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Dust Explosions: A Significant Hazard

Dust explosions are extremely dangerous, and can cause significant property damage and business interruptions.

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On July 29, 2008, John Bresland, Chair and CEO of the U.S. Chemical Safety and Hazard Investigation Board (CSB) testified before the U.S. Senate Committee on Health, Education, Labor and Pensions Subcommittee on Employment and Workplace Safety). He noted that since CSB was established in 1998, three out of the four deadliest accidents CSB has investigated were determined to be combustible dust explosions (Bresland, 2008).

> *Many believe that OHSA has not acted aggressively enough to prevent worker exposure to combustible dust fires and explosions.*

On Feb. 7, 2008, 13 workers died and 39 were injured at Imperial Sugar refinery in Georgia. Twenty-three people were burned from the fire and explosion, three of whom were still hospitalized in a burn center after 5 months of treatment.

On Jan. 29, 2003, six workers were killed and 39 were injured in a polyethylene dust explosion at West

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Pharmaceutical Services in Kinston, NC. The fuel for the explosion was a fine plastic powder that had accumulated above a suspended ceiling over a manufacturing area at the plant and had ignited.

On Feb. 20, 2003, seven people were killed and 37 were injured at CTA Acoustics Inc. in Corbin, KY. This incident severely damaged a 302,000-sq-ft manufacturing plant and temporarily shut down four Ford Motor Co. vehicle manufacturing plants. Combustible phenolic resin dust had accumulated throughout the facility and was the fuel for the explosion.

In November 2006, CSB completed a study on combustible dust. It found that combustible dust explosions have been a recurrent cause of disasters at U.S. industrial facilities. The study, which did not include primary grain handling or underground coal dust explosions, identified 281 dust fires and explosions that occurred at U.S. businesses between 1980 and 2005. These fires and explosions resulted in 119 deaths and 718 injuries (Bresland, 2008). CSB called for a comprehensive OSHA regulatory standard to prevent dust explosions in general industry, improved training of OSHA inspectors to recognize dust hazards and improvements to MSDS to better communicate dust hazards to workers (CSB, 2006).

As a follow-up to the Workforce Protections Subcommittee hearings "Have OSHA Standards Kept Up with Workplace Hazards?" and the Combustible Dust Explosion and Fire Prevention Act of 2008, H.R. 5522 was introduced in the 110th Congress on March 4, 2008. The bill was eventually sent to the U.S. Senate, where it was not passed before the session ended. It is speculated that the bill will resurface in the next session. The bill states that OSHA has not proceeded aggressively to prevent worker exposure to combustible dust fires and explosions.

Dust not only poses a hazard to people, but the resultant property damage from an uncontrolled dust fire or explosion is significant. It is likely that damage from an uncontrolled deflagration or explosion will totally destroy the building or equipment involved. Sprinkler system pipes installed to control fires may be broken, disabling the sprinklers in the area of the explosion. Broken sprinkler system feed mains may discharge so much water that the resulting available water and pressure for adjacent sprinkler systems is inadequate to control the fires from spreading to other areas of the facility. The explosion may create an unsafe condition for manual firefighting tactics by the in-plant emergency team or the local fire department.

The plant suffering the explosion may have a lengthy downtime. The cost of business interruption to the company may be more than a company or plant can overcome. The facility will also need to overcome the additional expense of rebuilding. Many municipalities will require an older facility to rebuild in accordance with current and state-of-the-art technology. The property insurance policy may not cover the cost of these upgrades. The additional costs are a burden for an already suffering plant. Employees laid off after the event may find other jobs and not return one the facility is rebuilt. The cost of lost experience and training new employees is substantial.

The effects of such an explosion may also devastate a community, and the loss of employee jobs may decrease the local community tax base. Businesses surrounding the plant may also suffer. They may rely on the facility as a major purchaser of goods or as a major supplier of goods. If contingency business continuity plans are not developed and tested, other plants may also be negatively impacted by the loss.

What Is a Dust Explosion?

Imagine trying to light a log on fire. By itself, it will be difficult to start and will require much energy to bring it to a sustainable burn. It will take hours to burn to ash. If the log is split into several smaller firewood pieces, it will be easier to ignite, will require much less energy to bring to a sustainable burn, will burn with a higher rate of heat release and will burn to ash more quickly than the same amount of wood as a log.

