

**DEVELOPING CRITERIA FOR PROPER HANDLING  
OF WOOD DUST FIRES**

**EXECUTIVE LEADERSHIP**

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## **ABSTRACT**

Proper handling of fires involving wood dust can be extremely important in preventing the occurrence of a dust explosion. Handling these dust fires as one would handle an ordinary fire could put responders at extreme risk.

The purpose of this research was to identify information that should be utilized in developing criteria for the proper handling of wood dust fires and establishing policy on safe handling of such incidents by Albany Fire Department personnel.

This study utilized action research methodology. Research questions were:

- What physical hazards may be present with regard to firefighting operations that should be considered?
- What factors should incident commanders take into consideration in selecting appropriate tactics to deal with dust fires?
- What information should be included in an emergency operation policy for personnel to use?

Findings revealed a number of factors that should be considered for safe handling of wood dust involved or potentially involved with fire. Based on the findings, a policy was developed for Albany Fire Department personnel for safely handling wood dust fires.

Review of the material indicated that the following should be taken into

consideration:

1. A risk assessment must be conducted prior to committing personnel to suppressing dust fires.
2. Personnel attacking dust fires need to be aware of associated hazards.
3. Facilities producing dusts under 420 microns should be identified.
4. Ensure that personnel are aware of the potential creation of dust clouds, secondary to dry pipe sprinkler activations.
5. Extreme caution must be taken when dealing with dust fires in silos, hoppers, bins, and bag houses.

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## INTRODUCTION

Dealing with fires involving wood dusts can be a common occurrence for fire department personnel. Handling these incidents properly is extremely important for a successful outcome. The Albany Fire Department is responsible for protecting two local industries that pose a high potential for dust fires.

One of these facilities produces particle board, and the other, a wood flour product used in wood putty and as a filler for explosives. Both facilities produce large quantities of extremely fine dusts. The particle board facility produces dusts as small as 5.3 to 7.1 microns, presenting a serious potential for fire or explosion, which if not handled properly, could result in a catastrophic event.

The purpose of this research was to determine appropriate factors to be considered in handling wood dust fires, determining potential hazards associated with wood dust fires, and developing a department policy for use on the fireground.

This study utilized action research methodology. Research questions were:

1. What physical hazards may be present with regard to firefighting operations that should be considered?
2. What factors should incident commanders take into consideration in selecting appropriate tactics to deal with dust fires?
3. What information should be included in an emergency operation

policy for personnel to use?

## **BACKGROUND AND SIGNIFICANCE**

On numerous occasions the Albany Fire Department has responded to incidents involving fires and explosions in dusts at two local manufacturing facilities. These typically involved creeping-type fires in or near conveyor systems and/or in material storage silos.

These fires have the potential of creating extreme hazards for Department personnel dependent on proper handling should a dust cloud ensue. The Department has responded to three major incidents where wood dust was a major contributor to fire involvement.

The first incident occurred in February 1985, when a fire of unknown cause began in the location of a truck dump building. Employees reported having seen fire traveling via the exterior of the conveyor system to two dry storage buildings of fine dust. Employees then noted multiple explosions, each one larger than the previous, and involving structural damage to the two buildings. Fire then spread to two additional product storage structures, where it remained contained.

The second incident involved a fire that occurred above a dryer assembly. It quickly spread through fugitive dusts located above the fire protection sprinkler system, activating over 100 sprinkler heads.

While completing this paper and preparing to send it in, an explosion and fire in the production area of the particle board plant occurred. An employee of the facility was working approximately 30 feet in the air on a man lift, changing a bulb in a light fixture.

As the employee was rising to the light, the man lift hit the bottom of the light. The support for the light gave away, and the light fell into the basket. As the light fell, the wiring connections on the light stripped, causing an arc and ignition of a dust cloud produced by the falling light. Workers in a nearby control booth stated that all of the lights in the area went out, and they observed fire engulfing the employee at the top of the man lift.

Then, in an attempt to extract himself from the fire, the employee hit a dust curtain with the man lift, causing a secondary dust release and an even larger fire ball. A third deflagration was noted by employees when the man lift struck machinery on the other side of the walkway. Employees who observed the fire, initially staffed hoselines in an attempt to provide protection to the worker while he tried to lower himself and exit the fire area. At that point, the strongest detonation was noted, and fire spread throughout the structure. The employees exited the area and the plant sprinkler system activated. Employees then noticed the employee, who had exited the man lift, standing in a dazed state approximately 50 feet inside a doorway, and they directed him outside.

The patient was transported to a local burn center with third degree burns over 70 percent of his body, including respiratory involvement, and ultimately became a victim of this fire.

The fire sprinkler system initially confined the fire to the immediately-involved area, including a number of spot fires in fugitive dusts. After suppression personnel searched with thermal imaging cameras to ensure that no active burning remained in the area, the decision was made to shut down the sprinkler system to assist with smoke removal. Personnel were posted at outside stem and yoke valves.

Smoldering fires were noted throughout the facility, and approximately two hours after the initial fire, suppression crews noted two new fires. One was to the west of the original fire. It had smoldered in dust and then began burning openly, rapidly progressing between two bowstring trusses in an area where the sprinkler system had not previously activated. This fire was controlled and extinguished with handlines prior to the sprinkler system activating.

A second fire was noted to the east of the initial fire, where a smoldering fire had burned undetected through a wall above a control room. Crews had checked the area just minutes earlier and heard a waterflow alarm in the area of the second fire. Crews advanced hoselines and began attacking the fire when additional sprinkler heads opened up on the system. The system in the facility is a

dry pipe system, and as the heads activated, interior suppression crews stated that a large fire ball ensued. At that time, an order was given to evacuate the building.

Interviews with suppression crews indicate that it appeared that as the air was released from the sprinkler system, dust in the area was suspended and a deflagration occurred. This subsequent fire was controlled again by the sprinkler system, and the fire was ultimately declared under control approximately 16 hours later and turned back over to the facility. Nearly 24 hours after the initial incident, the facility fire brigade stated they were still finding developing pockets of smoldering product. A total of 198 sprinkler heads were activated during this incident.

Some of the dust involved in this fire was the consistency of fine flour. Burning and smoldering product was noted floating on top of water in the facility at various times.

Although numerous improvements have been made over the years in these types of facilities, hazards and the potential for them still exist. Other incidents have occurred while emptying fire-involved silos. Facility personnel inadvertently opened a bottom discharge, releasing a large volume of product, creating a large dust cloud. And, had an ignition source been present, a catastrophic event would have resulted.

An article by Sara Emmons for the publication, Record, further supports

this concern:

A detailed study of dust explosion losses shows that wood and coal dust are by far the leading fuel sources for losses occurring at properties for Allendale Insurance, Arkwright, and Protection Mutual Insurance. Dust collectors are the leading equipment type. And any operation creating friction, such as hammer milling or sanding is vulnerable to a dust explosion (1995, p. 7).

This research was for Executive Leadership at the National Fire Academy (NFA) and the requirements of the applied research project. This paper is related to Unit 3 Developing Decisionmaking Skills, and addresses the Albany Fire Department's handling of fires involving wood dusts by developing policy for using appropriate actions to minimize hazards to personnel.

