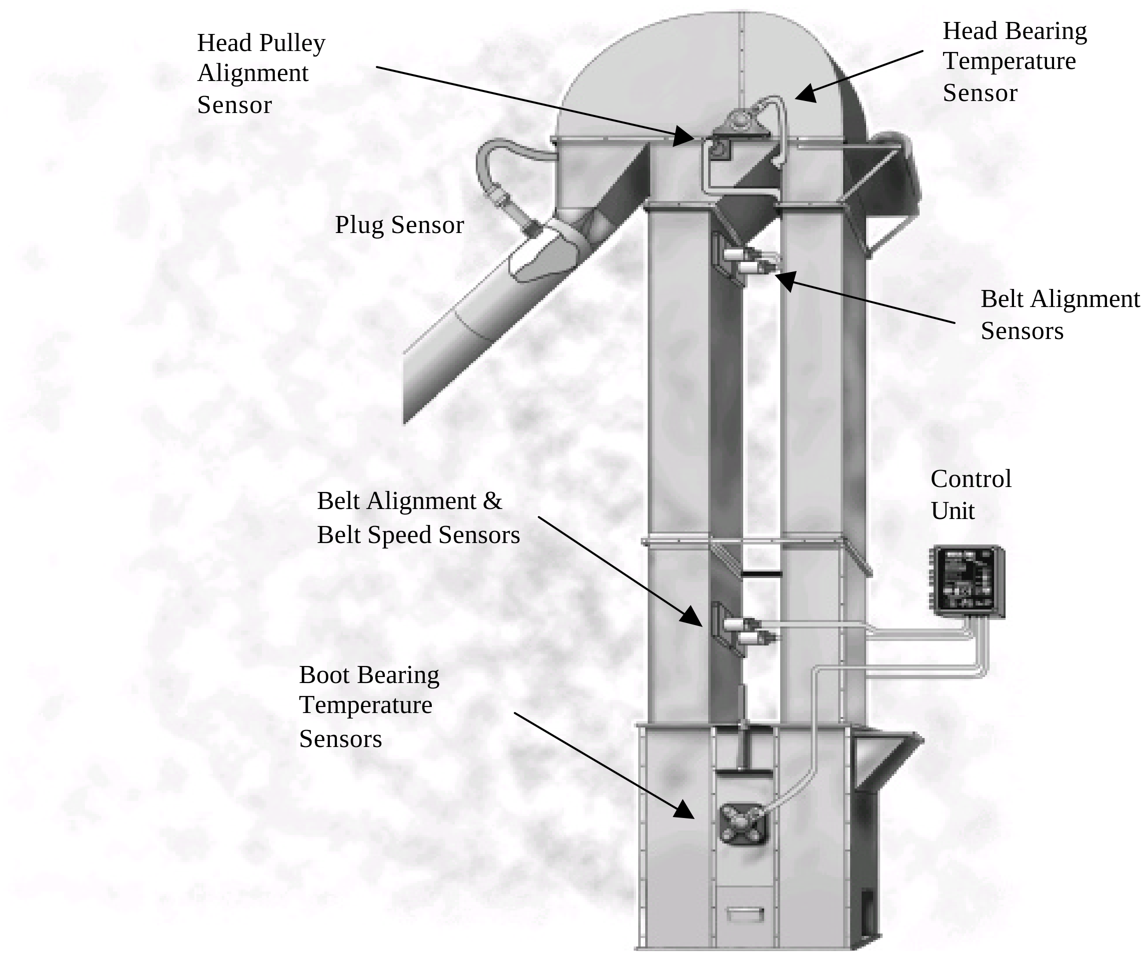


Introduction:

The correct mechanical operation of machines in any industrial environment is critical for the safety of plant, equipment and personnel. The dangers associated with incorrectly operating machines can be extremely serious when the machines are used within potentially explosive atmospheres like that found within the grain, feed and milling industries.

Grain Dust Explosion in Houston, TX 1976

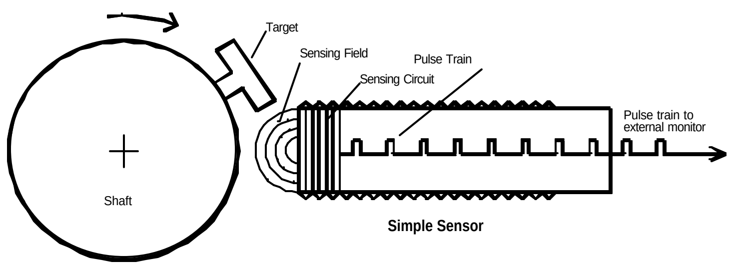
Within these industries there have been thousands of explosions throughout the world, causing millions of dollars of damage and taking hundreds of lives.

