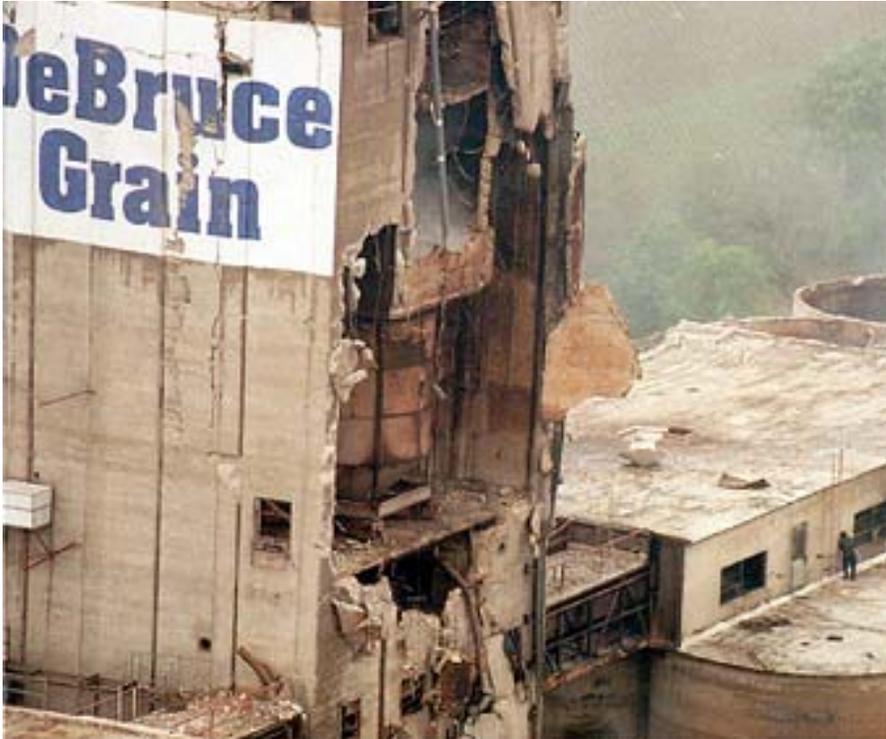


Combustible Dust: Safety and Injury Prevention

Awareness Training Program



Instructors Manual



Kirkwood Community College
Community Training and Response Center

Susan Harwood Grant Number SH-17797-08-60-F-19

Overhead (OVH) 1 &2

Cover Photo found on the following OSHA link:

http://www.osha.gov/as/opa/foia/hot_6.html

OVH 3

Disclaimer

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Acronyms Used in This Training

CDC	Centers for Disease Control
CFR	Code of Federal Regulations
CPR	Cardio pulmonary resuscitation
CSB	Chemical Safety and Hazard Investigation Board
JHA	Job hazard analysis
LEL	Lower explosive limit
MEC	Minimum explosive concentration
MSDS	Material safety data sheet
NEC	National Electric Code
NFPA	National Fire Protection Association
NGFA	National Grain and Feed Association
NOC	Not Otherwise Classified
NIOSH	National Institute of Occupational Safety and Health
OEC	Optimum explosive concentration
OSHA	Occupational Safety and Health Administration
SIC	Standard Industrial Classification Code
UEL	Upper explosive limit

OVH4

Overview

Dust explosions are a serious problem in many industries in the U.S. Over the last 28 years, there have been approximately 3,500 combustible dust explosions. Of those explosions, 281 have been major incidents resulting in the deaths of 119 workers and 718 workers sustained injuries. In 2005 alone, there were 13 reported agricultural dust explosions in the US, resulting in two fatalities and 11 injuries. These explosions have occurred in many different industries, including agriculture, food products, chemicals, textiles, forest and furniture, woodworking, metal processing, paper products, pharmaceuticals, and coal dust. Not only can these explosions cost lives and permanently change the lives of workers who are injured, there can also be serious economic hardships on workers and business owners alike. Businesses that suffer these explosions can be closed while the facility is being rebuilt; resulting in possible lost wages for employees and income for businesses. Some businesses may be forced to close permanently. The cost of these explosions can run into the millions of dollars.

One way to significantly reduce the possibility of dust explosions in businesses is through an aggressive education and training program designed to minimize the risk.

Providing all employees in at-risk facilities with awareness training in combustible dust explosions will certainly help to reduce the potential of such explosions in the work place. This training should include an overview of dust explosions, and provide explanations of what they are, how they occur and what can be done to prevent them. Through ongoing education and training, companies will reduce the risk to both their employees and facilities.

OVH 5

Goal

The goal of this training is to improve the safety of workers in environments where combustible dusts may be encountered by increasing employee awareness of this hazard, and by demonstrating how the hazard can be recognized and addressed in their workplace.

OVH 6

Enabling Learning Objectives

At the completion of this training, the participant will be able to:

- Identify the elements necessary for dust to explode
- Explain how to prevent dust from reaching combustible levels
- Describe the difference between primary and secondary dust explosions

OVH7

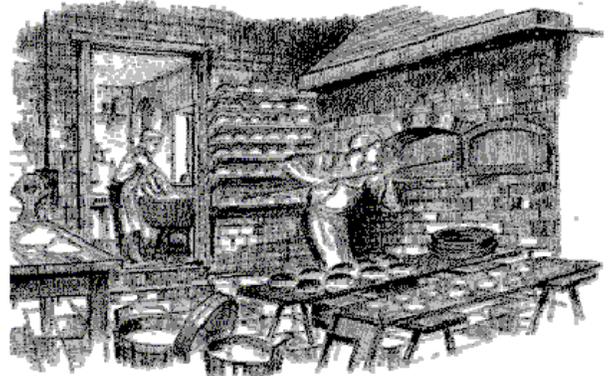
Terminal Learning Objective

Program participants will understand combustible dust danger in their industry; the Dust, Fire and Explosion Pentagon; and methods to prevent or mitigate the effects of a combustible dust explosion and resulting fire.

OVH 8

Introduction

The first documented dust explosion occurred in a **Turin, Italy, bakery in 1785**. The explosion was caused by the ignition of flour dust by a lamp in a bakery storeroom. Fortunately, the explosion did not cause any fatalities. It did lead to the realization that grain dust is a highly explosive substance that must be handled carefully.¹



A famous modern-day grain dust explosion occurred at a large export grain silo plant in Corpus Christi, Texas in April of 1981. This explosion resulted in nine fatalities, 30 injuries, and more than \$30 million in actual material damages. The suspected cause of the explosion was thought to be smoldering lumps of milo grain which ignited a dust cloud in a bucket elevator, though there has never been a consensus as to the cause.

OVH 9 Stress “Rare Event”

According to a report released by Robert W. Schoeff, professor emeritus, Kansas State University, and Ralph Regan, safety director, U.S. Department of Agriculture’s Federal Grain Inspection Service (FGIS), 13 grain dust explosions were reported in the United States during 2005. From 1996 to 2005 a total of 106 explosions resulted in 16 fatalities, injuring 126 at an estimated cost of \$162.8 million in damages to the facilities.²

The leading states from 1958 to 2005 are seen in the following table:

U. S. AGRICULTURAL DUST EXPLOSIONS
LEADING STATES - 1958 to Date³

State	1959-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	10 Year Total
Iowa	64	3	3	1	1	2	0	1	1	2	1	15
Illinois	58	1	1	1	1	0	4	1	1	0	0	10
Kansas	38	0	0	6	1	0	2	2	0	1	0	12
Nebraska	65	1	5	1	0	0	0	0	0	0	0	7
Minnesota	41	2	1	1	2	1	0	1	0	1	3	12
Ohio	26	0	1	1	0	0	1	0	2	1	1	7
Indiana	22	0	0	1	0	0	1	2	0	0	0	4
South Dakota	8	1	1	1	0	0	0	0	1	0	0	4
Texas	42	0	0	1	0	1	0	0	0	0	0	2
Louisiana	17	0	0	0	0	0	0	0	0	0	0	0
Washington	7	0	0	0	0	0	0	0	0	0	0	0
Missouri	27	0	0	1	0	0	0	0	0	0	0	1

¹ Parekh, Manisha, *Grain Dust Peril*. Industrial Fire World, Volume 13 Issue 4.

² Schoeff, Robert W., Kansas State University, in cooperation with FGIS-USDA, 20 Mar 2006.

³ ibid

OVHS 10,11,12,13,14,15,16, Used to explain that they do happen and the results are very tremendous.

OVH 17

OVH 18 Video 1976

Williamsburg Iowa grain fire and resulting dust explosion injured 3 firefighters

OVH19

What is a Dust Explosion?

A dust explosion occurs when a fine, combustible dust is suspended in air and ignited.



This causes a very rapid burning with a release of gaseous products and subsequent pressure rise. The resulting explosive force can damage plant, property, and people. Dust explosions can be categorized as either primary or secondary.