## **LITERATURE REVIEW**

A literature review was conducted to identify sources of information to assist in developing appropriate criteria for handling wood dust fires. Research included the National Fire Academy Learning Resources Center, National Fire Protection Association (NFPA), National Institute of Occupational Safety & Health (NIOSH) Web page, Occupational Safety & Health Administration (OSHA) documents, and a search on the Internet of wood dust and dust

explosions.

The review identified factors that should be considered in determining appropriate criteria for inclusion in policy on the safe handling of wood dust fires, including potential inhalation hazards from wood dusts, precautions to be taken in dust atmospheres, and the potential for explosion.

Finding information specifically related to certain aspects of proper handling of wood dust fires was somewhat limited. However, numerous resources were found with regard to grain and agricultural dust fires, that require a similar fire response to wood dusts.

In evaluating potential hazards presented by a wood dust to emergency responders, the size and moisture content of the product play a vital role in the potential propagation for a dust explosion.

In addressing wood dusts in general, the Fire Protection Handbook 18<sup>th</sup> Edition (Cote, Ed., 1997) by the NFPA addresses the issue in Section 3/Chapter 15 where they discuss woodworking facilities and processes. They state:

Fine wood particulate is very easily ignited. When suspended in air it burns very aggressively, producing a deflagration. When wood dusts exist in a mass, such as an accumulation on a floor, it can smolder for extended periods of time (days), producing a charred mass that can flare up as a deflagration as soon as sufficient air at sufficient velocity is provided to

suspend the particulate in the air stream (p.3-178).

In the information located on wood dusts, the size of dust required for a deflagration varies. The Fire Protection Handbook states that dusts greater than 420 microns will generally not result in a deflagration. Dusts classified smaller than 420 microns (that will pass through a U.S. Standard No. 40 Sieve), though, are classified as combustible dusts:

When dispersed in air and ignited, they will propagate a flame. As gaseous mixtures, there is a lower combustible limit that will support flame propagation. Dust clouds do not exhibit an upper limit that is of practical use in deflagration control. The introduction of a flammable gas into a dust cloud usually reduces the lower combustible limit of the dust/air mixture and also markedly decreases the ignition energy of the dust/air mixture (p.4-153).

This could have an impact in areas where dust may be present and a high-pressure hydraulic line is located on equipment. A rupture in a line could not only suspend dust that is present, but actually lower the possibility of an ignition.

In an article for Fire Prevention 228, J.P. Zeeuwen discussed dust explosion mechanics. In the article he described a dust explosion as a “rapid burning of fine combustible material (dust, powder, etc.) mixed with air”(1990, p.26). He also addressed particle size generally being smaller than 0.4 mm.

John Bowen addressed dust explosions in a 1978 article for Western Fire Journal. The article discussed the fact that most hazardous dusts are usually by-products of familiar materials. He also described dusts generally being particles less than 1,000 microns in diameter (0.04 inch).

In an article published in Bulk Solids Handling, May 1990, the author addresses the size of particles and the impact they can have on dust explosions “Below 200  $\mu\text{m}$  all dusts of combustible material can be considered explosive” (Spain, p.202).

A fire investigation report by NFPA of a furniture manufacturing facility dust explosion on November 20, 1994, destroying the facility in Lenoir, North Carolina, revealed that 32 to 42 percent of the wood dust present and tested was less than 200 microns in size.

The distribution of the dust and amount of dust required to reach the lower explosive level is another important factor in determining the potential for problems related to dusts and dust fires. In an article published by Fire Command, Irving Deutsch P.E. discussed the amount of dust required to create a cloud that could be ignited. For a dust cloud to develop that could support combustion, the following was stated:

If the dust cloud contains approximately 40 grams of dust per cubic meter (0.04 ounces per cubic foot); has a sufficient number of particles in the

size range of 60 microns (1 micron equals 1/1000 millimeter); and makes contact with an ignition source, there will be an explosion or puff...To illustrate the quantity of dust needed to produce a cloud in the explosive range, imagine 0.015 inches of dust on a floor of a tunnel 400 feet in length 8 feet in width, and 10 feet in height. This dust is enough to produce the minimum concentration (p.20).

The author also placed this example in another light by addressing the OSHA health standard of 15 milligrams per cubic meter for dusts, or approximately 1/3000 of the lower explosive limit.

Patrick and John Kennedy in their book on Explosion Investigation and Analysis also addressed both the required particle size and concentrations. With regard to size, "The finer the dust, the more violent the explosion. Most explosions hazard concentrations of dusts are when particles are of a diameter of 840 microns (0.033") or less" (1990, p.135). With regard to the actual concentration in air, they indicated the following:

The concentration of the dust in air has a profound effect upon its ignitability and the violence of the blast pressure wave. As with ignitable vapors and gases, there are minimum uniform concentrations of specific dust for propagation combustion to occur. Minimum concentrations can vary with the dust material from as low as 0.015 to 2.0 oz./cu.ft. with the

most common concentrations being less than one ounce per cubic foot (p. 135).

In the 1998 Edition, Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities, in their appendix, the NFPA addresses the hazards associated with wood dusts and the potential for explosions in woodworking facilities if proper maintenance of dusts are not maintained:

A relatively small initial dust explosion will disturb, and suspend in air, dust that has been allowed to accumulate on the flat surfaces of a building or equipment. This dust cloud provides fuel for the secondary explosion, which usually causes the major portion of the damage...Using a bulk density of 20 lb/ft<sup>3</sup> (320 kg/m<sup>3</sup>) and assumed concentration of 0.35 oz/ft<sup>3</sup> (350 g/m<sup>3</sup>), it has been calculated that a dust layer that averages 1/8 in. (3mm) thick covering the floor of a building is sufficient to produce a uniform dust cloud of optimum concentration, 10 ft (3m) high throughout the building. This is an idealized situation and several factors should be considered. First, the layer will rarely be uniform and cover all surfaces, and second, the layer of dust will not be completely dispersed by the turbulence of the pressure wave from the initial explosion. However, if only 50% of the 1/8 in (3mm) thick layer is suspended, this is still sufficient material to create an atmosphere within the explosive range for

most dusts (A-2-2.5).

This fact is also addressed in a 1995 article by Sara Emmons for Record. She indicated that if you can write your name in the dust, generally 1/8" for wood dust, too much dust is present. Relative to room explosions and concentrations, she stated, "The Lower Explosive Limit (LEL) for dust can be as low as 0.03 oz/ft<sup>3</sup> (30 g/m<sup>3</sup>)" (p. 5).

In addition to size and concentration of dusts, moisture content also comes in to play when addressing the combustibility of dust. In the Kennedy's material, they discussed the effect of the moisture content of the product: "Moisture content of the dust particles proportionately raises the ignition temperature and consequently the minimum ignition energy and ignitability" (1990, p.136).

This effect was also discussed in the Fire Protection Handbook in Section 4 Chapter 15. They mention that the moisture content of materials does effect the ignition temperature, raising the ignition temperature through heat absorption and vaporization. The moisture content of air surrounding the product; however, has no correlation to ignition temperature. It was also stated that moisture content cannot be looked at as a method to prevent an explosion. "In order for moisture to prevent ignition of a dust by common sources, the dust would have to be so damp that a cloud could not be formed" (1997, p.4-176).