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Taking those firewood-size pieces, further splitting them into small kindling wood and arranging them in a fashion that provides good air circulation will further change the ignition requirements. The energy required to ignite and bring a pile of kindling wood to a sustainable burn is even further reduced, the kindling will burn with a higher rate of heat release and will burn to ash quickly. This occurs chiefly because the surface area of the wood has been greatly increased, the configuration of the wood in the pile is more conducive to ignition and the air around the wood supplies enough oxygen to readily support combustion.

If the log is reduced to dust in fine particle size and suspended in a cloud with air around the particles, the dust cloud will burn so violently a flash fire will occur. The energy released within the few seconds that the cloud takes to burn depends on the size of the particles and the specific properties of the wood used. Think of the log taking hours to burn all of the wood to ash. That same wood and the energy needed to convert the log to ash are released in a matter of seconds.

Imagine that dust in a cloud with perfect density in air ignites in an open field with nothing around it. The fireball, or deflagration, is spectacular, and there is limited or no resultant damage other than the loss of the wood

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West Pharmaceutical Services, Kinston, NC, January 29, 2003. Six people lost their lives, and 38 were injured.

dust. Now imagine that same energy release in a confined space such as a machine or building. The pressure wave from the rapid burning of the dust cloud tries to expand quickly. The vessel contains the pressure and allows it to build until it rapidly bursts out of its confinement. This is typically called a dust explosion.

In the wood dust cloud scenario, people nearby may be injured or killed, and significant property loss can occur to the machine or building involved. This is the same principle used in forcing a bullet out of a gun at a high rate of velocity. The rapid burning of a material in the shell casing separates the bullet from the casing, forcing the projectile out the barrel of the gun and into the path of least resistance.

Explosible Range of Dust Clouds

Not all dusts are combustible. Some, such as sand, cement and rock, are typically not combustible. Organic dusts such as plant dusts are combustible. These include a wide variety of materials, such as sugar, flour, grain, linens, etc. Many synthetic organic materials, such as plastics, organic pigments and pesticides, are combustible. Coal and peat are combustible, as are some metals, such as aluminum, magnesium, zinc and iron.

The presence of the dust does not in and of itself make an explosive condition. The proper conditions must exist to realize a dust cloud deflagration or explosion. The dust must be of the proper size. A material must be of the correct particle size to enter into an explosive reaction.

One difficulty of dust accumulation is that a pile of dust may have many varied size particles. If even a small percentage of the particles are conducive to an explosion condition, the small percentage of particles of the correct size and physical characteristics may ignite. Generally, the smaller the dust particles, the more intense the rate of burning and the more devastating the explosion. A 40-mesh screen or approximately a 420-micron particle is a sufficient size for many dusts to be in the appropriate range. In the case of fibers, while they may be unable to easily pass through a screen, fine fibers are also candidates for rapid burning, resulting in an explosion.

The density of a dust cloud must also be in the proper range for that particular material. This is usually measured in grams/cubic centimeter or grams/cubic meter. Explosible dust tables identify the density and particle size that lend to an explosible condition. A finely divided solid or a dust must be dispersed in an atomizing medium. The cloud must be in the proper dispersion proportions in an oxidizing medium, such as air, oxygen or other industrial gas mixture.

A cloud will not start to burn without an ignition source. Ignition sources may include smoldering or burning dusts; open flames from welding, cutting, matches or lighters; hot surfaces, such as heaters, ovens, furnaces or hot bearings; heat from mechanical impact; and electrical discharges or arcs.

In addition to the ignition source, the material must be in the proper moisture content range. Typically, the drier the dust, the more susceptible it is to entering into the combustion process.

How Does a Dust Form a Cloud?

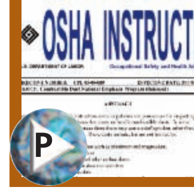
Dusts may form clouds in many ways. Grain discharging from a chute into the air when filling a silo can create a cloud. Emptying a silo through a valve at the base may also create a cloud. Pouring bags of dusts into a mixing chamber can create a dust cloud. Just about any bulk handling of dusts may lead to a potentially dangerous dust condition if the proper precautions are not followed.