For many years now it has been understood that one of the ways to eliminate the threat of explosion is to eliminate the ignition source. On bucket elevators there are three primary heat generating areas with the potential to ignite dust in the atmosphere or dust lying around the elevator. These are heat generated by the belt slipping on the head pulley, heat generated by the belt rubbing against the elevator casing, and heat generated by bearing failure.

Belt Slip:

Bucket elevators consisting of two pulleys and a belt are capable of generating dangerous amounts of heat during belt slip. Belt slip on the head pulley can occur when the belt is loose or is overloaded. If a belt could be infinitely tight and capable of handling an infinite load then a belt would never slip, and the drive motor running at constant speed would eventually stall when the load surpassed its full load rating. (as the load increases, 3-phase induction motors slow down only very marginally, they run at almost constant speed and when overloaded they stall). The motor load current during belt slip is actually less than the normal running load current and therefore contrary to common belief, current detectors or amp meters are not a good indication of belt slip. Slip must be detected by monitoring the speed of the belt directly from the belt or indirectly from the boot pulley rpm.

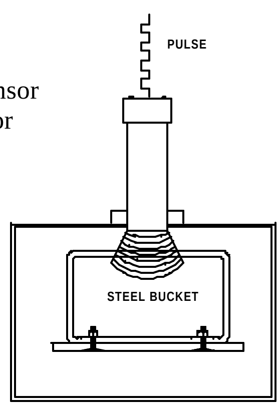
Because a 3-phase induction motor runs at constant speed independent of its load, a single sensor can be used to detect belt speed. This sensor can be mounted in one of two locations. Either by the boot pulley to detect the rpm of a target attached to the shaft or on the casing to detect the speed of the passing bucket bolts. Either location is suitable, although it is sometimes preferable to install sensors higher up on the casing to prevent possible damage from water and moisture in the boot area. When installing higher up on the casing, care must be taken not to be too far from the pulley. The further away from the pulley, the more the belt flaps and rolls, and the more difficult it is for the sensor to detect the bucket bolts consistently. The sensors for both locations are very different from each other and are not interchangeable. Because the target for the boot-mounted sensor is always uniform in its shape and its distance from the sensor, only a simple sensor with a short fixed range is required (**dia.1**). The sensor mounted on the casing however requires a much greater sensing range along with physical and electronic range adjustment so that it can be set-up correctly to cope with the side-to-side and front to back movement of the bucket bolts (**dia.2**). When ferrous buckets are used instead of plastic buckets, the sensor mounted on the casing must be moved to detect the buckets instead of the bolts, in order to prevent false readings due to the sensor detecting the steel buckets through the belt (**dia.3**). It must also be pointed out that the upside, or tight belt side of the elevator has less belt movement and it is easier to set-up the sensor and provide a more constant speed signal on this side.

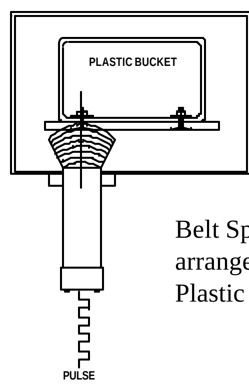


Dia. 1 Sensor Installed at the Elevator Boot Shaft
(Simplified Diagram)

Belt Speed Sensor
arrangement for
Steel Buckets

Dia.3





Dia.2

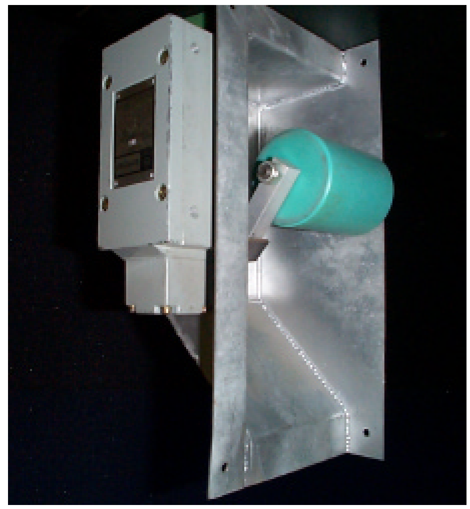
Belt Speed Sensor
arrangement for
Plastic Buckets

Sensor Installed on the Elevator Casing
to Detect Belt Slip

Belt Alignment:

Bucket elevators have sidewalls, which a misaligned belt can rub against. Heat generated by this rubbing action can quickly reach a dangerous level, especially near pulleys where the belt side forces are the greatest. There are a number of different sensing technologies, available to detect a misaligned belt.