Deutsch also addressed this fact in his article:

High moisture content and high humidity in the atmosphere tend to reduce the probability of dust fires and explosions, but don't count on it. It is difficult to access all of the necessary factors, plus theoretical consideration and real life experience are often badly out of step (1980 p. 20).

An important component of a dust explosion is the ignition source required to ignite a cloud of suspended material. In an article, Dust Explosion Protection, by Dr. J.C.R. Heydenrych for Fire Protection magazine, he discussed the five criteria necessary for dust explosions to occur. It must be able to sustain an explosion; generally be less than 200 microns in size; a dust concentration of at least 20 g/m<sup>3</sup> must be present; sufficient Oxygen present to support combustion; and an ignition source present to ignite the dust “(for wood dusts typically 20-60 mJ)” (1989, p.7).

J.P. Zeeuwen, in his article addressing dust explosions, addressed ignition factors of dust clouds that were at the lower explosive limit in lay terms with the following description: “Such a mixture will only explode if an ignition source is present within the dust air mixture. Potential ignition sources can be fire or open flames, smoldering material, hot surfaces, electrical, electrostatic and mechanical parts” (1990, p.26).

In a report by Factory Mutual Engineering Corporation dated 1981 on the

Dynamics of Dust Explosions, they compared how combustible and flammable vapors or gases respond in similar situations when in a suspension:

First, flammable liquids have a lower explosive limit (LEL) and an upper explosive limit (UEL). Below the LEL there is not enough vapor in proportion to air to support combustion-the mixture is too lean; about the UEL there is too much fuel as opposed to air to support combustion-the mixture is too rich. But anywhere between the limits, the fuel/air mixture will burn. The LEL and UEL vary for each flammable vapor or gas. But for dusts, there is an LEL which also varies, but there is virtually no UEL; therefore, any concentration above the LEL should be considered explosive. Secondly, flammable vapors or gases tend to explode all at once. Igniting a small amount of flammable vapor does limited damage: it may start a fire. But dust explosions can follow a chain reaction: a small amount of dust is stirred up and finds an ignition source. The resulting explosion shakes out more dust from floors, walls, and other surfaces, and this dust is ignited by the burning particles or by radiant energy of the initial explosion, releasing a pressure wave of even greater force...usually the third or fourth explosion is the one that does the greatest damage (1981, p.3).

In Rolf K. Eckhoff's first edition of his book on Dust Explosions in the

Process Industries, appendix table A1 contained information on the ignitability and explosibility of dust. In the table material, tests of three wood dusts were conducted, one included information on wood dusts from chip board. These dusts were tested as received. The median size of the chip board dust was 43  $\mu\text{m}$ ; the minimum explosive concentration required was 60  $\text{g}/\text{m}^3$ , with a maximum explosion pressure of 9.2 bar(g) and an ignition temperature of 490°C.

Spain also addressed ignition temperatures in his article for Bulk Solids Handling. He addressed the energy required and temperatures produced that may provide an ignition source. “A smoldering flake of tobacco can reach 600-800°C in still air and 1,000°C in the slightest draught” (1990, p.207).

Wood dust not only presents an explosion hazard, but it also presents a health hazard to employees. Oregon OSHA lists the eight-hour time weighted averages for wood dust at 10  $\text{mg}/\text{m}^3$ . A paper by Brian Kohler (with the Communications, Energy, and Paper Workers Union of Canada) on Wood Dust and Cancer presented information from the International Agency for Research on Cancer that wood dust is classified as a Group 1 carcinogen, with evidence of an ability to cause cancer in humans. He also addressed other contaminants that may be present. “For example, if the dust results from the sanding or shaping of particle board, it is likely to contain some amino resins (e.g. urea-formaldehyde, phenol formaldehyde, melamine-formaldehyde) that are used to bond the particles

together” (1995, p.1).

Dusts in a non-suspended state involved in fire can present a real hazard to personnel if not handled properly. An example of this was addressed in an article on a burn due to a sawdust explosion. In the publication, Burns, the author, described a fire that had occurred in a large silo. The burn victim was a contractor who was using a backhoe to excavate sawdust and wood chips out of a door near the bottom of a silo where a fire had occurred. The intent was to remove the smoldering mixture and finish extinguishing the product on the ground. During removal of the product, a cavity formed from the bridging of product still in the silo. Shortly after a bucket of chips was removed by the backhoe, the bridge of material collapsed. It was followed by an explosion and flash exiting the silo, engulfing the victim in flames. In the article, looking at the cause of the explosion and fire, the following was concluded:

An unextinguished dust fire was the apparent source of ignition. Sawdust explosions, to the best of our knowledge, have not been previously reported as a cause of burns. However, this dust is flammable and, in the proper combination with air, apparently can create an explosive mixture, as any such source may, in a suitable enclosed space (Still Jr., p165).

As mentioned in the article, there are few documented cases of burns suffered by personnel involved in wood dust fires. These fires are extremely

hazardous; however, and have similar burning characteristics to fires at grain handling facilities where numerous burn injuries have been reported.

Extreme caution is needed when dealing with fires in hoppers, silos, or other similar storage facilities. In July 1986, the NIOSH released an alert on Preventing Fatalities Due to Fires and Explosions in Oxygen-Limiting Silos. These silos are primarily used for storing agriculture products, and are also used in some wood- handling facilities. Similar precautions should be taken when dealing with combustible dust fires in silos that are not oxygen-limiting.

The main purpose of oxygen-limiting silos is to prevent combustion from occurring secondary to low oxygen. However, circumstances involving these silos have occurred, permitting an atmosphere to exist that has allowed support of combustion in stored products. “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” (p. 1).

When this occurs, similar problems exist whether one is dealing with an oxygen- limiting silo or other enclosed product storage vessel. The addition of oxygen in this situation may create the potential for an explosive environment:

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] (p. 1).

When dealing with oxygen-limiting silos NIOSH provided precautions for fire departments when dealing with fires in these vessels, and is included in Appendix A.

An example of the hazards associated with wood dust in this type of silo is illustrated in a report by John Kimball for the United States Fire Administration on an Industrial Silo Fire and Explosion in Iredell County, North Carolina, resulting in injury to three firefighters. The fire and explosion involved an oxygen-limiting silo that had been converted for use as a sawdust storage facility. The fire and explosion occurred after water had flowed via handlines for over two hours from the top of the silo.

The fire and explosion occurred after a decision had been made to open an access plate near the bottom of the silo to allow the product to be removed for overhaul. As the plate was being removed, water and burning material was noted flowing from the silo. There was a rush of air into the silo, followed by an explosion. Under lessons learned, the following comments were made:

Oxygen-limiting silos pose explosive hazards regardless of their use and application. In deep-seated fires of shredded combustible material,

regardless if it is silage, wood chips, or dust, the potential exists for fires to reach smoldering stage of high heat and low oxygen. Backdraft explosions have occurred in silos that have been converted to conventional-type agricultural silos because of the strong integrity of seams and joints in the shell, which are designed to prevent air incursion (Kimball, p.13).

The report also went on to discuss the need to conduct a hazard and risk assessment in determining appropriate actions involving fire and the positioning of personnel and hose streams:

Incident Commanders need to carefully evaluate the hazard and risk involved. Defensive tactics or direct aggressive attack may be indicated in cases of high life safety hazards, high property loss potential, or extreme potential for fire extension. If the fire is contained, or is not threatening life or high property loss, measures to greatly minimize the risk to firefighters should be utilized. Unstaffed hoselines, standby operations, or other low risk-level tactics should be considered (p. 13).

