REDUCING RISKS OF DUST EXPLOSIONS DURING HANDLING OF BULK MATERIALS: THE OLDS ELEVATOR

By William Skelley, Richard McIntosh and John Higley – Olds Elevator LLC

Introduction

Millions of tons of bulk materials ranging from grain and seed crops to metal ores and sands are processed every year so we can participate in the lifestyles that we enjoy. The processing and conveying of these bulk materials can generate dust and many of these dusts are explosive under certain conditions.

This paper will reference a few examples of recent dust explosions. One will identify bucket elevators as a common denominator in many dust explosions. When a source could be identified, bucket elevators have been acknowledged as the single most common source of the primary explosion in dust explosions, particularly in the U.S. grain industry. In another example, we will examine the OSHA response to a dust explosion and their ensuing citation of the business where the explosion occurred.

We then present the Olds elevator an alternative to the bucket elevator and an alternative to the after-the-fact monitoring associated with flame sensing and suppression technologies. We will show the Olds elevator as a technology that greatly reduces the risk of propagating a dust explosion and also serves as a "choke" to prevent the passage of a moving flame front from upstream or downstream process locations.

Case I – Wood Pellet Plant

OSHA has recently issued a citation to a wood pellet manufacturer as a result of an explosion incident. The conveying equipment moving hot pellets from a pellet mill did not have spark detection, fire suppression and fire isolation devices, and no effective method of preventing the ignition source or fire from spreading to the downstream pellet cooler was present. A problem in the pellet mill caused a spark or ember to travel along a horizontal conveyor, up a bucket elevator, then along a second conveyor and into the pellet cooler, where wood pellets ignited and caused a major fire. The absence of any spark detection or fire suppression devices in the dust collector ducting enabled the fire in the pellet cooler to travel and spread through the ductwork to the indoor pellet cooler dust collector, which exploded. The deflagration pressure blew off the dust collector door making it a missile hazard. Inadequately sized blow out patches allowed the explosion in the dust collector to blow back into the ductwork. The duct burst open and released the deflagration pressure inside the building near personnel. The blow out vents directed the fire toward two silos, which also caught fire.

The plant was also cited for:

- having no effective isolation method to prevent the spread of fire and explosion to other equipment or occupied areas.

- allowing layers of combustible wood dust to accumulate to depths and over surface areas that exposed workers to fire and/or explosion hazards.
- having no means to make inspections of the rotary drier to show whether cleaning was necessary to keep combustible dust and resin deposits to a minimum.

To summarize some of the pertinent issues noted by OSHA:

- Dust leaks out of the process equipment and accumulates in the room
- Embers can pass through conveying equipment until it reaches a location where the Minimum Explosive Concentration (MEC) condition is sufficient to allow an explosion.
- Process equipment can not isolate fire/explosion from moving to other connected equipment.
- Spark detection/fire suppression equipment is needed.
- Adequately designed and oriented blow out patches are required.
- Equipment needs inspection ports

<u>Case II – Forest Products Industry</u>

British Columbia, Canada has had a vibrant Forest Products industry for many years. Sawmills process timber for the construction industry and in recent years a large Wood Pellet manufacturing industry has grown up in British Columbia (BC). Wood pellets are made from sawdust and BC produces 60% of the wood pellets made in Canada. The bulk of these pellets are exported to markets in Europe and Asia to meet their demand for renewable energy.

In recent years there have been numerous fires and explosions in the BC forest products industry both in wood pellet plants and in sawmills. These industries face dust explosion risks on a daily basis as the nature of their business involves generating and processing potentially explosive sawdust.

The recent rash of BC fires and explosions has been so out of the ordinary that several insurance companies that serve this market have decided to pull out and others are raising their premiums dramatically to adjust to the risks. Why has there been an increase in the occurrence of fire-related accidents in this industry? A potential answer lies in the 1,000's of acres of pine forest that were killed off by an infestation of beetles in recent years. Normal sawmill and wood pellet operations involve handling freshly-harvested wood products with relatively high (35% -45%) moisture content. While dust generated from processing green wood can be explosive, the MEC is high enough to make explosion events uncommon. Processing dead timber from the forests blighted by the beetle infestation involves handling wood that has been drying for years and now has a moisture content as low as 8%. The MEC of dust from the "bugkill timber" is significantly lower than that of green timber.

