Combustible Dust... Elements of Dust Hazard Assessment

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Presentation: June 25, 2013

Introduction

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 that they had 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 which 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 injured 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. And, 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.

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 Department of Labor's Occupational Safety and Health Administration (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 to better communicate dust hazards to workers.

Combustible Dust Assessment

Combustible dust assessments are performed to assist management in identifying and defining hazardous conditions and risks so they may be eliminated or controlled. The analysis should examine the process, systems, subsystems, components, actions (or lack of actions), and their interrelationships.

The assessment and review of what can go wrong may not be an easy task. Many dust losses are not the result of a single cause. Rather, it is the confluence of multiple events which occur simultaneously or in a chain of events. Systems should be designed using methods considered to create a "safe" situation. The reliability of the components and assemblies must also be considered. When components or assemblies fail the initial design parameters are compromised. The compromised system is outside of the normal scope of design, and a loss is much more likely to occur.

A dust hazard analysis may be used wherever a dust condition exists. It may be a process which involves drying a liquid sprayed into a drying chamber. It may involve grinding, sifting, screening, or other manipulation of a product. The dust may be released from the process of pouring ingredients from a bag into a vessel. It may be dust within a conveying system. The dust may be tramp dust emissions, or escape material from process leakage points in a manufacturing situation. Dust may also be present from inadequate housekeeping. Dust hazards may exist where large pieces of material are handled, but in the manufacturing process, dusts are created in small amounts and allowed to accumulate over time.

There are good reasons to perform and document a Dust Hazard Analysis. The first is that a well performed hazard analysis will lessen the probability of a loss occurring. The analysis will help you identify hazards and implement safeguards. Those hazards may be mitigated through design or procedures to prevent a loss from occurring.

A good Dust Hazard Analysis will use recognized standards and levels of conduct considered to be what a prudent person would normally do to prevent a loss. It shows you have followed industry standards in your design and operation. It is a documented methodology to defend your actions. After a loss, especially one which takes a person's life, the documented Dust Hazard Analysis will show help in determining the cause.

Compatibilities are reviewed to ensure compatible parts and methods are being used and followed. It will ensure that a level of specification is followed and inferior components are removed from the process.

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 it 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, and 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 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 and igniting in a open field with nothing around it. The sight of this burning 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 which act like a vessel to contain the deflagration. 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 a dust explosion! In the wood dust cloud scenario, there can be injury or death to people nearby, and significant property loss to the machinery or building involved.

Explosible Range Of Dust Clouds

Not all dusts are considered 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 is combustible, as are some metals such as aluminum, magnesium, zinc, and iron.

The mere 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 varied sizes of particles. If even a small percentage of the particles are conducive to setting up an explosion condition, that 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 which will lend to an explosible condition.

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.

Many factors must come together at the same time for an explosion to occur. Some facilities may operate for many years without an explosion, then one day, all the characteristics which are needed for a deflagration come together at the same time, and a violent dust explosion occurs.

How Do I Know If My Dust Is Combustible?

Many dusts are known to be combustible. Organic substances such as sugar, wheat flour, and corn starch are known combustible materials. You may reference the MSDS sheet provided by the supplier or manufacturer. There are reference books which will identify if the material is combustible. Other materials may not be as readily identified as a combustible dust. In these cases, testing may be performed on the material. If you are not sure, or the dust has not been tested and confirmed as noncombustible, it should be considered a combustible dust.

Considerations when determining whether a dust is combustible include the material, the size, the dispersion density, the oxidizing medium, the energy source. The material may be tested by a laboratory. The laboratory may determine the material is noncombustible, and that is many times the extent of the testing required. In the event the laboratory test identify the material as combustible, they will identify the particle size, specific gravity, bulk density, and identify the moisture content. A report will be provided identifying the properties of the material.

Then, ignition testing may be performed. The laboratory will recommend the testing methods to employ, and will work with you to fully identify the combustibility and energy production from the material.