With regard to general handling of dust fires, the need to limit disruption of dusts was further stressed in an article for Fire Command by Irving Deutsch P.E.:

Particular attention must be paid to the danger of disturbing stored,

stacked, and in process materials. Vibration, impact, shaking, or the force of hose streams are likely to produce a catastrophic secondary or tertiary explosion that could endanger the lives of people inside and outside the plant (p. 21).

The article continued to discuss the need for use of protective equipment and respiratory equipment. They also address the fact that if lives are not at risk, personnel should not enter the structure until it has cooled throughout:

Even when the fire appears to be out and explosion hazards minimized, danger lurks in closed areas such as drums, tanks, silos, containers, storage bins, cyclones, feed hoppers, and bag filters. Each such area or item of equipment should be thoroughly cooled prior to ventilation...Then air cool or use a fine mist to cool all enclosed areas, always maintaining a safe distance (p.21).

Industrial Fire World had the following comments about handling dust fires in the context of an explosion, “Handle a dust explosion with kid gloves,” Phillips said. “As long as there is an ignition source (such as a fire) remaining, there is the possibility of another explosion” (Parekh, p.36). The article continued to address the danger of using straight stream patterns on smoldering fires that could result in a dust suspension and subsequent explosion.

“Use volume, not pressure. You can’t just bust in and treat it like a regular

structure fire.” Phillips also stressed that rescue services should keep their own safety in mind. “Rescue service are there to preserve life and property-life first, property second,” Phillips said. “Don’t risk your life to save property. Property can be replaced. You can’t put a price on life” (p.37).

A number of articles were located on proper handling of dust fires, and two of them were written by John E. Bowen. One was published in a 1978 edition of Western Fire Journal on dust explosions, and the other was an article in a 1983 edition for Fire Engineering on an overview of Grain Dust Explosions. The recommendations found in both articles are very appropriate for the continued safe handling of dust fires. In his 1978 article, he addressed the twofold function of fire departments to not only extinguish the fire, but also to prevent a dust explosion.

Dust fires can be either smoldering or flaming. The former type frequently occurs deep within a dust pile and may burn for a long time before it is detected. Potential ignition sources for dust fires are just about the same as for explosions with the added fact that fires often follow a dust explosion due to falling out of burning particles onto dust deposits (p.31).

The article also discussed the dangers of dust fires and the fact that if attacked, they must be approached very carefully to avoid disturbance and potential

explosions. “It is probably safest to allow the fire to burn itself out but this can only be done when the deposit is small and it also requires a constant watch” (p.31).

Most fires; however, will typically require extinguishment. In those cases, he stated the following precautions for responders. “It is absolutely essential that low pressure fog be employed, though. Never use straight streams or high pressure fog because these techniques will throw large quantities of dust into suspension and raise an extreme risk of explosion” (p.31).

He further described the effectiveness of water penetration on dusts and the fact that penetration will likely not be effective in extinguishing deep-seated fires, and that wet water may be an effective additive. Caution needs to be exercised in not stirring the pile during extinguishment and not walking on top of piles that may have burning material and pockets that someone could fall into.

In handling deep-seated fires such as those possibly encountered in a large pile, bin, silo, or similar container, the following precautions were offered. “A method that should be of last resort is digging the fire out of the dust pile. This is very dangerous and should only be used when circumstances make it essential” (p.31).

## **PROCEDURES**

The research involved relevant material located through the Learning Resource Center at the National Emergency Training Center, the National Fire Protection Association (NFPA), and the National Institute of Occupational Safety and Health (NIOSH) over the past six months. In addition, material from the Albany Fire Department, including past dust fire investigations, and sources from the Internet were used.

Firsthand experience and a subsequent incident that occurred at a local particle board plant while writing this paper added important insight into safety precautions with regard to handling combustible wood dust fires and the potential effect of dry pipe sprinkler systems on fine dust fires. The action research methodology was selected for this paper. The desired outcome was to gather and identify methodologies to determine what should be considered in developing criteria for safe, effective handling of wood dust fires that would be included in a policy for department members.

The hazards of combustible dusts and the potential based on particle size was well documented throughout the research material. The fact that there is essentially no upper limit to dust concentrations and the potential for deflagration in hazardous atmospheres, as well as the minimum amount of dust required to support a deflagration in the presence of an ignition source, were very enlightening.

With the information that was located, a department policy was developed on handling wood dust fires and the precautions to be taken to prevent distribution of a dust cloud in a potential atmosphere containing an ignition source.

### **Limitations**

During the research, current information on proper handling of wood dust fires was somewhat limited. Numerous articles were located; however, by some authors, that had primarily been updates of the same material.

With regard to handling wood dust fires, again, the material was somewhat limited on fires involving storage vessels, such as bins and silos. Although, a number of good articles were located addressing safe handling of grain and agricultural products in a dust form that present similar hazards as those involving wood dusts.

## **RESULTS**

The findings include answers to the following research questions:

1. What physical hazards may be present with regard to firefighting operations that should be considered?

In reviewing material on wood dust and the hazards presented in the safe handling of these incidents, a number of interesting facts were located. One of

those is the fact that wood dusts are classified by Oregon OSHA as a carcinogen with an 8- hour time weighted average for wood dust of 10 mg/m<sup>3</sup>.

It was also interesting to note an article from the Internet by Brian Kohler, where he documented the fact that wood dust has been classified as a Group 1 carcinogen, and that other products that may be part of the process may be included in the dusts. “For example, if the dust results from the sanding or shaping of particle board, its is likely to contain some amino resins (e.g. urea-formaldehyde, phenol formaldehyde, melamine-formaldehyde) that are used to bond the particles together” (1995, p.1).

Even though responders are not likely to hit the eight-hour time weighted averages for wood dust, appropriate precautions and personal protection should be considered and utilized.

As with any combustible material, the research also clearly showed the potential consequences if a fire or explosion occurred secondary to a deflagration or explosion involving wood dusts. Although little document evidence exists with regard to serious injuries resulting from incidents involving wood dusts, the potential definitely exists. This is evident from incidents involving wood dusts, as well experiences that have been documented regarding grain dust explosions and fires.

One documented case found in the publication, Burns, addressed the

incident of burns to an equipment operator assisting with unloading a hopper that had previously been involved in a fire. A dust explosion occurred when some bridged product collapsed with the vessel, creating a dust cloud and fire that engulfed the operator.

An unextinguished dust fire was the apparent source of ignition. Sawdust explosions, to the best of our knowledge, have not been previously reported as a cause of burns. However, this dust is flammable and, in the proper combination with air, apparently can create an explosive mixture, as any such source may, in a suitable enclosed space (Still Jr., p165).

We experienced a similar tragedy while I was completing this paper, where a worker at a local particle board plant was engulfed in a fire ball while changing a lightbulb in a fixture. The fixture fell, which created a dust cloud. The cloud found an apparent ignition source in the disconnected wiring as the fixture fell.

The employee who was working 30 feet off the ground in a hydraulic lift received third degree burns to 70% of his body with respiratory involvement, and succumbed to his injuries eleven days later.