Conveyors and Their Contributions to Dust Concentrations

Many processes use conveyers to move powders and bulk solids from place to place, both vertically and horizontally. Some of this process equipment adds to the problem of dust explosions by creating highly combustible dust mixtures due to how they convey and release material. Dust concentrations inside bucket elevators handling grain for example, are above the MEC during normal operating conditions. A spark from a loose bucket or a foreign metal object, or an overheated bearing could ignite a dust explosion at any time. Other process equipment, like hammermills, dryers and pellet mills, can also be the ignition source of these explosions due to the inherent ability to create sparks from either metal to metal contact or from build up of static charges. They can also create hot embers due to the pressures and shears achieved in their processing of the bulk materials. Small explosions inside process equipment can lead to pressure waves that can cause agitation of any dust that has settled around the plant on beams, equipment and floor surfaces. This aerated dust is a combustible mixture that can be ignited by the initial explosion to create a secondary explosion that is often larger and more devastating to the plant and its personnel.

Case III – Bucket Elevator Grain Explosion

The following is a report on the explosion of a bucket elevator used to elevate grain in Brazil:

"The explosion started in the shipping bucket elevators [that] were in operation, and was most probably due to belt misalignment. This primary explosion expanded quickly throughout the whole facility. The first explosion caused dust within the facility to be blown into suspension in the air, thereby contributing to a series of subsequent much more powerful secondary explosions. The secondary explosion was so strong that all resistant structures collapsed, even rail cars were turned over like toys, big pieces of concrete that weighed over 5 t were blown 300 m away, the steel shipping tower collapsed to earth. The destruction was followed by fire, which ignited the grain and continued burning for nearly three weeks."[1]

Minimum Explosive Concentrations for Various Dusts

The Minimum Explosive Concentration (MEC) for grain dust is estimated to be 0.05 to 0.15 ounces per cubic foot depending on particle size and moisture and energy content[2]. For wood dust it is 0.030 ounces per cubic foot[3]. For other common dusts see the Table 1 below.

Table 1 – Minimum Explosive Concentrations for Common Explosive Dusts

Dust	MEC (oz/ft^3)
Aluminum	0.045
Al-Mg alloy	0.020
Chromium	0.230
Coal	0.055
Coffee	0.085
Corn	0.055
Epoxy Resin	0.020
Iron	0.100
Lignite	0.030
Magnesium	0.020
Silicon	0.110
Sugar, powdered	0.045
Tin	0.190
Titanium	0.045
Uranium	0.060
Wheat Flour	0.050
Zinc	0.480

The industries in the following figure are also of interest due to their high incidence of combustible dust explosions:

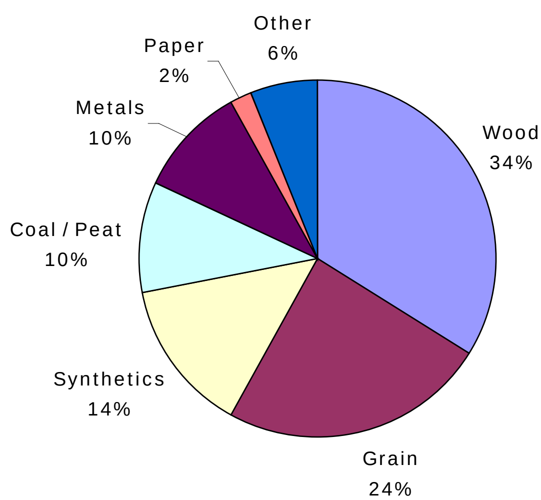

Figure 1 - Types of Dusts Involved in Dust Explosions[4]

Bucket Elevator – A Primary Ignition Source

As noted in Case III above, the bucket elevator is a potentially dangerous area for a grain dust explosion. An NFGA report states that "concentrations in the bucket elevator almost always exceed the minimum limits and thus constitute an explosive condition."[5] In a bucket elevator, the grain is always in motion, so dust is constantly generated. This dust is continuously swirled around the legs by the buckets. The presence of the dust in concentrations above the MEC in contact with ignition sources such as static discharge, metal on metal contact and friction heated bearings may provide all that is needed for a primary explosion.