Limit Switches. Mounted on the side of the elevator casing these devices are activated when a belt moves over. Wear on the switch, due to belt friction, is kept to a minimum by using steel or ceramic rollers to activate the limit switch. However these types of switch are outdated and dangerous. With the elevator belt running against the small roller, a typical roller speed of well over 1400 rpm can be generated. Serious problems can arise due to the bearings in the roller failing, resulting in dangerous heat generation. The mechanics of the switch can also wear out or become contaminated with material. This type of system is not failsafe in any way. If a switch becomes loose and moves away from its mount, there is no way of realizing that the system is no longer monitoring.



Typical Bucket Elevator Limit Switch incorporating a mounting box with an angled bottom to help "shed" material and prevent build-up. Unfortunately the system is not failsafe in any way.

Brass Rub-Blocks. Placed on the side of the casing these devices incorporate a temperature sensor, which is similar to the sensors used in bearing temperature monitoring but with a lower trip point. They are designed to detect the heat generated when the belt rubs against the brass block. Unfortunately these systems are out dated and dangerous. Firstly, they generate heat, which is what the device is trying to prevent, and secondly they wear away. Sometimes a belt misaligns and rubs against the brass for a short period of time, but not long enough for the sensor to detect the heat build-up. Over time, these sporadic misalignments wear through the brass block and render it ineffective. Rub-blocks are also not failsafe. As with limit switch misalignment sensors, if they become dislodged from their mounting they will not indicate that there is any type of problem.

Optical Sensors. Using an Infra Red transmitter and a receiver to detect the belt misalignment. Sometimes a number of sensor / receiver pairs are used to provide a warning and then a shutdown as a belt misaligns. However, the set up on these types of systems can be tedious as they lend themselves to false alarms due to sensor alignment problems and material covering the sensors lens. Sometimes air purging can help keep the lens clean.

Non-Contact Sensing. These systems are another popular belt misalignment detection technique used on bucket elevators. Extended range proximity sensors are mounted on the side of the casing and detect the passing buckets or bucket bolts continuously. When the belt is tracking normally, each sensor produces a signal as the bucket or bolt passes through the sensing range. When the belt misaligns, one of the sensors begins to miss pulses and the control unit determines this as a belt misalignment. Since all belts misalign to some extent without contacting the side of the casing, the better systems use two sensors so that this normal belt wander does not cause false alarms. The sensors also have a range adjustment so that they can be "dialed in" to the normal running of the elevator, and the control unit, which the sensors are connected to, usually has parameter adjustments for accurate set-up. The active continual sensing of these devices provides the only real failsafe solution for belt misalignment detection on bucket elevators at this time.

Solid State "TouchSwitch" belt misalignment sensor.

Solid State TouchSwitch. This device is the very latest development in belt misalignment detection, and can be used for bucket elevators and enclosed belt conveyors. These sensors measure the force applied to them by the belt as it touches their hardened stainless steel "button". Even the smallest deflection can be detected immediately so that the control unit is signaled and the elevator is stopped without delay. These sensors can also be used to detect the edge of the pulley, if it misaligns. Unaffected by material or dust build-up, no site adjustment is ever required.

Bearing Temperature:

All bearings create heat due to friction when running. When well maintained and lubricated this heat is minimal and well below the lower ignition temperature for the grain dust. However, if the bearing or lubricant fails in any way, rapid heat build-up can result. Very quickly the bearing casing can reach a temperature high enough to ignite any dust accumulated on or around the housing.

All bearings will eventually fail and even the very best preventative maintenance programs won't catch all bearings before they begin to fail. The only safe approach is to install automatic bearing temperature monitoring systems, which monitor the bearing temperature continuously. These systems incorporate a bearing sensor mounted to the bearing housing and wired to an alarm control panel. Control relays within the panel provide warning and shutdown contacts when the bearing exceeds a user defined trip point.