The minimal amount of dust required to be present to produce a deflagration, explosion, or fire was surprising as were the dangers associated with what one would likely consider normal extinguishing techniques for fire

suppression. It is clear that the largest risk to responders is the potentially devastating impact of a dust explosion if not properly handled.

Improper use of hose streams on fires involving wood dusts can be extremely harmful to emergency responders. This fact, as addressed by Irving Deutsch P.E. in his article for Fire Command, reinforced the care that needs to be taken by responders to prevent an explosion:

Particular attention must be paid to the danger of disturbing stored, stacked, and in process materials. Vibration, impact, shaking, or the force of hose streams are likely to produce a catastrophic secondary or tertiary explosion that could endanger the lives of people inside and outside the plant (p. 21).

2. What factors should incident commanders take into consideration in selecting appropriate tactics to deal with dust fires?

In assessing fires that involve the possibility of wood dust, Incident Commanders need to take a number of factors into consideration relative to safe and proper handling of fires. The first factor is the particle size of the product potentially involved.

Material by NFPA in their 18<sup>th</sup> Edition of the Fire Protection Handbook, classified dusts that are smaller than 420 microns or those that will pass through a U.S. Standard No. 40 Sieve as being classified as combustible dusts.

When dispersed in air and ignited, they will propagate a flame. As gaseous mixtures, there is a lower combustible limit that will support flame propagation. Dust clouds do not exhibit an upper limit that is of practical use in deflagration control. The introduction of a flammable gas into a dust cloud usually reduces the lower combustible limit of the dust/air mixture and also markedly decreases the ignition energy of the dust/air mixture (p.4-153).

In his article for Fire Prevention 228, J.P. Zeeuwen discussed dust explosion mechanics. He described a dust explosion as a “rapid burning of fine combustible material (dust, powder, etc.) mixed with air”(1990, p.26). He also addressed particle size generally being smaller than 0.4 mm.

Most sources addressed wood dust sizes under 420 microns as presenting a hazard for explosion potential. Spain, in his article for Bulk Solids Handling, addressed the fact that all dusts under 200 microns in size can be considered explosive. A NFPA investigation of a furniture manufacturing facility dust explosion found that 32 to 42 percent of the dust tested was less than 200 microns.

In the facility where we experienced the recent fire and fatality, some of the sander dusts were as small as 5.3 to 7.1 microns, the consistency of a flour. Particle size plays an important role in the potential volatility of dusts that may be

involved in a fire. In their book on Explosion Investigation and Analysis, John and Patrick Kennedy documented the following regarding dusts: “The finer the dust, the more violent the explosion. Most explosions hazard concentrations of dusts are when particles are of a diameter of 840 microns (0.033”) or less” (1990, p.135).

Extreme caution needs to be taken any time personnel are extinguishing fires involving dusts that may fall under these criteria. An important component of the potential hazards associated with dust smaller than 420 microns is the concentration of dust required to present a hazard to responders and something that Incident Commanders need to be aware of, and not take lightly.

Both the NFPA and an article by Sara Emmons discussed the fact that if enough dust is present for you to write your name, approximately 1/8” for wood dusts, too much dust is present. Her article stated, “The Lower Explosive Limit (LEL) for dust can be as low as 0.03 oz/ft<sup>3</sup> (30 g/m<sup>3</sup>)” (p. 5).

Another important factor to keep in mind with wood dusts is the fact that not unlike combustible liquids, combustible dusts have a lower explosive limit (LEL). However, unlike flammable liquids there is essentially no upper explosive limit (UEL). Once the LEL of a dust is reached, regardless how heavy of a concentration develops, an explosion or deflagration are strong possibilities.

In his article in Fire Command, Deutsch also highlighted the minimal

amount of dust needed to create a cloud that could be ignited.

If the dust cloud contains approximately 40 grams of dust per cubic meter (0.04 ounces per cubic foot); has a sufficient number of particles in the size range of 60 microns (1 micron equals 1/1000 millimeter); and makes contact with an ignition source, there will be an explosion or puff...To illustrate the quantity of dust needed to produce a cloud in the explosive range, imagine 0.015 inches of dust on a floor of a tunnel 400 feet in length 8 feet in width, and 10 feet in height. This dust is enough to produce the minimum concentration (p.20).

The author also placed this example in another light by addressing the OSHA health standard of 15 milligrams per cubic meter for dusts, or approximately 1/3000 of the lower explosive limit. The importance and effect of the concentration of a dust involved in an explosion plays a vital role in the impact of a potential dust explosion as the Kennedy's also discussed.

The concentration of the dust in air has a profound effect upon its ignitability and the violence of the blast pressure wave. As with ignitable vapors and gases, there are minimum uniform concentrations of specific dust for propagation combustion to occur. Minimum concentrations can vary with the dust material from as low as 0.015 to 2.0 oz./cu.ft. with the most common concentrations being less than one ounce per cubic foot

(1990, p. 135).

Factor Mutual Engineering Corporation addressed this in their 1981 report on the Dynamics of Dust Explosions.

First, flammable liquids have a lower explosive limit (LEL) and an upper explosive limit (UEL). Below the LEL there is not enough vapor in proportion to air to support combustion-the mixture is too lean; about the UEL there is too much fuel as opposed to air to support combustion-the mixture is too rich. But anywhere between the limits, the fuel/air mixture will burn. The LEL and UEL vary for each flammable vapor or gas. But for dusts, there is an LEL which also varies, but there is virtually no UEL; therefore, any concentration above the LEL should be considered explosive. Secondly, flammable vapors or gases tend to explode all at once. Igniting a small amount of flammable vapor does limited damage: it may start a fire. But dust explosions can follow a chain reaction: a small amount of dust is stirred up and finds an ignition source. The resulting explosion shakes out more dust from floors, walls, and other surfaces, and this dust is ignited by the burning particles or by radiant energy of the initial explosion, releasing a pressure wave of even greater force...usually the third or fourth explosion is the one that does the greatest damage (1981, p.3).

As mentioned above, with a dust explosion the normal progression is the gradual intensifying of subsequent explosions. This same fact has been verified in three incidents that the Albany Fire Department has responded to. In each incident, witnesses have stated that a small fire and blast was first noticed, and then a final, large detonation/ignition took place, usually on the third or fourth percussion.

The ignition temperatures required for suspended dusts is also quite low. In a book on Dust Explosions in the Process Industries, Eckhoff presented material on tests of dust from chip board (particle board). The median size of the dusts tested was 43 microns, with a minimum explosive concentration of 60 gm/m<sup>3</sup>, a maximum explosion pressure of 9.2 bar(g), and an ignition temperature of 490°C.

Most smoldering fires have the potential of providing an ignition source for a dust cloud meeting the LEL of the product. Heydenrych's article in Fire Protection magazine stated that for ignition of wood dusts under 200 microns in size, typically 20-60 mJ was sufficient energy.

Also of importance for those handling potential dust atmospheres in the LEL, is that moisture has little impact on the ignition temperature required to ignite a dust cloud and cannot be looked at as means to prevent an explosion. In fact, the NFPA Fire Protection Handbook made the following statement regarding

this fact: “In order for moisture to prevent ignition of a dust by common sources, the dust would have to be so damp that a cloud could not be formed” (1997, p.4-176).