The following is a table of equipment locations of the primary explosions of grain dust in grain elevator deflagrations (1958 -1975)

Table 2 - Location of Primary Explosions

Location	No. of Facilities
Unknown	107
Bucket elevator	58
Hammermills, roller mills, or other grinding equipment	17
Storage bins or tanks	13
Headhouse	9
Adjacent or attached feed mill	8
Basement	4
Processing equipment	3
Dust collector	3
Tunnel	2
Distributor heads	2
Passenger elevator or manlift shaft	2
Grain drier	2
Outside and adjacent to facility	2
Pellet collector	2
Conveyor system	2
Receiving pit	2
Other handling equipment	2
Processing plant	1
Down spout	1
Corn tester	1
Feed room	1
Sampler	1
Storage room	1
Boiler or feed mill	1
Electrical switch	1
Auger conveyer	1
Electrical panel	1

"Of 129 reported grain dust explosions in the US since 1988, 64 were in grain elevators … In 1997, 50 percent of primary explosions occurred in [bucket] elevator legs"[6]. This table shows both the large amounts of unknowns (due to the deflagrations being so all encompassing that the primary explosion location was not able to be identified) as well as the hazardousness of equipment that potentially generate sparks (those being farther up the list). An example of a bucket elevator elevating grain can demonstrate this hazard exposure. Stored grain typically contains two to 10 pounds of grain dust per ton. If a 12,000-bushel per hour leg handles wheat at 360 tons per hour, at the lower level of two pounds of dust per ton, 720 pounds per hour of grain dust is moving with the grain. If this leg is 130 feet high, the leg trunk casing volume is about 500 cubic feet. At the MEC level of 0.05 ounces per cubic foot, only 25 ounces, or 1.56 pounds, of free grain dust re-circulating in the air inside the leg is needed to reach the MEC.[7] It is this latter group, which contains bucket elevators, that the Olds elevator can be a successful alternative as an elevation device, process equipment isolator, and minimal dust generator.

The Hierarchy of Hazard Controls

The best way to control a hazard is to eliminate it. If a hazard can not be eliminated all together, there are several other ways to limit worker exposure to the hazard. Some of these ways are more effective than others. When all of these different hazard control methods are put in a chart, going from the most effective to the least effective way to control the hazard, the chart portrays the "hierarchy of hazard controls." It is considered good occupational safety and health practice to follow the hierarchy of controls.

<u>Hierarchy Of Hazard Controls</u>[8]

Most Effective	**1. Elimination**
↓	**2. Substitution**
	3. Engineering Controls (Safeguarding Technology)
	4. Administrative Controls (Training and Procedures)
Least Effective	**5. Personal Protective Equipment**

Currently, the recommended response to bucket elevator dust explosion potential is to provide adequate spark detection and explosion suppression to the entire structure as shown in the following brochure[9] excerpt:

THE PROBLEM [with bucket elevators]: DEFLAGRATION (EXPLOSION)
Dust suspension is generated due to the conveyance mechanics and material characteristics, creating explosive concentrations during product feed and discharge. All that is needed for an explosion to occur is an ignition source such as a hot surface, fire, sparks or embers. Upon ignition, the deflagration can propagate throughout the elevator enclosure to other connected process equipment and, in some instances, into the immediate surrounding area of the elevator enclosure, leading to secondary explosions within the facility.

THE SOLUTION: EXPLOSION VENTING/SUPPRESSION/ISOLATION

In the hierarchy list, equipping a bucket elevator with spark detection, flame suppression and explosion venting is a level 3 category solution. This is also true of OSHA's recommendations in the Case I example; the solutions are designed to contain a fire from spreading from the moment it is detected.

OSHA's recommendations were that "one feasible and acceptable abatement method to correct this hazard is to comply with relevant provisions in NFPA 664(2012)…, such as…8.2.4.1 which provides that **conveying systems with fire hazards shall be isolated to prevent propagation of fire both upstream and downstream into occupied areas or other critical process equipment,** and … 5.2.5.1 (4) particulate processing systems shall be designed, constructed, equipped and maintained to **prevent fire or deflagration from propagating from one process system to an adjacent process system**, and …8.2.4.4 **explosion isolation devises shall be installed, inspected and maintained** in accordance with Chapter 15 of NFPA 69"

Alternative to Bucket Elevators

A level 1 solution to some of these issues can be found using an Olds Elevator. The Olds design has the following advantages:

- A rotating casing creates a complete dust sealed elevating environment.
- The gentle nature of its elevation principle minimizes particle damage and dust creation.
- The Olds elevator conveys material upward in a completely filled casing along the path of a non-rotating screw helix, thus forming a long convoluted flow path of bulk solid that essentially plugs the casing height, isolating the upstream and the downstream process components.
- The Olds can be fitted with inspection spools along the casing as well as inspection ports and blow out patches in the hopper and discharge sections.

A discussion of using the Olds Elevator as a level 1 solution alternative is presented below.