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 are 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 being 100% moisture content, and the bottom at a 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 many 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 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 becomes a dispersion 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. The initial pressure wave may serve to loosen more dust from other building members creating a second, and potentially larger cloud. This secondary resultant dust cloud may also ignite with a larger pressure wave. Additional, larger, and more explosions may then occur, each larger than the last. Witnesses of dust cloud explosions have reported that there was 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 exploding with major proportion.

Codes and Standards

We follow several codes and standards. Each is written with an objective or purpose in mind, generally to help make a process or installation more safe. The governing rules and regulations we follow throughout our daily routines come from many sources. They may be acts of government, codes of conduct, codes of design, regulations, specifications, and guidelines. An individual or entity may value the various governing rules with different levels of interest. Nonconformance to standards may not have a detrimental effect on most days, and for long durations of time. Unfortunately, one day when we least expect it, nonconformance to good practice may become evident. The evidence maybe injury, loss of property, loss of business continuity, bad press, or death of employees.

Standards are a basis for design and most have been written as a direct result of a catastrophe, major loss, or multiple deaths. There is usually a very good reason for every paragraph written into a standard. They are the *minimum* level of care and design required to make a process or task reasonably safe. Minimum standards are just that, minimum standards. If an installation, process, or procedure fails to meet the minimum prescribed in a standard, it should be considered an unsafe situation.

NFPA Standards And Dust Explosion

The following NFPA standards 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 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 primary 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 is 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 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 relieve 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. Attention to such details can help in decreasing losses not only to buildings and equipment, but also life.

Automatic Suppression Of Dust Explosions

Fast acting fire extinguishing systems may be installed in enclosures to help prevent an uncontrolled deflagration and pressurization. Pressure sensitive, ultraviolet, or infrared detectors are used to sense the dust cloud ignition very early in its propagation and trigger the release of an extinguishing agent. In the past, halogenated agents were used in extinguishing systems. Today, due to environmental issues, powdered extinguishing agents are typically in use.

Management Programs, Training, And Procedures

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.

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 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 the 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.

In addition, self-inspection programs should be implemented. Ongoing maintenance to all equipment to ensure that it remains 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 which is reviewed by management, and for which corrective actions are taken immediately when deficiencies are found. 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. Identify process changes. The program should verify that maintenance, such as lubrication or bearings, is being completed. Records of the self-inspections and resultant maintenance and repairs performed should be well documented and maintained on file.

Housekeeping

Maintaining your facility in a state of good housekeeping is an important part of day to day activities , and is essential for processes that produce dusts. Good housekeeping will help keep the dust accumulations outside of the explosible range. A tight process system being operated with care should keep fugitive dust emissions to a minimum. It does not, however, take the place of maintaining a regular cleaning schedule.

Dust accumulations should not exceed defined limits. NFPA 654, Paragraph 6.1.1.1. states, "Those portions of the process and facility interior where dust accumulations exist external to equipment in sufficient depth to prevent discerning the underlying surface color shall be evaluated to determine if a dust explosion hazard or flash fire hazard exists."

Dust flash fire or dust explosion hazard areas should be evaluated by performing additional evaluations. The four methods identified in NFPA 654 include: Layer depth criterion method, Mass Method A, Mass Method B, or Risk Evaluation Method. Each method is described in the standard.

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 known to accumulate dust. 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 for that reason, is not generally recommended . However, if blowing down must be done, there are specific precautions in NFPA 654 which need to be met.

A Look Back in Time

In the grand scheme of the Industrial Revolution, systemized educational curriculums for safety and hazard analysis are relatively recent. Only a few decades ago, finding a college curriculum majoring in safety, fire protection, or process hazard safety were limited. Fortunately, today, such programs are more available and have sprung up at several colleges and universities around the country. Even in universities without dedicated safety programs, safety courses are offered, and even required, in many engineering curriculums. Safety is a topic of discussion in all aspects of engineering.

Early systematic processes were identified in aviation and military applications. Equipment or system failure at 20,000 ft. is not always a survivable event. Moving into the space age, NASA learned through failures that a systematic process must be followed to identify points of failure in each system installed and implemented into the space vehicles launched into outer space.