Primary Explosion

A primary explosion takes place in a confined atmosphere such as a cyclone, storage silo, or enclosed part of the manufacturing plant. After detonation, the shock wave can damage and often rupture walls, allowing burning dust and gases from the explosion to be expelled into the surrounding area.⁴

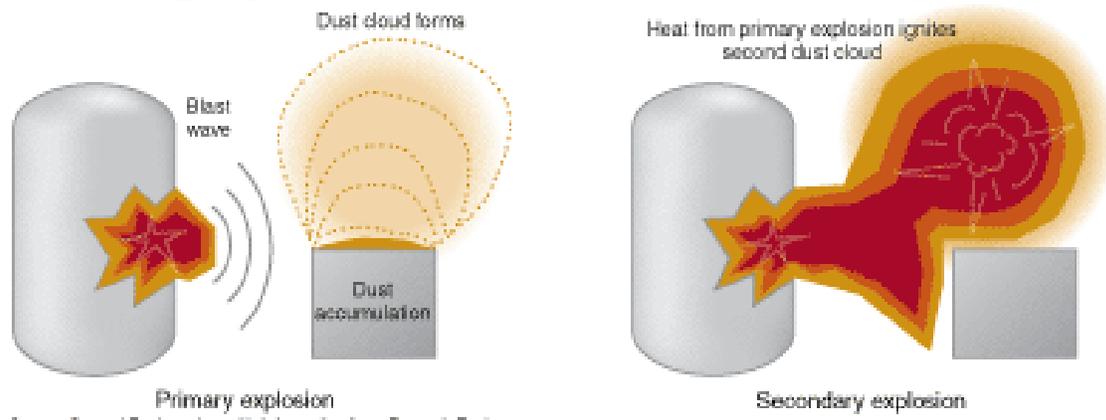
Secondary Explosion

The primary explosion will disturb settled dust that may have accumulated. **Once airborne, this dust can support a larger explosion; this is referred to as a secondary explosion.** Secondary explosions can cause severe damage to surrounding plant buildings. All large-scale dust explosions result from chain reactions of this type. There may be a chain reaction of many explosions caused by the initial explosion.

⁴ Kaulfersch, Joseph A., *Preventing Dust Explosions*. Control Engineering, January 11, 2007.

OVH 20

Cascading explosions



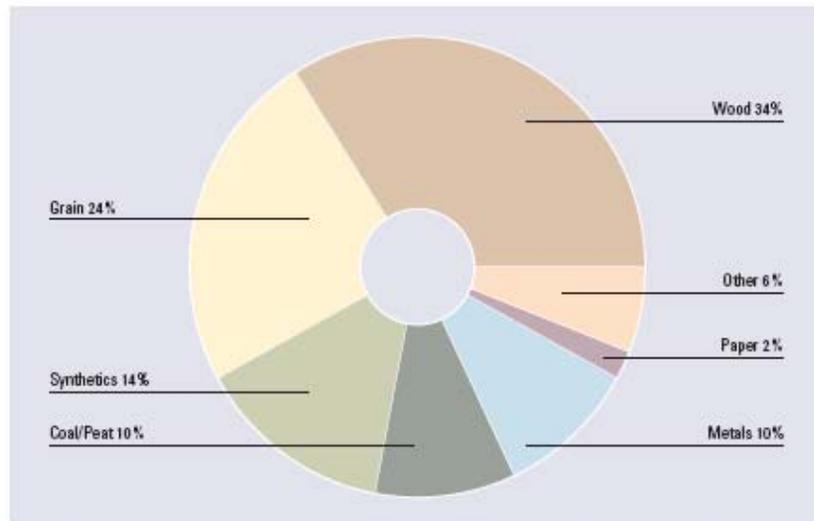
Source: Control Engineering with information from Pepperl+Fuchs

OVH 21 through 33

Shows progression of a dust explosion with time sequence and how much damage might be caused.

OVH 34

Types of Dusts Involved in Dust Explosions⁵



OVH 35

Required Conditions

For a dust explosion to take place, several key conditions must be present:

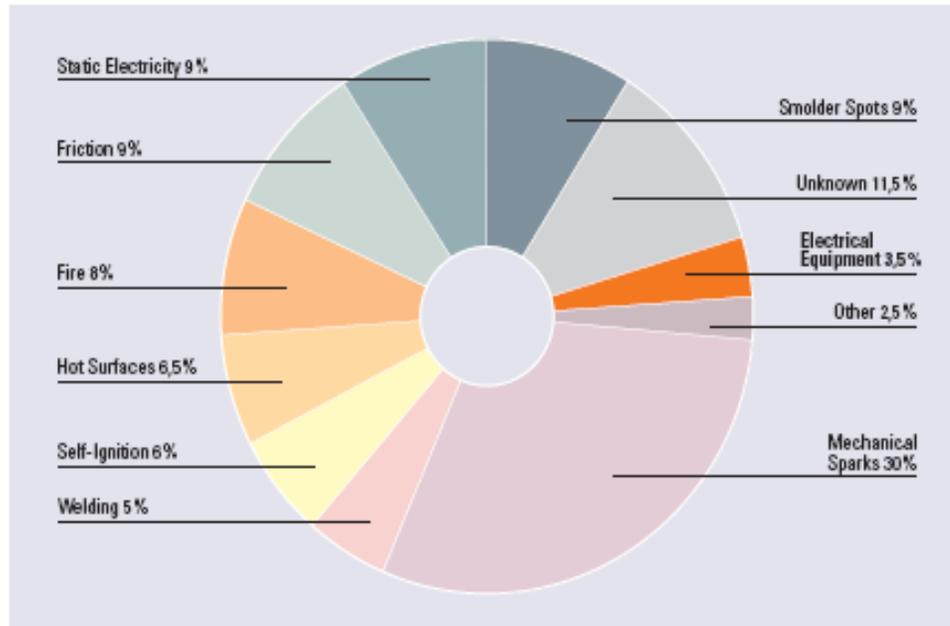
- The dust must be combustible and fine enough to be airborne.
- The dust cloud must be of explosive concentration; i.e. between the lower explosive limit (minimum explosive concentration) and upper explosive limits for that particular dust. These limits are 15g/m³ to 1200g/m³ Dust combustibility is in the range when you cannot see a 25 watt light bulb six feet away. This is the dust combustibility range which is LEL 2.5ug/m³ and 15mg/m³. This is called the minimum explosive concentration (MEC).
- There must be sufficient oxygen in the atmosphere to support and sustain combustion.
- The dust must be dry.
- The dust must be in a confined space.
- There must be a source of ignition⁶ such as the ones shown in the following chart.

⁵ R. Stahl Company, *Dust Explosion Protection*. Germany, www.dust-ex.stahl.de.

⁶ Ibid, *Preventing Dust Explosions*.

OVH 36

Ignition Sources of Dust Explosions⁷



Notice that 11.5% of ignition sources are unknown. This is because the totality of the destruction caused by the explosion makes it impossible to determine the cause of the ignition.

Other conditions under which a dust explosion occurs can result from the following:

- A complex combination of dust particle sizes
- The concentration of dust particles
- The energy of the ignition source
- The moisture content of the dust (or percent of relative humidity of the air)
- The actual composition of the dust
- Confinement of the dust in vertical elevator leg casing or housing, an enclosed drag conveyor, a dust bin, a silo, etc.

When these conditions are present and the concentration of suspended dust exceeds the minimum explosive concentration (MEC) of that particular dust, an explosion results.

OVH 37

Instructor Note

Deflagration is a technical term describing subsonic combustion that usually propagates through thermal conductivity (hot burning material heats the next layer of cold material and ignites it). Most "fire" found in daily life, from flames to explosions, is technically deflagration. Deflagration is different from detonation which is supersonic and propagates through shock compression.

In engineering applications, deflagrations are easier to control than detonations. Consequently, they are better suited when the goal is to move an object (a bullet in a gun, or

⁷ Ibid Stahl, *Dust Explosion Protection*.

a piston in an internal combustion engine) with the force of the expanding gas. Typical examples of deflagrations are combustion of a gas-air mixture in a gas stove or a fuel-air mixture in an internal combustion engine, a rapid burning of a gunpowder in a firearm or pyrotechnic mixtures in fireworks.

Explosive Concentrations

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. All grain dust and flour should be considered very dangerous.

OVH 38

As the size of the particle decreases, the risk of a deflagration or explosion increases. In order for a dust explosion to take place, the concentration must be between 40 grams per cubic meter and 4000 grams per cubic meter. The actual limits may vary based upon particle size and composition.

The optimum explosive concentration (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 volume. The MEC would be about 0.15 to 0.30 cubic inches per cubic foot. In a 1.0 cubic foot chamber, the bottom would be covered to a depth of 0.01 inches to 0.02 inches at the OEC level.