During our department’s last wood dust fire, burning piles of wood dust of flour consistency were noted floating on top of water on the floor, from the sprinkler system and handlines, and was observed to still be burning.

### **3. What information should be included in an emergency operation policy for personnel to use?**

Information included in results one and two are important information for responders as well Incident Commanders to have when making informed decisions on the proper way to handle dust fires and explosions. There is the additional importance of specific recommendations for dealing with these fires.

Extreme caution needs to be taken with fires involving silos, hoppers, or other similar storage facilities, especially oxygen-limiting silos storing wood dust. NIOSH has developed an excellent tool for fire departments on proper handling of fires involving oxygen-limiting silos (Appendix A). This material also provides an excellent guideline for handling fires in storage containers that are not oxygen-limiting.

The most important factor when dealing with a dust fire in a storage container, once life safety and exposure protection have been addressed is to

simply allow the fire to burn itself out, if possible. This was addressed in a report by the United States Fire Administration on a silo fire and explosion. The report made the following recommendations.

Incident Commanders need to carefully evaluate the hazard and risk involved. Defensive tactics or direct aggressive attack may be indicated in cases of high life safety hazards, high property loss potential, or extreme potential for fire extension. If the fire is contained, or is not threatening life or high property loss, measures to greatly minimize the risk to firefighters should be utilized. Unstaffed hoselines, standby operations, or other low risk-level tactics should be considered (p. 13).

Emptying and/or digging out these containers should be done only as a last resort, and extreme caution must be taken if this tactic is employed. Anytime product is being handled or moved that has been involved in a fire, the potential exists for a dust explosion. This was documented in the case of the equipment operator emptying a silo that contained product previously involved in a fire.

Deutsch addressed this in his article and the fact that personnel should not enter a structure until it has cooled throughout. The same can be said for emptying containers that have had fire involvement.

Even when the fire appears to be out and explosion hazards minimized, danger lurks in closed areas such as drums, tanks, silos, containers,

storage bins, cyclones, feed hoppers, and bag filters. Each such area or item of equipment should be thoroughly cooled prior to ventilation...Then air cool or use a fine mist to cool all enclosed areas, always maintaining a safe distance (p.21).

With regard to handling fires in wood dust, the most important matter is to prevent the suspension of the product in a cloud that could result in an explosion and fire. When extinguishment is required with hoselines, extreme caution cannot be overstated. Low pressure semi-fog streams should be utilized, as high pressure straight streams tend to disrupt the product into a cloud.

Industrial Fire World highlighted this fact in their publication:

“Use volume, not pressure. You can’t just bust in and treat it like a regular structure fire.” Phillips also stressed that rescue services should keep their own safety in mind. “Rescue service are there to preserve life and property-life first, property second,” Phillips said. “Don’t risk your life to save property. Property can be replaced. You can’t put a price on life” (Parekh, p.37).

In his articles, John Bowen addressed these issues and the potential negative effects hose streams can have on an incident and the importance of not only extinguishing the fire, but preventing an explosion as well. With regard to ignition of clouds created by hose streams, he had the following to say: “It is

absolutely essential that low pressure fog be employed, though. Never use straight streams or high pressure fog because these techniques will throw large quantities of dust into suspension and raise an extreme risk of explosion” (p.31).

In addition to the effect of hose streams on smoldering or burning piles, built-in fire protection systems can be effective on fires where an accumulation of dust exists. On our recent fire, suppression crews were looking for areas of smoldering product and extinguishing them. During this function, they observed a breakout of fire near the ceiling in an area of the plant not involved in the original fire and heard the water gong for that fire sprinkler system sound.

This fire quickly grew in size, and as they were beginning to attack the fire with handlines, additional sprinkler heads opened on the dry pipe system. As these heads opened and the crews heard the air releasing, they observed a large flash/explosion fire covering an area of approximately 50,000 square feet, secondary to the suspension of dust in the location of the sprinkler heads. Interior crews and Command ordered an emergency evacuation of the structure, accountability of all personnel, and reactivation of the sprinklers systems involved with the first fire.

The sprinkler system brought the majority of the fire under control, and after regrouping crews and arrival of additional responders, an evaluation of the structure was made. Crews were again assigned to extinguish spot fires and fire

above the sprinkler system at the roof level. A summary report for this fire has been included as Appendix B.

A lesson was learned on this fire that I had not seen addressed in any previous literature about fires of this type, but makes perfect sense relative to the potential of hose streams on fires. With a dry pipe system, air under pressure has the ability to create a dust cloud and ultimately a dust explosion, if accumulation of dust is present in the area.

Getting information to potential responders on the hazards associated with wood dust fires and how they can be properly handled will be accomplished through training and department policy (Appendix C).

## **DISCUSSION**

Handling wood dust fires properly is extremely important for a good outcome. These fires cannot be handled as one would a typical structure fire. Once a fire is detected, the potential for a dust explosion is a real and possible problem for responders.

Personnel must be adequately trained to properly handle these incidents and conduct a risk benefit analysis prior to assigning tactics and strategy. Fires involving fine dusts are extremely dangerous and should be handled accordingly.

It is important to identify facilities that may produce fine dusts of a size

that if suspended could result in an explosion. The research provided a great deal of information on safety precautions to protect personnel in handling fires in these types of situations.

Although this paper addressed the proper handling of fires involving wood dusts, the best action to protect personnel is a good preventive program to minimize accumulation of dusts and the likely consequences they cause.

## **RECOMMENDATIONS**

Improper handling of a wood dust fire could place emergency responders at extreme risk. It is highly important to ensure that emergency responders have appropriate information about proper handling of these fires in order to minimize the risk of an explosion and/or rapid fire involvement.

Upon completion of this report and literature review, a number of steps were identified to be provided to personnel for proper handling of fires involving wood dusts.

1. Incident Commanders must conduct a risk analysis of the hazard potential associated with dust fires and take appropriate action to minimize the dangers to personnel and equipment.
2. In those situations where dust fires must be attacked, it is extremely important for personnel to be aware of the associated

hazards and use appropriate tactics for safe extinguishment of the fire, as addressed in Appendix C.

3. It is important for departments to evaluate potential operations in their emergency response district that may produce dusts, especially facilities where fugitive dusts may be present, and evaluate the danger and potential based on particle size and concentrations.
4. Inform personnel of the potential of dry pipe sprinkler systems actually creating a suspension of dusts and intensifying a fire prior to the availability of water.
5. When dealing with fires involving silos, bins, bag houses, and cyclones, the best course of action is to allow the fire to burn itself out. If an inert atmosphere can be obtained, flooding these vessels with CO<sub>2</sub> or nitrogen may be a good alternative.
6. If the decision is made to empty a silo, bin, bag house, or cyclone, extreme caution must be taken. Bridging of material causing a collapse in the vessel can create a cloud and subsequent explosion.
7. Full protective equipment, including SCBA, should be used by personnel anytime the potential for a dust cloud exists.

