



Preventing Grain Dust Explosions

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An average of 10.6 agricultural grain dust explosions are reported per year in the U.S. resulting in 1.6 deaths, 12.6 injuries and millions of dollars in damages (Schoeff, 2006). Some of these events are spectacular and make the news, although most do not. Even the small explosions cause equipment damage, elevator downtime and potential for worker injury. Background information on grain dust management may help Oklahoma grain elevator managers focus on measures needed at their elevators to prevent dust explosions.

Controlling grain dust is an important part of good elevator management. Grain dust emission control is expensive, but so are grain dust losses. Besides the fact that control of grain dust emissions is required by the U.S. Clean Air Act of 1990 and the Oklahoma Clean Air Act of 1991, keeping grain dust in the grain mass by controlling grain dust emissions is simply good business practice. In addition, maintaining a safer, healthier, more profitable workplace and elevator neighborhood is a characteristic of a quality elevator operation.

Grain Dust Explosion Elements

For a grain dust explosion to occur, four basic physical elements must be present:

1. **fuel** – very small particles of dry grain dust from wheat, milo, oats, barley, wheat or oat flour, corn starch, etc. Grain dust must be suspended in the air to create an explosion. Layers of dust in a confined space provide explosive potential.
2. **oxygen** – adequate air supply with normal oxygen levels.
3. **confinement** – a vertical elevator leg casing or housing, an enclosed drag conveyor, a dust bin, a down spout, an aeration duct, a basement tunnel, a bin deck gallery, a bin, a silo, etc.
4. **ignition source** – an overheated bearing in an elevator leg boot, head or conveyor; an elevator leg belt rubbing against leg sidewall casing; an electrical arc from a non-explosion proof electrical device; an electrical short; phosphine pellets or tablets exploding in a wet aeration duct; static electricity; a cigarette lighter or lit cigarette; a cutting torch or welding; metal sparks from a grinder; metal to metal sparks; a dropped tool; lightning, etc.

All of the elements for a grain dust explosion are present in a grain handling facility. Oxygen and confined spaces are most difficult to control. This leaves eliminating ignition sources and controlling dust through material handling techniques and housecleaning as the important variables in eliminating dust explosions.

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Additionally, low relative humidity weather conditions are thought to be a major factor in explosions where static electricity may have been the ignition source and where the grain dust was very dry.

Explosive Limits for Grain Dust and Grain Flour Products

The minimum explosive concentration (MEC) for grain dust, grain flour, or ground feed ingredients varies according to the particle size (smaller particles are more powerful) and energy (caloric) nature of the product. Extracted flour from wheat, oats, and corn may have different explosive energy than wheat, corn, sorghum, milo, and oat dust. Corn starch is considered one of the more volatile and powerful grain products, but all grain dust and flour should be considered as very dangerous.

A Texas A&M University dust control scientist suggests that the MEC range is about 50 to 150 grams per cubic meter, depending on the type of dust and the size of particles (Parnell, 1998). This equates to the same MEC level used by the National Grain and Feed Association (NGFA). NGFA states that the broad, generally accepted MEC for grain dust explosions is about 0.05 ounces per cubic foot of volume. They say that the optimum explosive concentration (OEC) is about 0.5 to 1.0 ounces per cubic foot – about 10 times the MEC (Gillis, 1985, p.43).

Grain Dust Depths needed for Explosive Concentrations in Elevators and Mills

The OEC value of 0.5 to 1.0 ounces of wheat flour per cubic foot equates to about 1.5 to 3.0 cubic inches of grain dust per cubic foot of air volume. The MEC would be about 0.15 to 0.30 cubic inches per cubic foot. The following table converts minimum and optimum explosion concentrations to a depth of accumulated dust needed for an explosion:

<i>Height of enclosed space (ft)</i>	<i>Minimum depth of dust for explosion (MEC) in inches</i>	<i>Optimum depth of dust for explosion (OEC) in inches</i>
1	0.001 to 0.002	0.01 to 0.02
2	0.002 to 0.004	0.02 to 0.04
4	0.004 to 0.008	0.04 to 0.08
7	0.007 to 0.015	0.07 to 0.15
10	0.010 to 0.021	0.10 to 0.21

A single piece of paper is about 0.004 inches thick, so it doesn't take long to accumulate enough dust to reach the MEC. Gallery floors commonly accumulate one fourth- to one half-inch of dust in a week or two during harvest, and belt tunnel floors commonly accumulate this much dust when silos are being turned in July and August. Extra housekeeping is necessary during these times to keep dust levels below the MEC.

OSHA regulations for grain elevators require that grain dust not exceed a 1/8-inch depth within 35 feet of a bucket elevator. Based on the above MEC values, keeping grain dust depths at less than 1/8-inch deep on any working floor of an elevator generally would not keep that facility below the MEC. The MEC concentration of 0.05 ounces per cubic foot (50 grams per cubic meter) is more than three times the OSHA standard for worker exposure (15 grams per cubic meter).

An additional danger of having dust levels above the MEC involves visibility. Suspended grain dust at the MEC will obscure the visibility of other workers about 5 to 10 feet away.

Having 0.05 to 0.10 ounces of dry grain dust or flour per cubic foot of confined space with heat, a flame, or ignition spark does not necessarily result in an explosion. However, all the physical elements for an explosion are present in most grain handling facilities. What's missing is that the dust must be stirred up to the point that it is fairly uniformly mixed or concentrated in the air volume around the heat source for ignition to take place.

How Dust Explosions Develop

During a major dust explosion, there are two separate explosive phases – primary and secondary explosions. Primary and secondary explosions often are so close together (a split second apart) that they may be heard as one explosion or a series of explosions, like rolling thunder. The primary explosion is caused by confinement of airborne dust in contact with a heat source that ignites the dust.