The following examples help put these values of MEC and OEC into visual perspective in elevator, mill housekeeping, or sanitation terms. If the dust layer on the floor of a 10-foot by 10-foot Texas house gallery is at the OEC, dust will be one to two inches deep. In a 7-foot by 7-foot belt tunnel (roughly half the volume of the 10-ft by 10-ft Texas house gallery), a one half- to one-inch layer of dust would cover the floor. At the MEC level of 0.05 to 0.10 ounces per cubic foot, the dust layer would be about one eighth- to one fourth-inch deep in the gallery and about one sixteenth- to one eighth-inch deep in the tunnel.⁸

OVH 39

Explosive Limits

The MEC and OEC can be compared to the lower explosive limit (LEL) and the upper explosive limit (UEL) for vapors. **The LEL is the lowest mixture of air and chemical vapor that will support combustion if ignited.** LEL is measured as a percentage of air by volume. **The UEL is the highest mixture in air that will support combustion if ignited.** The flammable range is the mixture in air between the LEL and the UEL. Most dust is rated for the lower or MEC at 15m/g³ to 1200g/m³.

⁸ Noyes, Ronald T., *Preventing Grain Dust Explosions*. Current Report, CR-1737, OSU Extension Service.

OVH 40, 41, 42**The Prevalence of Dust**

Many materials, ranging from baking flour to metal dusts, can fuel dust explosions when present in a finely divided state. Some materials are intentionally used in a powder or dust form in manufacturing, while other dusts are created as unintentional byproducts. Examples of materials that have historically caused dust explosions include:

- Cosmetics
- Coal
- Dyes
- Grain and other dry foods
- Metal
- Pharmaceuticals
- Plastic and rubber
- Printer toner
- Soaps
- Textiles
- Wood and paper

Recent Trends

Between 2006 and 2008, there were 82 dust-related fires or explosions. In response to recent dust explosions, the U.S. Chemical Safety and Hazard Investigation Board (CSB) recommended that government agencies, insurers, and others provide their inspectors with increased training on recognition and prevention of dust explosion hazards. This and the publicity from recent catastrophic dust explosions will likely increase enforcement of standards for the prevention of dust explosions by inspectors.⁹

OVH 43**Where Do Dust Explosions Occur?**

Dust explosions for grain usually occur at transfer points such as bucket elevators or enclosed conveyors. Here small dust particles become dislodged from kernels due to tumbling, agitation, and kernel impacts as the 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. This is 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 129 reported grain dust explosions in the United States since 1988, 64 were



Bucket Elevator

⁹ *Dust Explosions*, Exponent Engineering, <http://www.exponent.com>

in grain elevators, and 48 were in grain milling facilities (wheat, corn, oat, and rice mills). The remaining 17 were in storage areas.

In 1997, 50 percent of primary explosions occurred in elevator legs (Schoeff, 1998). Stored grain typically contains two 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 re-circulating in the air inside the leg is needed to reach the MEC.**

OVH 44, 51

A National Grain and Feed Association (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.¹⁰

OVH 52

Explosion Safeguards

Safeguards need to be activated to control the chances of a dust explosion. *These safeguards are prevention, housekeeping dust control, eliminating fugitive dust (dust leaking from other sources), keeping the environment clean, and eliminating as many hazards as possible.*

Continuous housekeeping and sanitation and regularly scheduled bearing service should be top priorities at all grain elevators and 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.

¹⁰ *ibid*

OVH 53

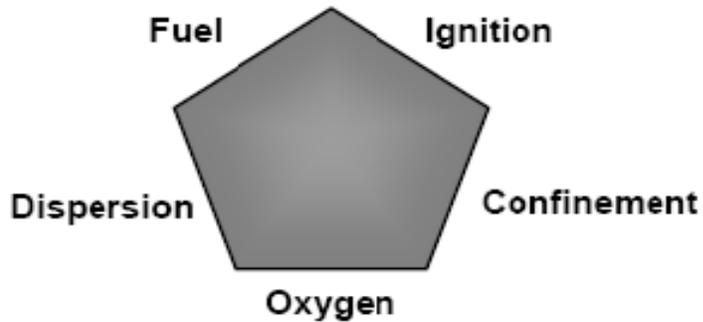
Prevention

Fire Prevention and Protection

Fires represent a major concern for many industries, including grain and feed mills, and result from many different causes. The end result of a fire, however, is always the same: personal injury, death, or loss of property.

The first and most important step in fire prevention is establishing a program to prevent fires from starting. This is particularly important in the feed and grain industries because of the potential for explosions and the track record of this industry for fires. A

comprehensive fire prevention program not only addresses housekeeping issues, but also addresses all work activities in which the conditions for starting a fire are present such as hot work, electrical machinery, belts and drives, and grain dryers.



The Dust, Fire, and Explosion Pentagon

OVH 54, 55

The fire prevention and protection program must address the following topics:

- Policies, practices and procedures designed to keep the conditions necessary for a fire from coming together. This is the fire pentagon (with two additional conditions) versus the traditional fire triangle¹¹:
 - Fuel (dust)
 - Dust is dry
 - Dust is at the MEC
 - Oxygen (air)
 - Ignition source
 - Confined or enclosed space
 - Mixing of the fuel and air (oxygen)
- Hot work permits
- Lockout/tagout policies
- Design specifications for storage of flammable materials
- Severity reduction policies, practices, and procedures designed to minimize the spread of fire and bring the fire to a quick end
- Emergency plans
- Alarm systems
- Portable fire extinguishers
- Cleanup policies, practices, and procedures designed to return the affected area to an operational level and reduce other losses created by improper cleanup
- First aid
- Recharging portable extinguishers
- Removal of debris to an appropriate waste site
- Equipment and facility repair¹²

OVH 56

Housekeeping

A crucial key to the reduction of fires and explosions is housekeeping.

Housekeeping, however, relates to hazards in addition to fires and explosions. Research has shown that facilities that are well maintained experience fewer fires, explosions, and other accidents, and are more profitable as well. Using vacuum cleaners to pick up the dust is a very good way to eliminate the hazard. It is extremely important to ensure that the vacuum cleaner is designated intrinsically safe for the job. **These vacuums must be approved for the Class II Division 1 Group EFG Hazardous Location use, which can be found in NFPA 654.**

¹¹ Amyotte, Paul, *Reduce Dust Explosions The Inherently Safer Way*. CEP Magazine, 2003.

¹² Ibid, OSU Current Report, CR-1737.

OVH 57, 63

Dust Control

Reducing dust accumulations is a major concern for facilities that produce dust. A good housekeeping program depends upon a combination of methods to control dust. The methods used in a given facility will depend upon the type of facility and the volume of organic material handled or produced.

In accordance with 29 CFR 1910.272(j), employers must develop, implement, and maintain a written housekeeping program that reduces accumulations of fugitive dust on ledges, floors, equipment and other surfaces. **Fugitive dust is defined as combustible particles of a particular size.** For grain elevators, the housekeeping program must address fugitive dust accumulations in the following priority areas:

- Floor areas within 35 feet of inside bucket elevators
- Floors of enclosed areas containing grinding equipment
- Floors of enclosed areas containing grain dryers located inside the facility`

In priority areas, fugitive grain dust accumulations may not exceed 1/8 inch. The removal of fugitive grain dust by use of compressed air (to blow dust from equipment, ledges, etc.) is not permitted when machinery that presents an ignition source is energized. The use of compressed air for cleaning (blow down) is not permitted unless all potential ignition sources are removed from the area.

Additionally, the housekeeping program must address proper procedures for removing grain dust spills from the work area. However, a grain dust spill is not considered fugitive grain dust.

OVH 64

Dust Control Methods

Methods for controlling grain dust accumulations include the following:

- Vacuum areas where dust accumulation is constant due to the job task being performed.
- Wash down procedures where hoses and water can be used to remove accumulated dust.
- Choke feeds to control the flow of grain and grain dust.
- Dust control systems such as filters or cyclones.

OVH 65-67 Discuss ways of contain dust accumulation

Recognizing Dust Hazards

All employees should be trained in hazard recognition.

- Conduct general facility-wide appraisals of dust explosion possibilities on a periodic basis.

- Conduct internal and external audits in order to identify potential explosion hazards.
- Encourage a preventative attitude among employees for eliminating dust explosions.
- Have employees and supervisors identify explosion hazards through job hazard analyses (JHAs).
- Pay particular attention to dust collection systems and other areas not in plain view during the assessment¹³.

OVH 68, 69

Engineering Controls

The following guideline and engineering controls will help to minimize the conditions under which a grain dust explosion could occur. These same guidelines have application to any facility where dust is an issue.

- Implement a weekly or bi-weekly (or as specified by the manufacturer) bearing lubrication program, based on the bearing manufacturer's specifications.
- Use a food-grade mineral oil spray system on grain during transfer and loadout.
- 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.
- Install belt rub sensors inside bucket elevator leg casings to detect belt misalignment to prevent friction heating.
- 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 to 20° F or more in a week or two) may indicate bearing failure and the need to replace the bearing.
- Replace steel cups with plastic cups in elevator legs.
- Use anti-static belting material in legs and horizontal belt conveyors. Install quick-opening cleanout doors on leg boot side panels for grain and dust cleanout.
- 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.
- Install dust aspiration or suction ventilation systems on inside enclosed legs and conveyors to keep suspended dust below MEC levels.