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## Appendix A

|  |                                                                                                                                                                                                       |
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|  | <p>Request for Assistance in...</p> <h2>Preventing Fatalities Due to Fires and Explosions in Oxygen-Limiting Silos</h2> <p>OSHA ALERT: July 1986<br/>         OSHA (NIOSH) Publication No. 86-118</p> |
|--|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**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.

ature]

onald Millar, M.D., D.T.P.H. (Lond.)

stant Surgeon General

ctor, National Institute for Occupational Safety and Health

ters for Disease Control

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**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 CO<sub>2</sub> or liquid nitrogen for other silo sizes. [\[Return to main text\]](#)

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*This page was last updated: 2/11/97*

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## Appendix B

### Albany Fire Department Fire Investigation Team Lead Investigator Report

Date of Incident: 05/25/2000  
 Time of Incident: 15:57  
 Incident #: 1599  
 Type of Incident: Industrial Structure Fire  
 Incident Address: 100 Old Salem Road Albany Oregon 97321  
 Lead Investigator: Michael McGilvray

#### Report:

At approximately 14:55 hours, I was heading east on Salem Road when a first alarm structure fire was toned out over the radio. I went in route, and within a minute reported back to the Battalion Chief 106, Larry Parent, that a large column of smoke was present from that area. Approximately two minutes later, I was on Old Salem Road driving parallel to the Willamette Industries Duraflake complex. I then reported to BC 106 that the fire was venting out of the roof at the rear of the large production building. BC 106 called for a second alarm fire assignment. I then reported that I was at the scene. I was approached by an employee of Duraflake who told me where the fire was located and that there was one person unaccounted for. BC 106 pulled behind me and took command of the fire scene. We were approached and told that a person was around back and needed medical attention due to burn injuries. Medic 13 responded and assisted with a burn victim, Mr. Todd Dixon. Mr. Dixon was immediately transported via ambulance to Albany General Hospital.

The fire had been knocked down considerably by the sprinkler system. Fire crews worked on the inside of the structure for approximately two hours, putting out hotspots of sawdust. BC 106 released all fire personnel except Engine 11 and me, 113. I was asked to conduct the fire investigation. I was told by a Duraflake employee that the area where the fire started had been secured and DO NOT ENTER tape was placed around the area.

At approximately 17:00 hours, I walked into the structure with BC106 and two employees from Duraflake. We were headed in to assess the damage and confirm that the area of origin was secured. I went to the area of suspected origin and found an area taped off around a High Boy Man Lift. I photographed the area making sure all items had not been disturbed or moved. At that time one of the employees of Duraflake yelled out that there was a fire on the west side of Line 4. BC 106 and I responded to that area and found fire had broke out on the underside of the ceiling. BC 106 radioed for Engine 11 to respond. I found a fire hose and began extinguishing the fire with the two employees from Duraflake. Once again, fire crews worked at putting out hot spots for about one hour.

At approximately 17:45 hours, I communicated with BC 106 and advised him that I had an appointment at 18:30 hours and would leave and take the pictures in to be developed, and that I would return the following morning to investigate the fire. I cleared the scene.

At approximately 18:15 hours, I heard a call over my radio for a second alarm fire at Duraflake. I

responded from home. Upon arriving on scene, I met again with BC 106. He told me that he was in the building with two fire crews when he heard what he thought sounded like a sprinkler system activating and hammering, and that all of a sudden there was an ignition and very rapid fire spreading through the south part of the building near the end of Line 3. BC 106 called for an evacuation of the structure. Fire crews worked until approximately 21:00 hours cooling down hot spots. At approximately 23:00 hours, all fire personnel were released except for Engine 13, which would stay until 07:00 hours. At approximately 06:00 hours on 10/26/00, I received a phone call from Fire Chief Kreitman at my residence advising me that I needed to respond to Duraflake at 07:00 hours to put together an investigation team and conduct the fire investigation. He also advised me that the individual that was transported to the burn center was in extremely critical condition, and unsure if he would survive.

At 07:00 hours, I reported to Duraflake. I relieved the duty crew that was there all night. I reported to Dispatch that I was conducting a fire investigation at Duraflake and to put me at the scene. I was informed by Dispatch that two Linn County Sheriff Detectives were on their way to be included in the investigation. I was also advised by Duraflake that a private investigator would be there shortly. His name was Linn Davis, and he was notified by the insurance company.

At 08:15 hours, I instructed a group of people who would make up the investigation team on the procedures that would be followed while conducting the fire investigation (see Investigation List). I spelled out how I wanted the investigation to proceed. First, photographs of the area would be taken. Nothing was to be moved until all people had completed the photographs. Then items that needed to be looked at and evaluated would be moved, one at a time, until such a time that we could move the man lift out and gain access up to the ceiling level where Mr. Dixon was working.

At 08:30 hours, the investigation team entered the building. Only four people at one time were allowed to enter the secured area. Photographs were taken after discovering the light fixture in the man lift and realizing the electrical pig tale was plugged in. Several scenarios of what might have occurred were discussed. The team and I moved to an area where we could physically look at a light fixture similar to the one we found in the man lift. We attempted to remove the light with it plugged in, and were unable to do so. We were not able to remove the light, even with force by hand (see photograph # 7). We determined that the only way the light could come down was if the plug had been disconnected, or the mounting bracket was damaged.

The light fixture found in the man lift showed little signs of extreme heat. The plastic lens was still intact. The light bulb was still intact and appeared to be an old bulb with signs of dark color on both ends of the tube.

At close look of the light fixture, there were areas of electrical arching on the metal where the wires entered the top of the light fixture (see photograph # 8).

The shade of the light fixture had an indentation of a curve that had bent the metal approximately three-quarters of an inch inward approximately 4 inches in length.

A light bulb was found approximately ten feet from the man lift bucket directly under the plug in for the light on the ceiling. The bulb was a new bulb still in its cardboard container (see photograph #2).

At approximately 11:30 hours, I was informed that three of the employees that were in the area just prior to the fire were at work this day. I asked to schedule a meeting with them at 13:30 hours so I could conduct interviews.

At approximately 12:00 hours, I left the area for lunch. BC 104, Rich LaBelle, stayed at the scene to provide security to the area.

At approximately 13:15 hours, I returned to the fire scene and started conducting interviews. The first interview was with CLINTON ARNOLD; the second Interview was with RON CUNNINGHAM; and the third interview was with TODD PRENOVEAU (see Voluntary Interview Statement).

Interviews were conducted at approximately 15:00 hours. Information obtained during the interview

confirmed that area Mr. Dixon was working in was the origin of the fire. In the case of Mr. Ron Cunningham who was working in the Line 3 operator's station, he remembers hearing a "pop" then all the lights went out. He looked over to his left and saw fire and an orange-like glow on the ceiling above Todd Dixon who was in the man lift. He remembers seeing Todd Dixon moving the lift to the left trying to get away from the fire. He said that Todd hit the other curtain with the lift because another fire erupted over the top of him and around the man lift. He remembers seeing Todd crouched down in the man lift as if something was in his way, as Todd was trying to get the lift down.

At approximately 15:45 hours, the decision to move the man lift was made. The man lift would not move on its own due to damage, so it had to be dragged from its position. While waiting for the man lift to be relocated, I removed the light fixture and placed it into evidence with the Albany Fire Department. All personal items found in the basket were removed and given to Tom Natsch, Safety Director, for Duraflake. Skin tissue that was present was disposed of utilizing bio hazard bags provided by Albany Fire Department.

At approximately 16:45 hours, the damaged man lift had been removed. another man lift was utilized to get up to where the light fixture was originally located. Pictures were taken of the electrical box and mounting hardware (see photographs #11-14).