Dust transported in a stream of air may cause a dust cloud condition inside plant ducts. Bag houses may also contain dust clouds. Plant ducting is such a common fixture that many do not think of a dust condition within the confines of the dust collecting system. The motors, gears and bearings, which may be part of these systems, can lead to an ignition and explosion if a malfunction occurs.

Dryers may contain a dust cloud. Some dryers have a particulate-laden liquid sprayed into a chamber under high pressure and temperature. As the material falls through the drying chamber, the moisture is removed, leaving a fine dry powder or dust in the base to be removed as a finished or intermediary product.

At some point in the dryer between the top at 100% moisture content and the bottom at 0% moisture content, an explosive condition is met in a portion of the vessel. Explosion does not occur on a daily basis because there is an insufficient ignition source inside that portion of the chamber. Some processes may use an inerting medium within the drying chamber to help prevent ignition.

Other processing equipment used in many various industries may also create dusts. Even if a primary process or product is not dust-related, dust hazards may still exist and should be safeguarded. Cutting equipment such as saw blades will create dust. Abrasion equipment used in sanding or polishing processes may create dust.



Grinding, pulverizing, mixing and screening equipment are in many various forms depending on the industrial process in use.

The atmosphere of the operating area may even create a potentially hazardous area. A coal mine by nature will have coal dust potential. The grinding, shoveling and conveying of coal lends itself to dust potential.

Dust in a manufacturing facility may accumulate on equipment and building surfaces. Any ledge in a building may be an accumulation point for dust. Roofing system members, such as bar joists, are also common accumulation points. A cloud may form when the dust falls from the equipment or building ledges. This may occur during cleaning. An equipment upset, earthquake or any other cause of building shaking may dislodge the dust from the members.

As dust falls, it disperses in the air. If the particle size is proper and the density of dust in the volume of air and an ignition source come together, a dust cloud deflagration or explosion may result. This initial pressure wave may serve to loosen more dust from other members, creating a second and potentially larger cloud, which may again ignite with a larger pressure from setting up even more subsequent events until a devastating explosion takes place. Witnesses of dust cloud explosions have reported that one or two small bangs occurred, followed by the lights going out, then a subsequent major explosion. This phenomenon may not be the lights going out but rather a dust cloud forming in such proportion that it obscures the ceiling lights then explodes with major proportion.

NFPA Standards & Dust Explosion

The following NFPA standards and code pertain to dust explosion:

•NFPA 654: Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing and Handling of Combustible Particulate Solids;

•NFPA 655: Standard for Prevention of Sulfur Fires and Explosions;

•NFPA 664: Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities;

•NFPA 61L: Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities (2002 Edition);

•NFPA 68: Standard on Explosion Protection by Deflagration Venting;

•NFPA 69: Standard on Explosion Prevention Systems;

•NFPA 2113: Standard on Selection, Care, Use and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire;

•NFPA 70: National Electrical Code

Preventing Explosible Dust Clouds & Explosions Through Design

NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing and Handling of Combustible Particulate Solids, discusses many aspects of preventing dust explosions. One leading item is designing the processes and facilities that handle combustible particulate solids appropriately. The design must take into account the physical and chemical properties that establish the materials' hazardous characteristics.

The building and processes should undergo a thorough hazard analysis. The study should look at equipment design, process procedures, worker training, inerting and other protection means. The process system should be designed to limit fugitive dust emissions to a minimum.

Any changes, additions or modifications to the system or process should be reviewed in a management of change evaluation. The major objectives in the review should be life and property conservation.

Structural integrity and damage-limiting construction are an important aspect. Mitigation for the spread of fire and explosion should be designed into the system. The design should adhere to existing codes and be of sound, proven technology and technique. NFPA 654 provides many sound methods for the design of dust-related occupancies and references several other NFPA codes and standards for specific concerns.

One leading item is designing the processes and facilities that handle combustible particulate solids appropriately.

Deflagration venting can prevent an unvented dust deflagration. Buildings should be built of damage-limiting construction. This may include a blowout wall construction in which predesigned friction fit or frangible fastener panels are installed to relieve in the event of a dust ignition.

Machines should have venting. This may be performed in many ways, such as hinged, weighted doors, bursting disks and other acceptable features.