¹³ *Combustible Dust Explosion Hazards*, Kentucky Dept of Labor Hazard Alert.

- Clean out dust collectors and change filter bags at intervals recommended by the manufacturer.
- Clean out dust cyclone collector holding bins at scheduled intervals.
- Install dump pit baffles on truck dump pits to provide a major reduction in airborne dust during dumping operation.

OVH 70

How to Prevent and Control the Hazard

Employers must adopt a comprehensive approach to preventing and controlling combustible dust hazards which includes, but is not limited to, the following measures:

- Avoid the use of compressed air (blow down), dry sweeping, or other cleaning methods that can disperse combustible dust into the air when feasible.
- Conduct workforce training and education courses regarding recognition and control of combustible dust hazards.
- Limit and control potential ignition sources in dust accumulation areas.
- Ensure electrical service in combustible dust areas is appropriate for hazardous (Class II) locations, as required by the National Electrical Code.
- Follow National Fire Protection Association (NFPA) standard 654, *Standard for the Prevention of Fire and Dust Explosions from Manufacturing, Processing, and Handling of Combustible Particulate Solids*, and other NFPA dust explosion prevention standards for specific industries, as applicable.
- Ensure operations involving dusts have proper engineering design and controls.
- Maintain an effective housekeeping program to prevent or eliminate dust build-up on ledges, ductwork, building framing, or other surfaces. Even small accumulations of dusts (**as little as 1/32 of an inch**) can create a dust explosion hazard if spread over sufficient surface area.
- Establish and maintain a preventative maintenance program to preserve the integrity of process equipment and minimize the release of fugitive dust particles.

Explosion Damage Control

Examples of methods which have been developed to minimize the damage caused by dust explosions can be found in: NFPA 69, *Standard on Explosion Prevention Systems*¹⁴.

OVH 71, 72

Lessons Learned

CSB Investigations of Dust Explosions¹⁵

West Pharmaceutical Services, Inc.

On January 29, 2003, a massive dust explosion at the West Pharmaceutical Services facility in Kinston, North Carolina, killed six workers and destroyed the facility. The explosion involved a part of the building used to compound rubber.

West produced rubber syringe plungers and other pharmaceutical devices at the facility. In the rubber compounding process, freshly milled rubber strips were dipped into a slurry of polyethylene, water, and surfactant to cool the rubber and provide an anti-tack coating. As the rubber dried, fine polyethylene powder drifted on air currents to the space above a suspended ceiling.

Polyethylene powder accumulated on surfaces above the suspended ceiling, providing fuel for a devastating secondary explosion. While the visible production areas were kept extremely clean, few employees were aware of the dust accumulation hidden above the suspended ceiling, and the MSDS for the polyethylene slurry included no dust explosion warning. Even those employees who were aware of the dust accumulation had not been trained about the hazards of combustible dust. West did use a safety review process when the compounding system was designed and modified, but the dust explosion hazard was not addressed during the reviews.



¹⁴ ibid

¹⁵ Chemical Safety Hazard Investigation Board, Report No. 2006-H-1, November 2006.

The West Pharmaceutical Services Explosion That Killed Six

Representatives from OSHA, the local fire department, an insurance underwriter, and an industrial hygienist had inspected the facility, but none had identified the potential for a dust explosion. In addition, the electrical equipment above the suspended ceiling in the rubber compounding section was not rated for use around combustible dust, as the National Electric Code (NEC) requires (for areas where combustible dust can accumulate). The CSB determined that if West had adhered to NFPA standards for combustible dust, the explosion could have been prevented or minimized.

OVH 73, 74

CTA Acoustics, Inc.

On February 20, 2003, a series of dust explosions at the CTA Acoustics facility in Corbin, Kentucky, claimed the lives of seven workers, injured 37, and destroyed the manufacturing facility. This facility primarily made acoustic insulation for automobiles.

The manufacturing process began by impregnating a fiberglass mat with phenolic resin, and then used air to draw the resin into the fiberglass webs. On the day of the explosion, a curing oven that had been left open because of a temperature control problem likely ignited the combustible resin dust stirred up by workers cleaning the area near the oven.

The CSB also found that plant design, work practices, and housekeeping problems contributed in causing the explosions. The CTA building was not designed to prevent or minimize secondary dust explosions (minimizing flat surfaces where dust can accumulate and using fire walls to separate production lines). Although management was aware of dust explosion hazards associated with the materials being used, dust had accumulated in dangerous amounts throughout the production areas, in vent ducting, and in dust collector housings, due to inadequate housekeeping and maintenance. In addition, employees routinely used compressed air and brooms to clean production lines, creating clouds of resin dust.



CTA Acoustics Production Area after Resin Dust Explosion

The MSDS for the resin used at CTA did not adequately communicate that the material posed a dust explosion hazard. In addition, the resin supplier, Borden Chemical had not communicated to CTA the safety lessons from the 1999 Jahn Foundry resin dust explosion, even though documents obtained by the CSB indicated that Borden was aware of the explosion, which involved a resin similar to the one used at CTA.

The Kentucky Office of Occupational Safety and Health (KYOSHA) had inspected the facility, but had not issued citations regarding combustible dust hazards. In addition, the CTA facility had never been inspected by the Kentucky State Fire Marshal's Office, and frequent inspections by CTA's insurer had failed to identify phenolic resin as an explosion hazard. The CSB determined that if CTA had adhered to NFPA 654 (2000) standards for housekeeping and fire/explosion barriers, the explosions could have been prevented or minimized.

OVH 75, 76

Hayes Lemmerz International

On October 29, 2003, aluminum dust exploded at the Hayes Lemmerz International facility in Huntington, Indiana, killing one worker and injuring several others. This explosion, which involved equipment used to re-melt scrap aluminum, occurred in a part of the building where Hayes made cast aluminum and aluminum alloy automobile wheels.

Scrap aluminum from the wheel manufacturing lines was chopped into small chips, pneumatically conveyed to the scrap processing area, dried, and fed into a melt furnace. Transporting and drying the aluminum chips generated explosive aluminum dust, which was then pulled into a dust collector.

The CSB determined that the explosion likely originated in the dust collector, which had not been adequately vented or cleaned, and was located too close to the aluminum scrap processing area. The initial explosion spread through ducting, causing a large fireball to emerge from the furnace.



Intense Fire after Aluminum Dust Explosion, Hayes Lemmerz International

The dust collector system was not designed or maintained to prevent dust explosions, or to prevent a dust collector explosion from spreading through ducting. When the scrap and dust collector systems were added to the facility, Hayes did not follow management of change procedures that might have identified the dust explosion hazard.

Hayes had also not cleaned dust from overhead beams and other structures. Some of this accumulated dust exploded (a secondary explosion), damaging the building roof. Previous dust fires at the facility were not investigated, facility employees had not been trained on the explosive nature of aluminum dust, and the Indiana Occupational Safety and Health Administration (IOSHA) had not identified dust explosion hazards during previous facility inspections. The CSB, in its report, determined that if Hayes Lemmerz had adhered to the NFPA 484 (2000) standard for combustible metals, the explosion could have been prevented or minimized. The CSB report also included a recommendation for additional research to develop improved explosion protection for dust collectors in aluminum service.

OVH 77, 78 : stress importance of these lessons that were learned from the tragedies mentioned in the prior three incidents

Lessons Learned

Safety Issues Neglected

The three examples provided above, along with most other incidents, reveal several common factors which can contribute to an explosion. These factors include the following:

Facility management failed to conform to NFPA standards that would have prevented or reduced the effects of the explosions.

- Company personnel, government enforcement officials, insurance underwriters, and health and safety professionals inspecting the facilities failed to identify dust explosion hazards or recommend protective measures.
- The facilities contained unsafe accumulations of combustible dust and housekeeping was inadequate.
- Workers and managers were often unaware of dust explosion hazards.
- Procedures and training to eliminate or control combustible dust hazards were inadequate.
- Previous fires and other warning events were accepted as normal, and their causes were not identified and resolved.
- Dust collectors were inadequately designed or maintained to minimize explosions.
- Process changes were made without adequately reviewing them for potential hazards.

OVH 79, 80

Summary

Dust explosions continue to be a persistent problem for many industries in the U.S resulting in loss of life, injuries and destruction of property. Even those individuals most highly trained, including government enforcement officials, insurance underwriters and company safety professionals often lack awareness of combustible dust hazards. MSDSs are also ineffective in communicating to employers and workers the hazards of combustible dust explosions and ways to prevent them. This is all the more reason for all employees to have a basic awareness of the hazards of dust explosions and the best way to mitigate those risks.

Investigations into numerous serious dust explosions have found several common causal factors for dust incidents. These factors include:

- Facilities fail to follow the widely recognized standards of good engineering practice in the NFPA's voluntary consensus standards.
- Facilities do not:

- Implement appropriate engineering controls.
- Perform adequate maintenance.
- Implement good housekeeping practices.
- Follow other measures that could have prevented the explosions.
- Facilities do not provide adequate hazard recognition training for employees.
- Facilities do not establish overall safe work practices.

