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Savannah Sugar…Case Studies of Recent Dust Explosions

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Introduction

Exhibit 1. Imperial Sugar Refinery's Savannah facility after the explosion. Thirteen workers died, and 39 were injured in this incident. Dust accumulations far exceeded NFPA's recommended limits. (Photo courtesy U.S. Chemical Safety and Hazard Investigation Board.)

On July 29, 2008, Mr. John S. Bresland, Chairman and Chief Executive Officer of U.S. Chemical Safety 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 1998, the year that the CSB was established, three out of the four deadliest accidents they have investigated were determined to be combustible dust explosions.[1] Thirteen workers died, and 39 were injured, at the Imperial Sugar refinery on February 7, 2008. Twenty-three people were burned from the fire and explosion, three of whom were still hospitalized in a burn center after five months of treatment. At West Pharmaceutical Services in Kinston, North Carolina, six workers were killed and 39 injure in a polyethylene dust explosion on January 29, 2003. The fuel for the explosion was a fine plastic powder, which had accumulated above a suspended ceiling over a manufacturing area at the plant and had ignited. At CTA Acoustics, Inc,. in Corbin, Kentucky, seven people were killed and 37 were injured on February 20, 2003. This incident severely damaged a manufacturing plant of 302,000 sq. ft., and temporarily shut down four Ford Motor Company vehicle manufacturing plants for a time. Combustible phenolic resin dust had accumulated throughout the facility and was the fuel for the explosion.

Exhibit 2. West Pharmaceutical Services, Kinston, NC, January 29, 2003. Six people lost their lives, and 38 were injured. (Photo courtesy U.S. Chemical Safety and Hazard Investigation Board.)

In November 2006, the CSB completed a study on combustible dust. The CSB found that combustible dust explosions have been a recurrent cause of disasters at U.S. industrial facilities. Their 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.[2] The Board 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 Material Safety Data Sheets (MSDSs) to better communicate dust hazards to workers.[3]

As a follow-up to the Workforce Protections Subcommittee hearings, titled ‘‘Have OSHA Standards Kept up With Workplace Hazards?” the Combustible Dust Fire and Explosion Prevention Act of 2008, as 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 prior to the end of the session. The bill stated that OSHA has not proceeded aggressively to prevent worker exposure to combustible dust fires and explosions.[4]

ASSE Weighs in on Combustible Dusts

On January 19, 2010, ASSE sent a formal letter to OSHA Regarding: *Combustible Dust—Advanced Notice of Proposed Rulemaking* (OSHA Docket No. OSHA-2009-0023). The letter may be found at: http://www.asse.org/professionalaffairs_new/communications/federal/docs/011910combdustcommentFINALe.docx.

On December 14, 2009, Adele Abrams, Esq., testified on behalf of ASSE at the public hearings in Washington, DC regarding: *Combustible Dust—Advanced Notice of Proposed Rulemaking* (OSHA Docket No. OSHA-2009-0023). The testimony may be found at: http://www.asse.org/professionalaffairs_new/communications/federal/docs/011910combdustcommentFINALe.docx.

ASSE remains a solid voice of the safety industry, continues to be involved in the OSHA Proposed Rulemaking process, and strives to significantly improve employers' safety and adherence to widely accepted practices of managing combustible dust risks.

Other Impacts from a Combustible Dust Explosion

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 the 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 down time. The cost of the business interruption to the company may be more than a company or plant can overcome. One of the factors the facility will need to overcome includes 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 cost of these upgrades may not be totally covered by the property insurance policy. The additional costs are a burden for an already suffering plant. Employees who are laid off after the event may find other jobs, and not return to the site after the rebuilding is completed. The cost of lost experience, and the cost of training new employees, is substantial.

The effects of such an explosion may also be devastating to a community. The loss of employee jobs may decrease the local community tax base. Other businesses surrounding the plant may also suffer, from the diner needing the plant for customer base, to the contractors and vendors who are no longer providing goods and services to the shut-down plant.

Other businesses may rely on this facility as a major purchaser of goods or as a major supplier of goods. As noted above, four Ford auto manufacturing plants were temporarily closed. If contingency business continuity plans have not been developed and tested, the other plants may also be negatively impacted by the loss.

What Is a Dust Explosion?