Typical Bearing Temperature Control Unit

In addition, some alarm panels incorporate a display, which indicates the bearing temperature and allows the user to easily adjust the trip point from a panel-mounted keypad. Sometimes the control panel is connected to a serial printer for historical data print out and may also be connected to a computer or PLC for integration into the plant's control system.
Sensor manufacturers use a number of different technologies to convert the bearing temperature to a voltage or current signal, which can be read by a control unit.
These technologies include:

Thermo-couple sensors, use a junction of dissimilar metals, which produces a small voltage in proportion to the temperature sensed. The technology has been used for many years and is quite reliable, however special thermocouple wire and wiring techniques must be used since every connection becomes a potential thermal junction.

Resistance Temperature Detector (RTD): The most commonly used RTD has a Platinum element with a resistance of 100 ohms at 0ºC. The resistance increases linearly with temperature rise. 3 or 4-wire RTD's are very accurate as they compensate for the resistance of the cable connecting the sensor to the control unit.

Thermistor sensors: these are thermally sensitive resistors and are available as Positive and Negative Temperature Coefficient versions (PTC and NTC respectively). The PTC sensor's resistance increases exponentially as the temperature rises, and the NTC sensor's resistance changes inversely to a temperature rise. PTC sensors are usually used to indicate when a certain temperature has been reached. NTC sensors can provide a variable signal, which can be used, for continuous temperature sensing.

Typical Bearing Temperature Sensor

Semiconductor Sensors: The latest development in temperature sensing uses silicon semiconductor technology. Usually manufactured as a six-pin integrated circuit (IC), these sensors are small, accurate, linear and low cost. As more and more facilities being built are using serial communication links instead of hard wire the digital sensor with individual address capability is becoming more popular. Instead of thousands of cables running through a plant, one main 4-wire communication cable is installed, with branches and nodes to individual machines. Thesel sensors have a unique identification number, which can be addressed by a central computer or plant PLC. When addressed, temperature data is sent from the sensor along with the sensor ID number. The ID number and temperature is then displayed and used for alarms and machine shutdown.

Some of the serial communication systems being designed today will accept the older RTD, Thermocouple or Thermistor technology by converting the signal to a digitally addressable data format. Thus enabling users to couple existing sensors to a data network, and also mix the old sensors with the new.

Multi-Hazard Monitoring System: Some systems incorporate inputs from a number of different sensors to monitor not just Belt Speed but also Belt Alignment, Bearing Temperature, Plug Condition, and Pulley Alignment. These tried and tested systems are designed specifically for monitoring in the hazardous environments found within the feed and grain industries.

Typical
Multi-Hazard Monitoring System
Belt Speed, Belt Alignment, Bearing Temperature, Plug Condition, and Pulley Alignment for Conveyors and Bucket Elevators.

Serial Communication Sensors: The latest developments in motion monitors incorporate serial communication capability. As more and more facilities being built are using serial communication networks (also known as serial bus systems) instead of hard wire the availability of a new type of sensor with individual address capability is growing. Instead of thousands of cables running through a plant, one main 4-wire communication cable is installed, with branches and nodes allowing routing to separate areas in the plant and individual machines. These new types of sensor have a unique identification number, which can be addressed by a central computer or plant PLC. When addressed, speed data is sent from the sensor along with the sensor ID number. The ID number and speed is then displayed and used for alarms and machine shutdown.

Also available are “gateway” devices, which allow standard sensors without serial communication capability to be connected to a serial communication network. The standard sensors are individually wired to the “gateway” device, which then connects to the serial network.

Although these types of systems are becoming more popular, as with any safety-monitoring device, care must be taken to ensure the integrity of the whole system. Some serial communication systems are designed to be safe systems, however the safest system is still the one, which is hard wired directly to the motor starter.

Safety Labels:

Because of the explosive dust atmosphere found within grain and feed facilities, electrical and electronic devices must not present a hazard in themselves. To ensure that the products are safe, they must be designed, manufactured and tested to national/international standards, and approved by a Nationally Recognized Testing Laboratory (NRTL). Not only the product but the manufacturing facility also, must go through a rigorous approval process. The NRTL inspectors check the company’s quality standards, procedures and policies. In addition to the initial inspection, continued unannounced follow-up visits, by the NRTL inspectors, are made to the manufacturing facility to check that the high standards are maintained. Only when everything has been checked and documented can a product carry the safety label. For grain dust areas look for Class 2 Division 1 and Division 2 Group G safety labels from NRTL’s like CSA, FM, or UL.