Dust simulator DVD

Show dust simulator: that is owned by Kirkwood Community College, the simulator is built to resemble a country grain elevator, the simulator is divided off into two separate structures with a walk way between the two. Walls and roof are simulated with paper. Two tablespoons of dust is put into a small cylinder, a spark is ignited air is shot into cylinder to suspend the dust, once the explosion point is reached there is an explosion in the first chamber, it blows out the wall to the walkway, there is dust on the floor of the walk way that is then suspended it also ignites and explodes, this results in the roof being blown off. The final shows that even though the explosion is done there is still enough suspended dust that if ignited it will flash, this flash is what causes a lot of burns to employees.

OVH 81 Thank you! Any questions

Questions in the future

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Instructor note: **The following sections cover the OSHA standard and NFP regulations on combustible dust, most questions that may be asked the answers can be found in these sections.**

Appendix A OSHA Grain Handling Facilities Standard 29 CFR 1910.272

Overview

This document, condensed from Section 1910.272, Appendix A of the Occupational Safety and Health Act (29 CFR), is not intended to be totally inclusive but rather to highlight the information and requirements in the complete OSHA standard that owners and managers of agricultural businesses should understand. Refer to the OSHA Web site given below for the complete standard and for court interpretations of the standard.

http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9874

Contents of OSHA Standard 1910.272, Appendix A

- Section 1 -- Scope and Application
- Section 2 -- Emergency Action Plan
- Section 3 -- Training
- Section 4 -- Hot Work Permit
- Section 5 -- Entry into Bins, Silos, And Tanks
- Section 6 -- Contractors
- Section 7 -- Housekeeping
- Section 8 -- Filter Collectors
- Section 9 -- Preventive Maintenance
- Section 10 -- Grain Stream Processing Equipment
- Section 11 -- Emergency Escape
- Section 12 -- Dryers
- Section 13 -- Inside Bucket Elevators

Examples presented in this appendix may not be the only means of achieving the performance goals in the standard.

Section 1 -- Scope and Application

The provisions of this standard apply in addition to any other applicable requirements of this Part 1910 (or Part 1917 at marine terminals). The standard contains requirements for new and existing grain handling facilities. The standard does not apply to seed plants which handle and prepare seeds for planting of future crops, nor to on-farm storage or feed lots.

Section 2 -- Emergency Action Plan

The standard requires the employer to develop and implement an emergency action plan. The emergency action plan (1910.38(a)) covers those designated actions employers and employees are to take to ensure employee safety from fire and other

emergencies. The plan specifies certain minimum elements which are to be addressed. These elements include the establishment of an employee alarm system, the development of evacuation procedures, and training employees in those actions they are to take during an emergency.

The standard does not specify a particular method for notifying employees of an emergency. Public announcement systems, air horns, steam whistles, a standard fire alarm system, or other types of employee alarm may be used. However, employers should be aware that employees in a grain facility may have difficulty hearing an emergency alarm, or distinguishing an emergency alarm from other audible signals at the facility, or both. Therefore, it is important that the type of employee alarm used be distinguishable and distinct.

The use of floor plans or workplace maps which clearly show the emergency escape routes should be included in the emergency action plan; color coding will aid employees in determining their route assignments. The employer should designate a safe area, outside the facility, where employees can congregate after evacuation, and implement procedures to account for all employees after emergency evacuation has been completed.

It is also recommended that employers seek the assistance of the local fire department for the purpose of preplanning for emergencies. Preplanning is encouraged to facilitate coordination and cooperation between facility personnel and those who may be called upon for assistance during an emergency. It is important for emergency service units to be aware of the usual work locations of employees at the facility.

Section 3 -- Training

It is important that employees be trained in the recognition and prevention of hazards associated with grain facilities, especially those hazards associated with their own work tasks. Employees should understand the factors which are necessary to produce a fire or explosion, i.e., fuel (such as grain dust), oxygen, ignition source, and (in the case of explosions) confinement. Employees should be made aware that any efforts they make to keep these factors from occurring simultaneously will be an important step in reducing the potential for fires and explosions.

The standard provides flexibility for the employer to design a training program which fulfills the needs of a facility. The type, amount, and frequency of training will need to reflect the tasks that employees are expected to perform. Although training is to be provided to employees at least annually, it is recommended that safety meetings or discussions and drills be conducted at more frequent intervals.

The training program should include those topics applicable to the particular facility, as well as topics such as:

- Hot work procedures
- Lock-out/tag-out procedures
- Bin entry procedures
- Bin cleaning procedures

- Grain dust explosions
- Fire prevention
- Procedures for handling "hot grain"
- Housekeeping procedures including methods and frequency of dust removal
- Pesticide and fumigant usage
- Proper use and maintenance of personal protective equipment
- Preventive maintenance

The types of work clothing should also be considered in the program at least to caution against using polyester clothing that easily melts and increases the severity of burns, as compared to wool or fire retardant cotton.

In implementing the training program, it is recommended that the employer utilize films, slide-tape presentations, pamphlets, and other information which can be obtained from such sources as the Grain Elevator and Processing Society, the Cooperative Extension Service of the U.S. Department of Agriculture, Kansas State University's Extension Grain Science and Industry, and other state agriculture schools, industry associations, union organizations, and insurance groups.

Section 4 -- Hot Work Permit

The implementation of a permit system for hot work is intended to assure that employers maintain control over operations involving hot work and to assure that employees are aware of and utilize appropriate safeguards when conducting these activities.

Precautions for hot work operations are specified in 29 CFR 1910.252(a), and include such safeguards as:

- Relocating the hot work operation to a safe location if possible
- Relocating or covering combustible material in the vicinity
- Providing fire extinguishers
- Providing provisions for establishing a fire watch.

Permits are not required for hot work operations conducted in the presence of the employer or the employer's authorized representative who would otherwise issue the permit, or in an employer authorized welding shop or when work is conducted outside and away from the facility.

It should be noted that the permit is not a record, but is an authorization of the employer certifying that certain safety precautions have been implemented prior to the beginning of work operations.

Section 5 -- Entry into Bins, Silos, and Tanks

In order to assure that employers maintain control over employee entry into bins, silos, and tanks, OSHA is requiring that the employer issue a permit for entry into bins, silos, and tanks unless the employer (or the employer's representative who would otherwise authorize the permit) is present at the entry and during the entire operation.

Employees should have a thorough understanding of the hazards associated with entry into bins, silos, and tanks. Employees are not to be permitted to enter these spaces from the bottom when grain or other agricultural products are hung up or sticking to the sides which might fall and injure or kill an employee. Employees should be made aware that the atmosphere in bins, silos, and tanks can be oxygen deficient or toxic. Employees should be trained in the proper methods of testing the atmosphere, as well as in the appropriate procedures to be taken if the atmosphere is found to be oxygen deficient or toxic. When a fumigant has been recently applied in these areas and entry must be made, aeration fans should be running continuously to assure a safe atmosphere for those inside. Periodic monitoring of toxic levels should be done by direct reading instruments to measure the levels, and, if there is an increase in these readings, appropriate actions should be promptly taken.

Employees have been buried and suffocated in grain or other agricultural products because they sank into the material. Therefore, it is suggested that employees not be permitted to walk or stand on the grain or other grain product where the depth is greater than waist high. In this regard, employees must use a full body harness or boatswain's chair with a lifeline when entering from the top. A winch system with mechanical advantage (either powered or manual) would allow better control of the employee than just using a hand-held hoist line, and such a system would allow the observer to remove the employee easily without having to enter the space.

It is important that employees be trained in the proper selection and use of any personal protective equipment which is to be worn. Equally important is the training of employees in the planned emergency rescue procedures. Employers should carefully read 1910.134(e)(3) and assure that their procedures follow these requirements. The employee acting as observer is to be equipped to provide assistance and is to know procedures for obtaining additional assistance. The observer should not enter a space until adequate assistance is available. It is recommended that an employee trained in CPR be readily available to provide assistance to those employees entering bins, silos, or tanks.

Section 6 -- Contractors

These provisions of the standard are intended to ensure that outside contractors are cognizant of the hazards associated with grain handling facilities, particularly in relation to the work they are to perform for the employer. Also, in the event of an emergency, contractors should be able to take appropriate action as a part of the overall facility emergency action plan. Contractors should also be aware of the employer's permit systems. Contractors should develop specified procedures for performing hot work and for entry into bins, silos, and tanks and these activities should be coordinated with the employer.

This coordination will help to ensure that employers know what work is being performed at the facility by contractors; where it is being performed; and, that it is being performed in a manner that will not endanger employees.

Section 7 -- Housekeeping

The housekeeping program is to be designed to keep dust accumulations and emissions under control inside grain facilities. The housekeeping program, which is to be written, is to specify the frequency and method(s) used to best reduce dust accumulations.