Imagine trying to start a log on fire. By itself, it will be difficult to start, and require a lot of 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, and 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. 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, and the kindling will burn with a higher rate of heat release, and will burn to ash very quickly. This is due to a number of factors, but 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.

Taking this analogy another step further, if the log is reduced to dust in fine particle size, and suspended in a cloud with air around all of the many 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 is dependent upon the size of the particles and the specific properties of the wood used. Think of the log taking hours to burn all the wood to ash. That same wood, and all the energy needed to convert the log to ash, is all released in the matter of a few seconds.

Imagine that dust in a cloud with perfect density in air, igniting 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 dust. This is often called a fireball or deflagration. Now, imagine that same energy release in a confined space, such as a machine or a building. The pressure wave from the rapid burning of the dust cloud tries to expand very quickly. The vessel contains the pressure and allows it to build until it bursts out of its confinement in a very rapid fashion. This is typically called a dust explosion. In the wood dust cloud scenario, there can be injury or death to people nearby, and significant property loss 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, 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.

Just the presence of the dusts 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 needs to be of the correct particle size to enter into an explosive reaction. One of the difficulties of dust accumulations is that a pile of dust may have many particles of various sizes. If even a small percentage of the particles are conducive to setting up an explosive condition, the small percentage of particles of the correct size and physical characteristics may ignite. Generally speaking, 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 not be able 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. There are explosible dust tables which identify the density and particle size that will lead 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 be from:

- 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
- Electrical discharges or arcs

In addition to the ignition source, the material needs to 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 various 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.

Ducts in a plant may have a dust cloud condition inside the duct. The dust may be transported in a stream of air. Bag houses may also contain dust clouds. Ducting through plants is such a common fixture, many do not even 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 resulting explosion if there is a malfunction.

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 very 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 zero percent moisture content, there is a portion of the vessel in which an explosive condition is met. The reason there is no explosion on a daily basis is that there is not a sufficient 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 various industries may also create dusts. Even if your primary process or product is not a dust-related product, 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 dust creators 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 due to being a coal mine. 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 be during such activities as cleaning. An equipment upset, earthquake, or any other cause of building shaking may dislodge the dust from the members. As the dust falls, it disperses in air. If the particle size is proper, 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 larger pressure, setting up even more subsequent events, until a devastating explosion takes place. Witnesses of dust cloud explosions have reported that there were one or two small bangs, 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 and Dust Explosion

The following NFPA standards pertaining 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 61	*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*

There are many associated standards with one of the major codes, NFPA 70, *The National Electrical Code.*

Preventing Explosible Dust Clouds and Explosions Through Design

Unfortunately, there is no easy answer to preventing explosions. 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 of the leading items 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 hazardous characteristics of the materials. The building and processes should undergo a thorough hazard analysis study. 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. The structural integrity and damage-limiting construction are important aspects. 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 a number of sound methods for the design of dust-related occupancies, and references several other NFPA codes and standards for specific concerns.

Deflagration venting is a major factor in preventing an unvented dust deflagration. Buildings should be built of damage-limiting construction. This may include a blow-out wall construction, in which predesigned friction fit, or frangible fastener panels, are installed to provide relief in the event of a dust ignition. Machines should be provided venting. This may be performed in a number of ways, such as hinged, weighted doors, bursting disks, and other acceptable features.

Automatic Suppression of Dust Explosions

The first patent for a fast-acting dust explosion suppression system was in 1912 in Germany. It was called the "rapid dry powder extinguisher." Both the British and Germans realized during World War II that most of their total losses of aircraft were from fires. Fast-acting extinguishers were developed, using pressurized extinguishers with very large discharge orifices, and equipped with quick-release valves operated by explosive charges. These same features apply to today's automatic extinguishing systems. The detectors may be pressure-sensitive detectors, or ultraviolet or infrared detectors. In the past, halogenated agents were used in extinguishing systems. Today, due to environmental issues, powdered extinguishing agents are typically in use.

Management Programs

Management is ultimately responsible to ensure appropriate precautions are implemented and maintained. However, safety is not a top-down program; all employees should be a significant part of a pro-active 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 Programs

Self-inspection programs must be implemented to ensure safe conditions. The self-inspection program should be a frequent, written program that is reviewed by management, and under which corrective actions are taken immediately. The self-inspection 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 the 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. Potential ignition sources should be identified. Electrical systems and interlocks should be inspected. Changes should be identified and processed. It should be verified that maintenance, such as lubricating bearings, is completed. Records of the self inspections and resultant maintenance and repairs performed should be maintained.