The Olds Elevator

An example of equipment that can be used as an isolation device is the Olds Elevator. Used to elevate powders and bulk solids vertically, its inherent operating properties allow for minimized dust creation and the formation of a filled vertical column of transported material that isolates upstream and downstream process equipment. Where a bucket elevator is operated in an explosive dust cloud under normal conditions, Olds elevators operate without the presence of airborne dust in the elevator. No dust means no dust explosion potential. There will still be a small amount of dust from the material falling from the Olds discharge to the inlet of the next process, but this is considerably less volume that would require the above mentioned detection/suppression equipment with the addition of containing the volume by the forming of a vertical plug.

Principle of Operation

The Olds elevator is similar to a screw elevator in appearance and design yet its principle of operation is quite different. The Olds elevator utilizes a static screw (fixed to the bottom of the elevator) inside a rotating tubular casing (see Figure 2). The lower end of the tubular casing is equipped with intake scoops. As the casing is rotated the intake scoops direct product into the casing to fill the lower screw flight volume and the annulus between the screw and the casing. The boundary layer of product against the inner casing surface is caused to rotate by contact friction with the casing inner wall. Material resting on the surface of the screw is pulled up the inclined face of the flight by frictional drag of the product in this rotating boundary layer. Material is prevented from falling back down the elevator as further material enters via the scoops. Material will continue to flow up the elevator and out the top of the casing over the slinger, as long as there is material in the hopper that covers the intake scoops. If the level of material in the hopper drops below the scoops, material can flow back at the angle of repose of the material into the hopper and flow out the top of the elevator will cease. The casing will remain full of material, as the material in the casing will not behave as a fluid. In fact, even if the casing rotation is halted, only material that can flow out the scoops until the angle of repose is reached, will exit the casing; the remainder of the column stays full (see Figure 3). The casing can only be emptied by removing the material in the hopper and then rotating the casing backwards thus allowing the casing material to be dragged out the scoops.

The Olds elevator will elevate product at virtually any casing speed between 0 RPM (or the lowest speed the motor/VFD configuration can provide significant start-up torque) and the maximum RPM of the elevator design. Using a variable speed motor and controller allows operators to control the flow rate with great precision.

Additional Features

The Olds elevator provides a unique feature to the elevation of flammable or explosive particulate material. Because the rotating casing is filled with the bulk material, there is no dust cloud present in the vertical leg. The void space of the elevated material is similar to its resting bulk density and thus provides a convoluted path of significantly smaller open cross sectional area than the conveying ducts to and from the elevator. A flame front moving toward the elevator from either direction would encounter this “plug” of material and the change in open area would vary the flame front speed enough to prevent flame sustainability through the column of material. This property is inherent to the Olds elevator while elevating material as well as when flow has stopped because the column remains full even when the casing is not rotating.

Because the Olds elevator is gentler on the elevated material, less particle damage occurs and less dust is formed. The Olds elevator can run slowly because it does not need to make up for fall back down the annular region of say, a vertical screw conveyor. The fact that the bulk material in the Olds moves up the flight path similarly to a nut travelling up a thread means that there is little tumbling or impact between individual particles thus allowing a safer vertical transition.

The Olds elevator can be provided with inspection ports to enable viewing of internal casing and screw surfaces for build up of combustible materials and cleanliness.

Olds Elevator as an Isolation Device

Having an elevator that serves as a choke is a good thing. Many fires start as a spark in one location and result in a fire in another, the spark often drawn through the process equipment by the dust control system. A glowing ember will be transported along with other material through any other material elevator, as it will with the Olds Elevator. However, the vertical column of the Olds Elevator is not an explosive dust mixture and as such, is not an explosive ignition source.

Also, the Olds Elevator operates at a much lower rotational speed to lift the same flow rate of material than, for example, a vertical screw conveyor. This means the material is more gently flung out the top of the vertical tube and thus causes much less solids/dust separation.

Obviously, the Olds Elevator is not the miracle cure for all combustible dust explosions, but should be considered an integral part of an overall plant engineering philosophy to improve conflagration protection measures. It can be an important factor in isolating connected process equipment components while elevating product.