Ship, barge, and rail loadout and receiving areas which are located outside the facility need not be addressed in the housekeeping program. Additionally, truck dumps which are open on two or more sides need not be addressed by the housekeeping program. Other truck dumps should be addressed in the housekeeping program to provide for regular cleaning during periods of receiving grain or agricultural products. The housekeeping program should provide coverage for all workspaces in the facility and include walls, beams, etc., especially in relation to the extent that dust could accumulate.

Dust Accumulations

Almost all facilities will require some level of manual housekeeping. Manual housekeeping methods, such as vacuuming or sweeping with soft bristle brooms, should be used which will minimize the possibility of layered dust being suspended in the air when it is being removed.

The housekeeping program should include a contingency plan to respond to situations where dust accumulates rapidly due to a failure of a dust enclosure hood, an unexpected breakdown of the dust control system, a dust-tight connection inadvertently knocked open, etc.

The housekeeping program should also specify the manner of handling spills. Grain spills are not considered to be dust accumulations.

A fully enclosed horizontal belt conveying system where the return belt is inside the enclosure should have inspection access such as sliding panels or doors to permit checking of equipment, checking for dust accumulations and facilitate cleaning if needed.

Dust Emissions

Employers should analyze the entire stock handling system to determine the location of dust emissions and effective methods to control or to eliminate them. The employer should make sure that holes in spouting, casings of bucket elevators, pneumatic conveying pipes, screw augers, or drag conveyor casings, are patched or otherwise properly repaired to prevent leakage. Minimizing free falls of grain or grain products by using choke feeding techniques, and utilization of dust-tight enclosures at transfer points, can be effective in reducing dust emissions.

Each housekeeping program should specify the schedules and control measures which will be used to control dust emitted from the stock handling system. The housekeeping program should address the schedules to be used for cleaning dust accumulations from motors, critical bearings and other potential ignition sources in the working areas. Also, the areas around bucket elevator legs, milling machinery

and similar equipment should be given priority in the cleaning schedule. The method of disposal of the dust which is swept or vacuumed should also be planned.

Dust may accumulate in somewhat inaccessible areas, such as those areas where ladders or scaffolds might be necessary to reach them. The employer may want to consider the use of compressed air and long lances to blow down these areas frequently. The employer may also want to consider the periodic use of water and hoses to wash down these areas. If these methods are used, they are to be specified in the housekeeping program along with the appropriate safety precautions, including the use of personal protective equipment such as eyewear and dust respirators.

Several methods have been effective in controlling dust emissions. A frequently used method of controlling dust emissions is a pneumatic dust collection system. However, the installation of a poorly designed pneumatic dust collection system has fostered a false sense of security and has often led to an inappropriate reduction in manual housekeeping. Therefore, it is imperative that the system be designed properly and installed by a competent contractor. Those employers who have a pneumatic dust control system that is not working according to expectations should request the engineering design firm, or the manufacturer of the filter and related equipment, to conduct an evaluation of the system to determine the corrections necessary for proper operation of the system. If the design firm or manufacturer of the equipment is not known, employers should contact their trade association for recommendations of competent designers of pneumatic dust control systems who could provide assistance.

When installing a new or upgraded pneumatic control system, the employer should insist on an acceptance test period of 30 to 45 days of operation to ensure that the system is operating as intended and designed. The employer should also obtain maintenance, testing, and inspection information from the manufacturer to ensure that the system will continue to operate as designed.

Aspiration of the leg, as part of a pneumatic dust collection system, is another effective method of controlling dust emissions. Aspiration of the leg consists of a flow of air across the entire boot, which entrains the liberated dust and carries it up the up-leg to take-off points. With proper aspiration, dust concentrations in the leg can be lowered below the lower explosive limit. Where a prototype leg installation has been instrumented and shown to be effective in keeping the dust level 25% below the lower explosive limit during normal operations for the various products handled, then other legs of similar size, capacity and products being handled which have the same design criteria for the air aspiration would be acceptable to OSHA, provided the prototype test report is available on site.

Another method of controlling dust emissions is enclosing the conveying system, pressurizing the general work area, and providing a lower pressure inside the enclosed conveying system. Although this method is effective in controlling dust emissions from the conveying system, adequate access to the inside of the

enclosure is necessary to facilitate frequent removal of dust accumulations. This is also necessary for those systems called "self-cleaning."

The use of edible oil sprayed on or into a moving stream of grain is another method which has been used to control dust emissions. Tests performed using this method have shown that the oil treatment can reduce dust emissions. Repeated handling of the grain may necessitate additional oil treatment to prevent liberation of dust. However, before using this method, operators of grain handling facilities should be aware that the Food and Drug Administration must approve the specific oil treatment used on products for food or feed.

As a part of the housekeeping program, grain elevators are required to address accumulations of dust at priority areas using the action level. The standard specifies a maximum accumulation of 1/8 inch dust, measurable by a ruler or other measuring device, anywhere within a priority area as the upper limit at which time employers must initiate action to remove the accumulations using designated means or methods. Any accumulation in excess of this amount and where no action has been initiated to implement cleaning would constitute a violation of the standard, unless the employer can demonstrate equivalent protection. Employers should make every effort to minimize dust accumulations on exposed surfaces since dust is the fuel for a fire or explosion, and it is recognized that a 1/8 inch dust accumulation is more than enough to fuel such occurrences.

Section 8 -- Filter Collectors

Proper sizing of filter collectors for the pneumatic dust control system they serve is very important for the overall effectiveness of the system. The air-to-cloth ratio of the system should be in accordance with the manufacturer's recommendations. If higher ratios are used, they can result in more maintenance on the filter, shorter bag or sock life, increased differential pressure resulting in higher energy costs, and an increase in operational problems.

A photohelic gauge, magnehelic gauge, or manometer, may be used to indicate the pressure rise across the inlet and outlet of the filter. When the pressure exceeds the design value for the filter, the air volume will start to drop, and maintenance will be required. Any of these three monitoring devices is acceptable as meeting paragraph (l)(1) of the standard.

The employer should establish a level or target reading on the instrument which is consistent with the manufacturer's recommendations that will indicate when the filter should be serviced. This target reading on the instrument and the accompanying procedures should be in the preventive maintenance program. These efforts would minimize the blinding of the filter and the subsequent failure of the pneumatic dust control system.

There are other instruments that the employer may want to consider using to monitor the operation of the filter. One instrument is a zero motion switch for detecting a failure of motion by the rotary discharge valve on the hopper. If the rotary discharge valve stops turning, the dust released by the bag or sock will accumulate in the filter

hopper until the filter becomes clogged. Another instrument is a level indicator which is installed in the hopper of the filter to detect the buildup of dust that would otherwise cause the filter hopper to be plugged. The installation of these instruments should be in accordance with manufacturer's recommendations.

All of these monitoring devices and instruments are to be capable of being read at an accessible location and checked as frequently as specified in the preventive maintenance program.

Filter collectors on portable vacuum cleaners, and those used where fans are not part of the system, are not covered by requirements of paragraph (l) of the standard.

Section 9 -- Preventive Maintenance

The control of dust and the control of ignition sources are the most effective means for reducing explosion hazards. Preventive maintenance is related to ignition sources in the same manner as housekeeping is related to dust control and should be treated as a major function in a facility. Equipment such as critical bearings, belts, buckets, pulleys, and milling machinery are potential ignition sources, and periodic inspection and lubrication of such equipment through a scheduled preventive maintenance program is an effective method for keeping equipment functioning properly and safely. The use of vibration detection methods, heat sensitive tape or other heat detection methods that can be seen by the inspector or maintenance person will allow for a quick, accurate, and consistent evaluation of bearings and will help in the implementation of the program.

The standard does not require a specific frequency for preventive maintenance. The employer is permitted flexibility in determining the appropriate interval for maintenance provided that the effectiveness of the maintenance program can be demonstrated. Scheduling of preventive maintenance should be based on manufacturer's recommendations for effective operation, as well as from the employer's previous experience with the equipment. However, the employer's schedule for preventive maintenance should be frequent enough to allow for both prompt identification and correction of any problems concerning the failure or malfunction of the mechanical and safety control equipment associated with bucket elevators, dryers, filter collectors and magnets. The pressure-drop monitoring device for a filter collector, and the condition of the lagging on the head pulley, are examples of items that require regularly scheduled inspections. A system of identifying the date, the equipment inspected and the maintenance performed, if any, will assist employers in continually refining their preventive maintenance schedules and identifying equipment problem areas. Open work orders where repair work or replacement is to be done at a designated future date as scheduled, would be an indication of an effective preventive maintenance program.

It is imperative that the prearranged schedule of maintenance be adhered to regardless of other facility constraints. The employer should give priority to the maintenance or repair work associated with safety control equipment, such as that on dryers, magnets, alarm and shut-down systems on bucket elevators, bearings on bucket elevators, and the filter collectors in the dust control system. Benefits of a

strict preventive maintenance program can be a reduction of unplanned downtime, improved equipment performance, planned use of resources, more efficient operations, and, most importantly, safer operations.