The first explosion sends an air shock wave, or a pressure front, at about 1,000 feet per second along gallery corridors, tunnels, and vertical shafts in the elevator, which stirs up layered dust. A flame front traveling at about 10 feet per second follows the pressure wave, igniting airborne dust as it progresses through a structure. Part of the dust from the primary explosion source may be carried along with the pressure wave, providing additional fuel for secondary explosions. Secondary blasts send additional pressure waves throughout the structure (Parnell, 1998).

Parnell (1998) quotes 1973 research by Palmer, who reported pressures of 2 pounds per square inch during primary explosions, with secondary explosion pressures greater than 80 pounds per square inch. So, if a dust explosion is limited to a primary explosion because of good housekeeping and sanitation, far less damage is done than if secondary explosions occur.

Once initiated, a continuous series of explosions occurs as long as adequate fuel and confinement are present. The result is a chain reaction of secondary explosions that move with destructive force throughout an elevator (wherever grain dust levels are above the MEC), causing major structural damage. This is why empty silos are blown out of an annex in some explosions, while full silos may not be directly affected.

Where Do Dust Explosions Occur?

Dust explosions usually occur at grain transfer points – in bucket elevators or enclosed conveyors – where small dust particles become dislodged from kernels due to tumbling, agitation, and kernel impacts, as fast-flowing grain hits bucket elevator cups or changes direction in drag or belt conveyors. This turbulent grain movement causes high levels of suspended dust particles (two to 20 microns in diameter) in the airspace, often close to a hot leg boot section bearing or a spark from tramp metal in a dump pit or drag conveyor. According to national survey data, of 106 reported grain dust explosions in the U.S. since 1988, 51 were in grain elevators, and 34 were in grain milling facilities (wheat, corn, oat, and rice mills). (Schoeff, 2006)

Many primary explosions originate in elevator legs. Stored grain typically contains 2 to 10 pounds of grain dust per ton (Parnell, 1998). 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 recirculating in the air inside the leg is needed to reach the MEC.

An NGFA report on grain dust levels in bucket elevators states that “Concentrations in the bucket elevator almost always exceed the minimum limits and thus constitute an explosive condition” (Buss, 1981). So, when only 0.05 ounces of dust per cubic foot is needed to reach the MEC, as dust concentrations build inside a leg, they can quickly exceed the MEC, even in some aspirated or ventilated legs when excessively dusty grain, like sorghum, is being transferred.

Belt speeds for a 12,000-bushel per hour leg typically run between 600 and 800 feet per minute, or about 10 to 13 feet per second. The belt in a 130-foot leg makes one revolution in about 20 seconds. Part of the airborne dust tends to circulate continuously as the air is dragged along by the cups in the leg casing. Even though only a portion of the total dust is entrained in the air in the leg casing, much of the dust in non-ventilated legs remains concentrated in the air circulating in the leg housing during continuous operation, usually exceeding NGFA's MEC value of 0.05 ounces per cubic foot (Buss, 1981).

Explosion Safeguards

Continuous housekeeping and sanitation (regular cleaning of the elevator), and regularly scheduled bearing service should be top priorities at all grain elevators and at flour and feed mills. Many insurance companies insist on strict housekeeping, sanitation, and preventive maintenance at insured elevators. Grain, broken kernels and grain dust accumulate in the leg boots and should be cleaned out periodically. Some elevators install easily removable doors on leg boot side panels for quick, easy cleanout.

Listed below are a number of grain dust control and prevention procedures. All elevators and mills should be doing item number one, housekeeping and sanitation, for elevator safety and worker health, as well as for integrated pest management (IPM) purposes. It is the most important safety practice in any elevator or mill.

Guidelines to Minimize Grain Dust Explosion Conditions

1. Maintain a rigorous housekeeping and sanitation program inside the grain elevator structure. Keep grain dust cleaned up in all working areas of the elevator.
2. Implement a weekly or bi-weekly (or as specified by the manufacturer) bearing lubrication program, based on the bearing manufacturer's specifications.
3. Use a food-grade mineral oil spray system on grain during transfer and loadout.
4. Install bearing temperature monitors on leg boot, head, and knee pulley shafts, on horizontal drag head and boot bearings, and on belt conveyor drive and idler bearings.
5. Install belt rub sensors inside bucket elevator leg casings to detect belt misalignment to prevent friction heating.
6. Maintain a periodic (weekly or bi-weekly) bearing temperature monitoring program. Document periodic bearing temperature readings and compare with previous readings. A substantial bearing temperature increase (10 F to 20 F or more in a week or two) may indicate bearing failure and the need to replace the bearing.
7. Replace steel cups with plastic cups in elevator legs.
8. Use anti-static belting material in legs and horizontal belt conveyors.
9. Install quick-opening cleanout doors on leg boot side panels for grain and dust cleanout.
10. Install dust aspiration systems at grain transfer points or ventilation systems in tunnels and galleries with open conveyors, and truck dump pits where dust accumulation is a problem.
11. Install dust aspiration or suction ventilation systems on inside enclosed legs and conveyors to keep suspended dust below MEC levels.
12. Clean out dust collectors and change filter bags at intervals recommended by the manufacturer.
13. Clean out dust cyclone collector holding bins at scheduled intervals.
14. Install dump pit baffles on truck dump pits to provide a major reduction in airborne dust during dumping operation.
15. Incorporate explosion relief panels and devices in elevator design.
16. Install explosion proof electrical outlets and equipment in sensitive areas.
17. Train employees on the dangers and prevention of dust explosions.

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