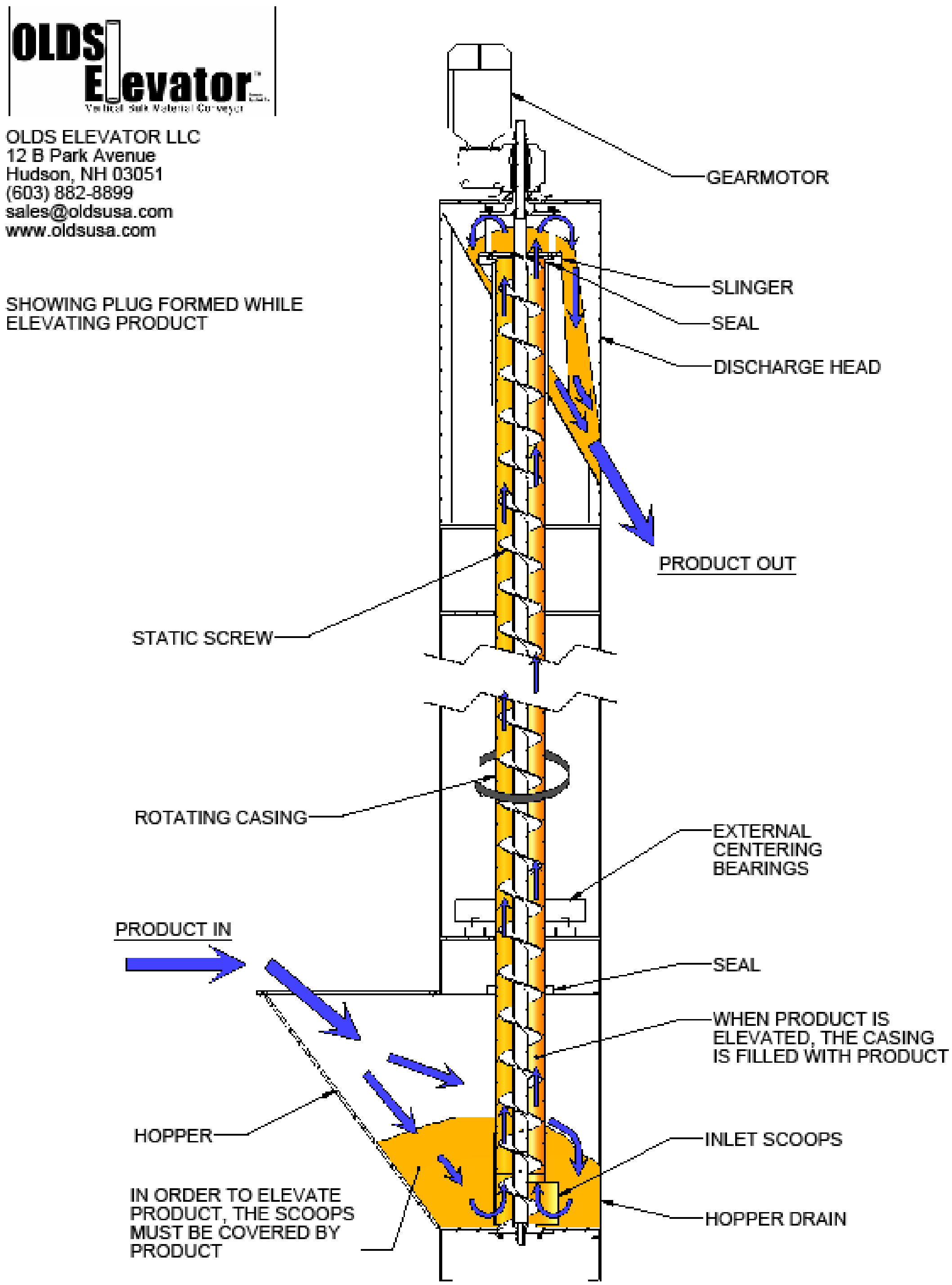

Figure 2 – Olds Elevator in operating mode

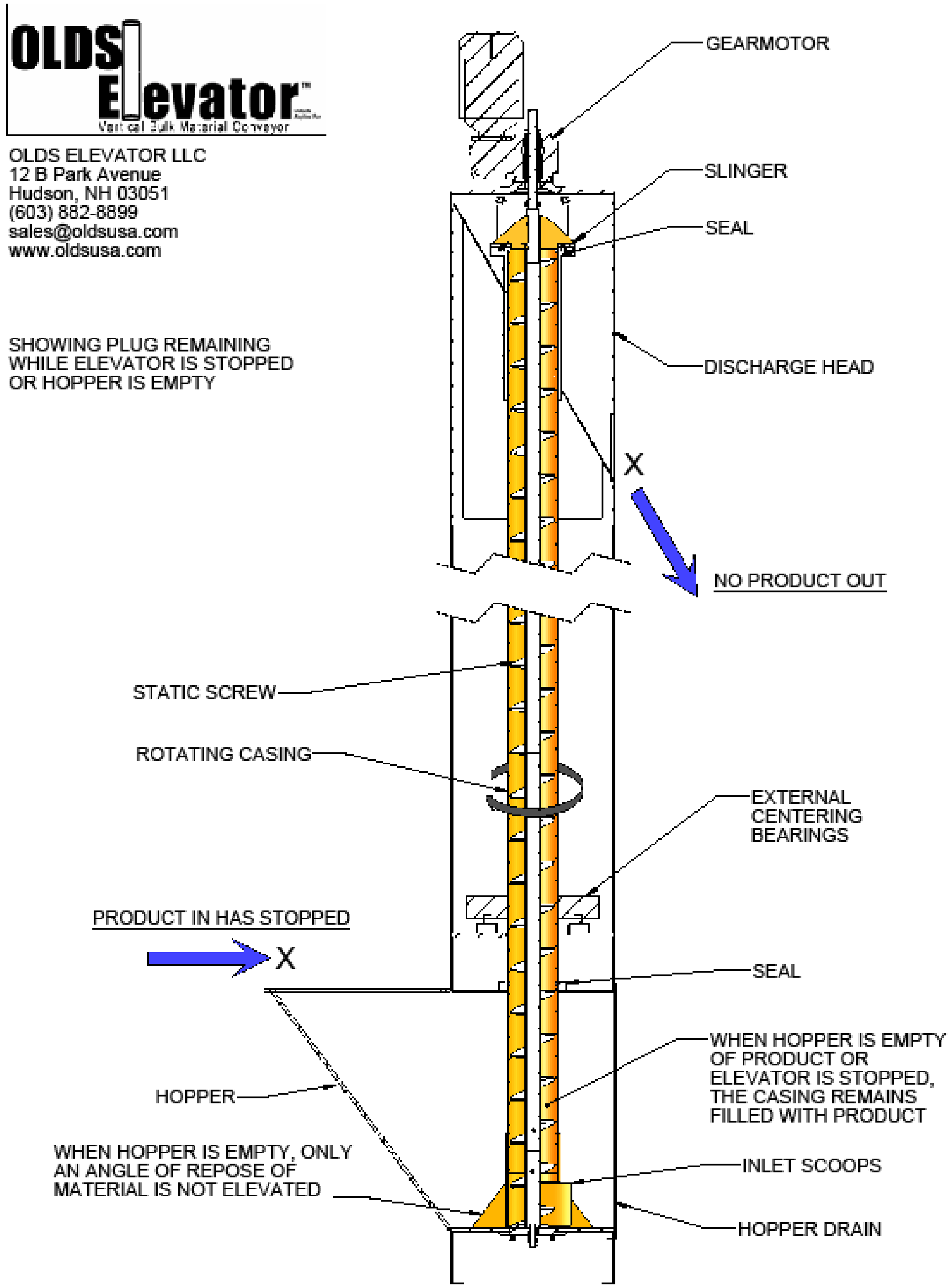

Figure 3 – Olds Elevator stays full when hopper is emptied

References

1. Hajnal, R.D., Dust explosions: A report on recent major explosions in Argentina and Brazil, TMSA Group, DOI: 10.5073/jka.2010.425.012.

2. Noyes, Ronald T., Preventing Grain Dust Explosions, OSU Current Report CR-1737.

3. Emmons, Sara, 1995, Fourth Quarter, Recipe for a Dust Explosion, Record, Vol 72, Issue 4, 3-8

4. Occupational Safety in Grain Elevators and Feed Mills, DHHS (NIOSH) Publication No. 83-126, National Institute for Occupational Safety and Health, 85 pp. (1983).

5. Buss, Kenneth L., 1981 Dust Control for Grain Elevators, National Grain and Feed Association, Washington, DC, pp 64-87.

6. Schoeff, Robert W., 1998, Agricultural Dust Explosions in 1997, Department of Grain Science, Kansas State University, Manhattan, KS, Feb 27,1998, 5 pp.

7. Harwood, Susan, Combustible Dust: Safety and Injury Prevention, Awareness Training Program Instructors Manual, Kirkwood Community College Community Training and Response Center, Grant Number SH-17797-08-60-F-19.

8. United Steelworkers, Resource Handout: Controlling Hazards.

9. Fike, Brochure, Application Profile: Bucket Elevator.

For more information, contact:

Olds Elevator LLC
12 B Park Avenue
Hudson, NH 03051
603 882 8899
info@oldsusa.com
www.oldsusa.com