The standard also requires the employer to develop and implement procedures consisting of locking out and tagging equipment to prevent the inadvertent application of energy or motion to equipment being repaired, serviced, or adjusted, which could result in employee injury. All employees who have responsibility for repairing or servicing equipment, as well as those who operate the equipment, are to be familiar with the employer's lock and tag procedures. A lock is to be used as the positive means to prevent operation of the disconnected equipment. Tags are to be used to inform employees why equipment is locked out. Tags are to meet requirements in 1910.145(f). Locks and tags may only be removed by employees that placed them, or by their supervisor, to ensure the safety of the operation.

Section 10 -- Grain Stream Processing Equipment

The standard requires an effective means of removing ferrous material from grain streams so that such material does not enter equipment such as hammer mills, grinders and pulverizers. Large foreign objects, such as stones, should have been removed at the receiving pit. Introduction of foreign objects and ferrous material into such equipment can produce sparks which can create an explosion hazard. Acceptable means for removal of ferrous materials include the use of permanent or electromagnets. Means used to separate foreign objects and ferrous material should be cleaned regularly and kept in good repair as part of the preventive maintenance program in order to maximize their effectiveness.

Section 11 -- Emergency Escape

The standard specifies that at least two means of escape must be provided from galleries (bin decks). Means of emergency escape may include any available means of egress (consisting of three components, exit access, exit, and exit discharge as defined in 1910.35), the use of controlled descent devices with landing velocities not to exceed 15ft/sec., or emergency escape ladders from galleries. Importantly, the means of emergency escape are to be addressed in the facility emergency action plan. Employees are to know the location of the nearest means of emergency escape and the action they must take during an emergency.

Section 12 -- Dryers

Liquefied petroleum gas fired dryers should have the vaporizers installed at least ten feet from the dryer. The gas piping system should be protected from mechanical damage. The employer should establish procedures for locating and repairing leaks when there is a strong odor of gas or other signs of a leak.

Section 13 -- Inside Bucket Elevators

Hazards associated with inside bucket elevator legs are the source of many grain elevator fires and explosions. Therefore, to mitigate these hazards, the standard

requires the implementation of special safety precautions and procedures, as well as the installation of safety control devices. The standard provides for a phase-in period for many of the requirements to provide the employer time for planning the implementation of the requirements. Additionally, for elevators with a permanent storage capacity of less than one million bushels, daily visual inspection of belt alignment and bucket movement can be substituted for alignment monitoring devices and motion detection devices.

The standard requires that belts (purchased after the effective date of the standard) have surface electrical resistance not to exceed 300 megohms. Test methods available regarding electrical resistance of belts are:

- The American Society for Testing and Materials D257-76, "Standard Test Methods for D-C Resistance or Conductance of Insulating Materials"
- The International Standards Organization's #284, "Conveyor Belts, Electrical Conductivity, Specification and Method of Test."

When an employer has a written certification from the manufacturer that a belt has been tested using one of the above test methods, and meets the 300 megohm criterion, the belt is acceptable as meeting this standard. When using conductive belts, the employer should make certain that the head pulley and shaft are grounded through the drive motor ground or by some other equally effective means. V-type drive belts should not be used to transmit power to the head pulley assembly from the motor drive shaft because of the break in electrical continuity to the motor ground.

Employers should also consider purchasing new belts that are flame retardant or fire resistive. A flame resistance test for belts is contained in 30 CFR 18.65.

Combustible Dust National Emphasis Program (Reissued)

The following is a link to [CPL 03-00-008 - Combustible Dust National Emphasis Program \(Reissued\)](#) Or you can access the Directive by going to the OSHA website www.OSHA.gov to Laws and Regulations on the right hand side of the webpage and click on the Directives link. Where it says Text Search, type in Combustible Dust National Emphasis Program (Reissued).

Appendix B OSHA Fact Sheet

OSHA[®] Fact Sheet

Hazard Alert: Combustible Dust Explosions

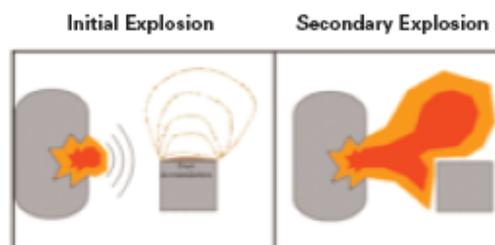
Combustible dusts are fine particles that present an explosion hazard when suspended in air in certain conditions. A dust explosion can be catastrophic and cause employee deaths, injuries, and destruction of entire buildings. In many combustible dust accidents, employers and employees were unaware that a hazard even existed. It is important to determine if your company has this hazard, and if you do, you must take action now to prevent tragic consequences.

How Dust Explosions Occur

In addition to the familiar fire triangle of oxygen, heat, and fuel (the dust), dispersion of dust particles in sufficient quantity and concentration can cause rapid combustion known as a deflagration. If the event is confined by an enclosure such as a building, room, vessel, or process equipment, the resulting pressure rise may cause an explosion. These five factors (oxygen, heat, fuel, dispersion, and confinement) are known as the "Dust Explosion Pentagon". If one element of the pentagon is missing, an explosion cannot occur.

Catastrophic Secondary Explosions

An initial (primary) explosion in processing equipment or in an area where fugitive dust has accumulated may dislodge more accumulated dust into the air, or damage a containment system (such as a duct, vessel, or collector). As a result, if ignited, the additional dust dispersed into the air may cause one or more secondary explosions. These can be far more destructive than a primary explosion due to the increased quantity and concentration of dispersed combustible dust. Many deaths in past accidents, as well as other damage, have been caused by secondary explosions.



A pharmaceutical plant after a dust explosion.

Industries at Risk

Combustible dust explosion hazards exist in a variety of industries, including: agriculture, chemicals, food (e.g., candy, sugar, spice, starch, flour, feed), grain, fertilizer, tobacco, plastics, wood, forest, paper, pulp, rubber, furniture, textiles, pesticides, pharmaceuticals, tire and rubber manufacturing, dyes, coal, metal processing (e.g., aluminum, chromium, iron, magnesium, and zinc), recycling operations, and fossil fuel power generation (coal).

Prevention of Dust Explosions

To identify factors that may contribute to a explosion, OSHA recommends a thorough hazard assessment of:

- All materials handled;
- All operations conducted, including by-products;
- All spaces (including hidden ones); and
- All potential ignition sources.

Dust Control Recommendations

- Implement a hazardous dust inspection, testing, housekeeping, and control program;
- Use proper dust collection systems and filters;
- Minimize the escape of dust from process equipment or ventilation systems;
- Use surfaces that minimize dust accumulation and facilitate cleaning;
- Provide access to all hidden areas to permit inspection;
- Inspect for dust residues in open and hidden areas at regular intervals;
- If ignition sources are present, use cleaning methods that do not generate dust clouds;
- Use only vacuum cleaners approved for dust collection; and
- Locate relief valves away from dust deposits.

Ignition Control Recommendations

- Use appropriate electrical equipment and wiring methods;
- Control static electricity, including bonding of equipment to ground;
- Control smoking, open flames, and sparks;
- Control mechanical sparks and friction;
- Use separator devices to remove foreign materials capable of igniting combustibles from process materials;
- Separate heated surfaces from dusts;
- Separate heating systems from dusts;
- Select and use industrial trucks properly;
- Use cartridge activated tools properly; and
- Use an equipment preventive maintenance program.

Injury and Damage Control Methods

- Separation of the hazard (isolate with distance);
- Segregation of the hazard (isolate with a barrier);
- Deflagration isolation/venting;
- Pressure relief venting for equipment;
- Direct vents away from work areas;
- Specialized fire suppression systems;
- Explosion protection systems;

This is one in a series of informational fact sheets highlighting OSHA programs, policies or standards. It does not impose any new compliance requirements. For a comprehensive list of compliance requirements of OSHA standards or regulations, refer to Title 29 of the Code of Federal Regulations. This information will be made available to sensory impaired individuals upon request. The voice phone is (202) 693-1999; teletypewriter (TTY) number: (877) 889-5627.

- Spark/ember detection for suppression activation;
- Develop an emergency action plan; and
- Maintain emergency exit routes.

Applicable OSHA Requirements Include:

- 51910.22 Housekeeping
- 51910.307 Hazardous Locations
- 51910.1200 Hazard Communication
- 51910.269 Electric Power Generation, Transmission and Distribution (coal handling)
- 51910.272 Grain Handling Facilities
- General Duty Clause, Section 5(a)(1) of the *Occupational Safety and Health Act* (Employers must keep workplaces free from recognized hazards likely to cause death or serious physical harm).

Resources

Readily available from www.osha.gov are:

- Combustible Dust National Emphasis Program
- Safety and Health Information Bulletin (SHIB) (07-31-2005) *Combustible Dust in Industry: Preventing and Mitigating the Effects of Fires and Explosions*

See the SHIB or www.osha.gov for other applicable standards.