Automatic Suppression of Dust Explosions

In 1912, the first patent for a fast-acting dust explosion suppression system was obtained in Germany. It was called the rapid dry powder extinguisher. Both the British and Germans realized in World War II that most of their total losses of aircraft were from fires. Fast-acting extinguishers were developed using pressurized extinguishers with large discharge orifices and were equipped with quick-release valves operated by explosive charges.

These same features apply to today's automatic extinguishing systems. Detectors may be pressure-sensitive, ultraviolet or infrared. In the past, halogenated agents were used in extinguishing systems. Today, due to environmental issues, powdered extinguishing agents are typically in use.

Management Program

Management is ultimately responsible for ensuring that appropriate precautions are implemented and main-

Housekeeping conditions such as this may lead to a major loss incident.

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tained. However, safety is not a top-down program; all employees should be a significant part of a proactive program. Training should be provided for all who enter the facility. Self-inspection programs should be implemented. Maintenance to maintain equipment in proper working condition is also important.

Self-Inspection Program

A self-inspection program must be implemented to ensure safe conditions. This program should be reviewed by management frequently with corrective actions taken immediately. Such a program should include housekeeping conditions and all of the systems in place to safeguard the operation from loss.

Fire and explosion prevention and protection equipment should be inspected in accordance with applicable codes. Water-based systems should be inspected in accordance with NFPA 25, Standard for the Inspection, Testing and Maintenance of Water-Based Fire Protection Systems. Alarms should be inspected in accordance with NFPA 72, National Fire Alarm Code. Other systems should be inspected in accordance with their related codes and standards.

Dust control equipment should be inspected, and potential ignition sources should be identified. Electrical systems and interlocks should be inspected. Changes should be identified and processed, and maintenance, such as lubrication of bearings, should be completed. Self-inspection, maintenance and repair records should be maintained.

Housekeeping

Maintaining a facility in a state of good housekeeping is an important part of the daily activities to be followed in a facility that processes dusts. Good housekeeping will help keep dust accumulations below the explosible range. A tight process system operated with care should limit fugitive dust emissions to a minimum, however, management should maintain a regular cleaning schedule.

Depending on the NFPA code referenced, dust accumulations should not exceed 1/16 in. or 1/32 in. This is about the thickness of a dime. While bulk density methods may be used to establish acceptable dust accumulation thicknesses, NFPA 654 does not yet provide these calculation formulas. The next revision of NFPA 654 may include such provisions. NFPA 654 requires that regular cleaning frequencies be established for walls, floors and horizontal surfaces, such as equipment, ducts, pipes, hoods, ledges and beams, and above suspended ceilings and other concealed surfaces to minimize dust accumulations.

The inspection program for housekeeping must be proactive and actively seek areas of dust accumulations. This includes roof members and hidden areas not readily visible from the floor level. Dust accumulations may be above the ceiling, as with the loss incident at West Pharmaceutical Services. Whenever fugitive dust emissions develop, an active repair program should be in place to make corrections to prevent future emissions. Vacuum systems should be used for cleaning dust emissions. Vigorous sweeping or blowing down with steam or compressed air produces dust clouds and generally is not recommended because a dust cloud may be formed. However, specific precautions in NFPA 654 must be met if blowing down must be performed.

Training & Procedures

Management should ensure that operating and maintenance procedures and emergency plans are developed. Regular and annual reviews and updates should be provided. Initial training should be implemented, and regular refresher training should be provided for all employees involved in operating, maintaining and supervising facilities that handle combustible particulate solids.

NFPA 654 also requires the employer to certify that training and review for employees have been provided. In addition to employee training, it may be prudent to provide awareness and procedure training for contractors and visitors.

Fugitive Dusts: An Insidious Workplace Hazard

When Bresland spoke before the U.S. Senate Committee on Health, Education, Labor and Pensions Subcommittee on Employment and Workplace Safety about the Imperial Sugar refinery loss on July 29, 2008, he stated, "Combustible dust is an insidious workplace hazard when it accumulates on surfaces, especially elevated surfaces." Between January 2006, when CSB released its study on dust explosions, and July 29, 2008, when Bresland testified, 82 dust explosions were reported. This is an average of almost three explosions per month. This record must be improved. With a new awareness and diligent care, U.S. industry can help change these dust explosion statistics. ✪

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