Housekeeping

Maintaining your facility in a state of good housekeeping is an important part of the day-to-day activities to be followed in a facility that processes dusts. Good housekeeping will help keep the dust accumulations outside of 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.


Exhibit 3. Ducts, conduits, and building members should be maintained free of dust accumulations.

Depending on the NFPA code referenced, dust accumulations should not exceed 1/16 inch or 1/32 inch. 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 regular cleaning frequencies be established for walls, floors, and horizontal surfaces, such as equipment, ducts, pipes, hoods, ledges, 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 that are not readily visible from the floor level. Dust accumulations may be above the ceiling, as with the loss incident at West Pharmaceutical Services in Kinston, North Carolina. 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 is not generally recommended because a dust cloud may be formed; however, there are specific precautions in NFPA 654 that need to be met if blowing down must be performed.

Exhibit 4. Housekeeping conditions such as this may lead to a major loss incident. (Photo courtesy U.S. Chemical Safety and Hazard Investigation Board.)

Training and Procedures

Management should ensure that operating and maintenance procedures and emergency plans are developed. Regular and annual reviews and updates should be provided. An initial training program 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 that the employer 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 Are an Insidious Workplace Hazard

When Mr. 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 the CSB released its study on dust explosions and July 29, 2008, when Mr. Bresland testified, there were 82 reported dust explosions. This is an average of almost three explosions a month. This record needs to be improved. With a new awareness and diligent care, U.S. industry can help change these dust explosion statistics.

CSB Links

The main web page for the U.S. Chemical Safety Board is http://www.csb.gov.

CSB Report No. 2006-H-1 titled, “Investigation Report: Combustible Dust Hazard Study” may be found at:
http://www.csb.gov/assets/document/Dust_Final_Report_Website_11-17-06.pdf

The webpage to find the final report and video presentation of the Savannah Sugar Refinery explosion is: http://www.csb.gov/investigations/detail.aspx?SID=6&Type=2&pg=1&F_All=y

The web page for the PDF of the final report on Imperial Sugar is:
http://www.csb.gov/assets/document/Imperial_Sugar_Report_Final_updated.pdf

The webpage to find the final report of the West Pharmaceutical Services Dust Explosion and Fire, Kinston, NC, may be found at:
http://www.csb.gov/investigations/detail.aspx?SID=36&Type=2&pg=1&F_All=y

The web page for the PDF of the final report on the West Pharmaceutical Services Dust Explosion and Fire may be found at:
http://www.csb.gov/assets/document/CSB_WestReport.pdf

The webpage to find the final report and video presentation of the CTA Acoustics Dust Explosion and Fire, Corbin, KY, may be found at:
http://www.csb.gov/investigations/detail.aspx?SID=35

The web page for the PDF of the final report on the CTA Acoustics Dust Explosion and Fire, Corbin, KY, may be found at:
http://www.csb.gov/assets/document/CSB_CTA_Investigation_Report.pdf

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U.S. Chemical Safety and Hazard Investigation Board, *Investigation Report, , Combustible Dust Hazard Study, Report No. 2006-H-1*, November 2006.

United States Department of Labor, Occupational Safety & Health Administration, *Hazard Information Bulletin - Dust Explosion Hazard in Certain Textile Processes*, October 6, 1998.

[1] Oral Testimony of John S. Bresland, Chairman and Chief Executive Officer, U.S. Chemical Safety Board

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[2] Oral Testimony of John S. Bresland, Chairman and Chief Executive Officer, U.S. Chemical Safety Board Before the U.S. Senate Committee on Health, Education, Labor, and Pensions Subcommittee on Employment and Workplace Safety, July 29, 2008.

[3] U.S. Chemical Safety and Hazard Investigation Board, *Investigation Report, , Combustible Dust Hazard Study*, Report No. 2006-H-1, November 2006.

[4] U.S. House of Representatives, *Combustible Dust Explosion And Fire Prevention Act Of 2008*, HR 5522, March 4, 2008.