The primary National Fire Protection Association (NFPA) consensus standards related to this hazard are:

- NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids
- NFPA 61, Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities
- NFPA 484, Standard for Combustible Metals
- NFPA 664, Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities
- NFPA 655, Standard for the Prevention of Sulfur Fires and Explosions
- See www.nfpa.org to view NFPA standards.

For more complete information:



U.S. Department of Labor

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(800) 321-OSHA

DSG 3/2008

Appendix C

Other NFPA Standards Related to Combustible Dust Explosion Hazards¹⁶

Appendix A NFPA Publications Relevant to Combustible Dust Hazard Controls

NFPA Number	Title	Current Edition
61	Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities	2008
68	Guide for Venting of Deflagrations	2007
69	Standard on Explosion Prevention Systems	2008
70	National Electrical Code	2008
77	Recommended Practice on Static Electricity	2007
85	Boiler and Combustion Systems Hazards Code	2007
86	Standard for Ovens and Furnaces	2007
91	Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids	2004
484	Standard for Combustible Metals	2006
499	Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas	2008
654	Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids	2006
655	Standard for Prevention of Sulfur Fires and Explosions	2007
664	Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities	2007

¹⁶ *ibid*

Appendix D

NIOSH Alert – Publication Number: 86-118, July 1986

	<p><i>Request for Assistance in...</i></p> <p>Preventing Fatalities Due to Fires and Explosions in Oxygen-Limiting Silos</p> <p>NIOSH ALERT: July 1986 DHHS (NIOSH) Publication No. 86-118</p>
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WARNING!

Fire departments responding to incidents involving oxygen-limiting silos are cautioned that directing water or foam onto the fire through the top openings of an oxygen-limiting silo may result in the silo exploding.

SUMMARY

This Alert requests the assistance of fire department personnel, farm owners and workers, and silo manufacturers in the prevention of fatalities due to fires and explosions occurring in oxygen-limiting silos.

Several recent incidents occurred while fighting oxygen-limiting silo fires which resulted in the death of fire fighters. Other fire fighters lost their lives as a result of similar explosions in the late 1960s. The problems associated with burning silos appeared to have abated during recent years, but these incidents demonstrate the need to renew efforts to minimize their recurrence. A concerted effort should be made to prevent silo fires from occurring and to provide training programs on controlling this type of fire.

BACKGROUND

Oxygen-limiting silos by design have all their openings sealed to prevent oxygen from entering the silo. Generally, these silos are of steel or concrete construction of varying heights and diameters. The openings (bottom and top) are normally sealed with rubber-gasketed hatches. When these hatches are tightly closed and the silo is

filled, the oxygen concentration should be insufficient to support a fire. If the hatches are left open or the oxygen-limiting features are not properly maintained, spontaneous heating can occur with subsequent ignition of the silage [1].

If improperly sealed or otherwise not operating as designed, the amount of oxygen entering the silo may be sufficient to allow a fire to smolder, causing an accumulation of combustible gases due to incomplete combustion. Any additional increase in oxygen content in such an environment can create an explosive atmosphere. Thus, merely opening the top hatches of such silos, or applying water or foam by hose stream from the top of the silo, could allow sufficient oxygen to enter the silo and create an explosive atmosphere [1-4]. Dust explosions may also occur if dust inside the silo becomes suspended as a result of the hose stream, and is ignited by the heat of the smoldering fire [3,5].

CASE REPORT OF A FATAL INCIDENT

The following case report resulted from a NIOSH investigation of the circumstances of the incident as part of the NIOSH Fatal Accident Circumstances and Epidemiology Program.

On August 27, 1985, three fire fighters were killed when a burning oxygen-limiting silo exploded. The fire fighters were spraying water onto the fire from the top of the silo at the time of the explosion. The explosion lifted the concrete roof of the silo approximately four feet in the air and the fire fighters were thrown from the silo.

This explosion was due either to a build up of combustible gases from incomplete combustion or a dust explosion, or a combination of the two. Regardless of the ultimate cause of the explosion, directing water into the top of the silo appears to have been an improper method for fighting this silo fire.

In this incident nothing should have been done to increase the level of oxygen inside the silo. Opening the top hatches to apply water to the fire could have increased the level of oxygen and created an explosive atmosphere. Air entrained in the water stream may have also contributed. Additionally, the water spray could have suspended the dust and increased the risk of explosion.

NIOSH is aware of three other explosions that occurred in oxygen-limiting silos at about the same time as the incident described in the case report. Two of the incidences occurred in the same geographical area as the incident described above. No fire fighters were applying water to these silos at the time, and there were no injuries. The third fire which occurred in another geographical area resulted in the fatal injury of one fire fighter [4].

REGULATORY STATUS

There are no specific OSHA regulations covering fire hazards of oxygen-limiting silos. Also, since most farms employ less than ten workers, other general OSHA regulations that might apply are not used. Therefore, OSHA estimates that over 90% of all farms in the U.S. are not covered by OSHA regulations.

RECOMMENDATIONS FOR ACCIDENT PREVENTION

A. Basis for Needed Actions

The following collected in this case study suggests that the following factors may have contributed to the fatal accident as reported:

1. Improper fire fighting methods; and
2. Lack of proper operating and maintenance procedures on the silo.

B. Recommended Measures

Acknowledging concern for the above factors, NIOSH recommends the following steps for both the prevention of fires and explosions in oxygen-limiting silos, and for fire control procedures once a fire has developed:

1. Prevention

- a. When not being filled or emptied, oxygen-limiting silo hatches should be kept closed. If an oxygen-limiting silo is properly sealed, there is very little likelihood of a fire occurring by spontaneous heating, since the amount of oxygen trapped in the silo is usually insufficient to support a fire.
- b. Proper maintenance of the silo should be performed to ensure the integrity of the oxygen-limiting features. The manufacturer of the silo should be contacted for proper operating and maintenance procedures for the silo.
- c. The moisture content of stored silage should be controlled, as should the type of cut of the silage. Filling rates recommended by the manufacturer should also be followed to reduce the possibility of spontaneous heating of stored silage. "Elements of good silage" can be obtained from the bulletin, "Extinguishing Silo Fires," NRAES-18, published by the Northeast Regional Agricultural Engineering Service, Cornell University, Riley Robb Hall, Ithaca, New York 14853.

2. Fire Control

- a. During fire fighting operations on oxygen-limiting silos, water or foam should not be directed onto the fire through the top hatches, since this may allow oxygen to enter the silo and cause the suspension of explosive dust.
- b. Placards should be placed on the oxygen-limiting silos warning fire fighters that the silo is in fact an oxygen-limiting silo, and should include information concerning the proper extinguishing techniques.
- c. If the roof hatches of oxygen-limiting silos are open, no attempt should be made to close them if there is smoke or steam coming from the open hatches or if the silo is vibrating.
- d. The roof hatches should be safe to close if the silo is quiet and there has been no smoke or steam coming from the hatches for several hours. Do not secure the hatch. This will permit the relief of any subsequent pressure that may build up.

e. Large quantities* of carbon dioxide or liquid nitrogen should be injected into the silo to extinguish the fire. Some silos have valves specifically designed for this. If it is necessary to drill a small hole in the side of the silo for insertion of the gas tube, care should be taken not to allow additional oxygen to be pulled into the silo. All precautions normally associated with either nitrogen or carbon dioxide should be taken when handling these gases.

f. Manufacturers, in conjunction with local fire departments, should establish a program to provide valves designed for injection of gases for fire control on all new and existing oxygen-limiting silos.

g. Certain manufacturers have step-by-step instructions on how to extinguish fires in their silos. Therefore, farm owners are encouraged to contact the silo manufacturer to obtain these instructions.

NIOSH has published the following documents which contain further information.

NIOSH Alert: Request for Assistance in Preventing Hazards in the Use of Water Spray (Fog) Streams to Prevent or Control Ignition of Flammable Atmospheres, DHHS (NIOSH) Publication No. 85-112.

Occupational Safety in Grain Elevators and Feed Mills, DHHS (NIOSH) Publication No. 83-126.

NIOSH requests that the technical information and warning contained in this Alert be disseminated to personnel of fire departments, fire training academies, other emergency response organizations, farm extension associations, farm workers and owners, and manufacturers of silos.

Requests for additional information or questions related to this announcement should be directed to Mr. John Moran, Director, Division of Safety Research, National Institute for Occupational Safety and Health, 944 Chestnut Ridge Road, Morgantown, West Virginia 26505, Telephone (304) 291-4595.

We greatly appreciate your assistance.

[signature]

J. Donald Millar, M.D., D.T.P.H. (Lond.)

Assistant Surgeon General

Director, National Institute for Occupational Safety and Health

Centers for Disease Control

NOTE

* As an example, for a 20-foot diameter by 60-foot-high silo, the estimated amount of carbon dioxide or liquid nitrogen would be: 20 standard cylinders of carbon dioxide or 40 standard cylinders of liquid nitrogen. Reference #1 provides estimated amounts of CO₂ or liquid nitrogen for other silo sizes. [\[Return to main text\]](#)

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