The electrical receptacle was in tact along with the mounting hook. No physical damage was apparent. The pigtail wire showed signs of arching back and burning up the wire.

Lynn Davis tried placing the damaged light back onto the holder as I photographed the procedure. The light fixture was able to be put on and taken off of the mounting without any problem. The pigtail was still plugged in (see photograph #15).

The electrical conduit was cut approximately 15 inches on both sides of the receptacle and mounting hook. The assembly was removed from the ceiling truss and taken into evidence by the Albany Fire Department.

#### FIRE SUMMARY:

It is the opinion of this fire investigator that the fire was accidental in nature. It appears that while Todd Dixon was in the process of changing a light bulb, several situations occurred. The Tommy Highlift that Todd Dixon was in came in contact with the light fixture and the curtain, most likely pushing the fixture upward and off the mounting hook. Dust particles from the curtain became suspended around the area. When the lift retracted, the light fixture fell onto the basket causing a separation of the electrical wire creating a parting arch. The arch was the ignition factor. The suspended dust created an environment for a rapid deflagration. It appears that there were as many as three dust fires. The third fire was the most significant in terms of force.

Further inspection of other light fixtures revealed as much as 1.5 inches of dust on the surface of the fixture. Other areas of the building revealed a fire extinguisher with 2.5 inches of settled dust (see photograph #A13).

#### CONCLUSION:

Accidental dust fire caused by electrical wire connection failure.

Signed:

Michael McGilvray, Deputy Fire Marshal

## Appendix C

### Albany Fire Department

## **Operation Procedure for Proper Handling of Wood Dust Fires**

Research has shown that wood dusts under 420 micron in size and suspended in air have the potential of creating an explosion if an ignition source is located. The City of Albany has two major manufacturing facilities that produce and/or handle large quantities of dusts under this size. Dust of this size or less could also be present in a number of cabinet shops in the community.

The Duraflake Particle Board Plant and the Menesha Corporation both have dusts/flours on site that meet size requirements for dusts that could present an explosion hazard. Dusts from the sanders at the Duraflake facility can range in size from 5.3 to 7.1 microns. This is well below the size required to support an explosion when disturbed in air. These two facilities present additional concerns, in that these dusts present a fugitive dust problem throughout the structures.

Accumulations of dust as little as 1/8" are deep enough to result in an explosion if disturbed into a cloud and an ignition source is present. The normal progression of dust explosions is a small blast suspending additional dusts that ignite and create a secondary explosion. This is followed by a third and larger release of dust that usually results in the largest and most damaging explosion.

In the explosions and fires we have encountered at the Duraflake facility, similar circumstances have been reported by on-site personnel who witnessed the incidents. Smoldering product that is disturbed into a cloud has the potential to have all the elements necessary for an explosion.

Wood dust, not unlike flammable liquids, has a lower explosive limit (LEL) that must be present for an explosion to occur. As discussed above, 1/8" of dust can be enough to support an explosion. Documentation has shown that at as little as 10 mg/m<sup>3</sup> can be a high enough concentration for ignition. An additional hazard with wood dust, unlike flammable liquids, is the fact that **no** upper explosive limit (UEL) exists for wood dusts. Once you are above the LEL, regardless of the concentration in the air, explosion potential exists.

The application of water or addition of moisture is not enough to stop the potential for an explosion. A higher moisture content can raise the ignition temperature of the dust, but studies indicate that unless the dust is so wet that a cloud cannot form, an explosion hazard still exists.

When dealing with a fire involving wood dust, the most important aspect for suppression crews is to prevent suspension of the product in a cloud that could result in an explosion and/or fire.

Penetration of water in fine dust fires is extremely poor. Cases of fires involving dust have been documented where water flowed into a closed vessel for a considerable amount of time and still failed to reach the seat of the fire.

Do not walk on top of piles of product that have signs of fire. Smoldering fires may create a void that can collapse.

It should be noted that Wood dust has been identified as a carcinogen with an Oregon OSHA 8-hour time weighted average of 10 mg/m<sup>3</sup>. Personal protective equipment should be used any time possible exposure is present at these levels.

### **Handling Fires Involving Silos, Hoppers, Bag Houses, or Other Enclosed Areas**

- Ensure that all equipment operating in the area that could disturb material in the vessel or allow it to be transmitted to another area has been shut down.
- If no life hazards or exposures are present and the fire is contained, the best approach is to let the fire burn itself out.
- Utilize thermal imaging camera to assist in determining location of the fire and temperature.
- For fires involving silo or oxygen-limiting silo, review and follow attached material from NIOSH on Preventing Fatalities Due to Fires and Explosions in Oxygen-Limiting Silos.
- If emptying and extinguishing storage containers is required, it should only be done as a last resort and extreme caution must be taken. This is extremely hazardous and may result in rapid open burning if a smoldering fire is exposed to air. It also creates the potential risk for an explosion if a dust cloud is created.
- Remote hoselines and defensive actions should be used when possible.
- A plan of action needs to be developed and discussed with those involved to prevent suspension of product in air.
- Be aware that a number of the storage silos at Duraflake contain suppression systems located in the top of the silo. If these systems have flowed, there is a good chance that product will cake inside the vessel. Any time a vessel is emptied, bridging of the material may occur. A later collapse of this product in the structure will create a suspension of dust. This can result in a powerful explosion if smoldering product is still contained in the structure or another ignition source is located.
- The best method for extinguishment would be to seal the container and place it under an inert atmosphere of carbon dioxide or nitrogen until the fire is out. If this method is used, personnel should be kept a safe distance from the vessel. If they need to approach, they should only do so in appropriate protective clothing and SCBA. The air should also be monitored to ensure that an oxygen-deficient atmosphere does not exist near the structure.
- At no time should personnel be placed on top of a container suspected of containing a fire or smoldering product.

### **Handling Wood Dust Fires in Production and Storage Buildings**

- Be aware that multiple explosions are not uncommon and that the third or fourth explosion is the most powerful, creating the most damage. It is not uncommon for wood dusts in confined areas to develop pressures well above 9.2 bar(g).
- Extreme caution needs to be taken if entering the structure after an explosion and resultant fire. If life safety has been accounted for, the structure should not be entered until it has been ensured that the structure has cooled and the possibility for further explosions is minimized.
- Be aware of the potential for structural instability and overhead hazards that may exist.
- In handling spot fires that may still exist, extreme caution needs to be taken to prevent suspension of dust secondary to hose stream use. Semi-fog streams at low pressure should be utilized. If using a task force nozzle, set it to the emergency setting in these situations.
- Wet water or Class A foam can be of assistance in penetrating deep-seated fires. At no time should straight stream or high pressure streams be used on dust fires.
- Be aware that dry pipe sprinkler activation in an area of a fire may result in a dust suspension and subsequent explosion. This in no means; however, should be reason to shut down a system.
- Fires in fine dusts can smolder for some time prior to going to an open burning state. Once this transpires, rapid burning can occur across dust layers.
- Stirring piles in an attempt to extinguish fires should also be avoided to prevent suspension of product.
- In situations where a fire has been controlled by the sprinkler system and a decision is made to shut it down, personnel will be posted at controls to reactivate the system if necessary.
- Keep in mind that a burning dust fire can rapidly and without warning progress to an explosion if the material is suspended.