In the 1960's, the process and chemical industries embraced Process Hazard Analysis. Calling it HAZOP, for Hazard and Operability Method, it became better identified and published in the 1970's. Its introduction into process safety regulations in the 1980's and 1990's caused a dramatic increase in the implementation of the process. Industries performing high hazard operations have incorporated process hazard analysis into their design and analysis procedures.

Sometimes, product liability drives the need for safety analysis. Today, auto makers perform hazard analysis for each vehicle they make, but this was not always so. Prior to the 1970's, safety hazard analysis studies were not routinely performed on new car designs. One prominent example was the Ford Pinto. Its gas tank had a tendency to explode into flames upon rear impact. According to some accounts, Ford Motor Company performed cost benefit analysis and identified that the cost to make changes to the vehicle would be greater than the cost of anticipated legal claims. The legal battles over occupant deaths and injuries of the Ford Pinto changed the auto industry's attitude toward safety analysis on their auto designs. Today, auto makers routinely analyze their vehicles for failure in an attempt to identify weaknesses. The industry has changed over the last 40 years and vehicle safety is a major selling point.

Today, the practice of performing hazard analysis is spreading across general industry. Hazard analysis and safety assessments are provided for many reasons. Companies are concerned with product liability, safety of a hazardous process, property conservation, business continuity, and worker safety. While many corporations have concerned management, there are some who will be dragged into the process through losses, government fines, and litigation.

Hazard Analysis and Combustible Dust

Regarding combustible dust, NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids, requires that the design of the fire and explosion safety provisions be based on a process hazard analysis.

NFPA 654, Section A.4.2.1 discusses that the requirement of a process hazard analysis may be satisfied when the analysis is conducted in accordance with the methods outlined by the AIChE Center for Chemical Process Safety in Guidelines for Hazard Evaluation Procedures.

An important provision identified in the standard is that the process hazard analysis be reviewed and updated at least every 5 years. This is extremely important to confirm the process integrity. It is an opportunity to review the process and procedures as they are currently implemented, and incorporate newly developed safety methodologies.

NFPA 654, A.4.2.1 identifies some key points to consider when determining if a dust deflagration hazard exists:

- Determine if the dust is explosible using laboratory testing.
- Determine where in the process a dust cloud may exist. Loss records and knowledge of process conditions should be used.
- Identify likely ignition sources. Recognize that ignition sources are complex and not always predictable. It is best to assume ignition is possible in all cases.
- Consider what the predictable consequences might be. Be conservative and assume a worst case scenario. Both predictable primary events and less likely secondary events should be considered. Is the risk tolerable? How can the risk be reduced?
- Identify probabilities for an event to occur. Some materials will have a greater likelihood of an event than others.
- Assign accountability and responsibility for the program, including the implementation and follow-up of improvements.

Should Our Facility Have A Combustible Dust Assessment?

Every facility which manufactures, processes, handles, or otherwise has dust in its facilities should perform a dust hazard analysis. The analysis should be performed by a multidisciplinary team of people. This will allow for varied perspectives and backgrounds to provide input into the process.

Methodology

When a process is designed and installed, codes, regulations, standards, and ordinances are followed in the construction process. The design is using these prescriptive methods to prevent a loss. Your dust assessment needs to go a step farther. Dust assessment is not a cut and dried program or procedure. Your dust assessment should be performance-based. At this moment, there is no specific dust assessment analysis or procedure to follow. A well developed assessment depends upon the discipline and ingenuity of those involved. Recognized and Generally Accepted Good Engineering Practice (RAGAGEP) should be followed in the evaluation. A very good basis for your analysis is to follow process safety management procedures. Although PSM is designed for the chemical industry, the processes, procedures, and documentation used in PSM will readily transfer to dust hazard analysis.

A good dust hazard assessment will have many benefits. Some of the benefits include:

- A reduction in the probability of loss.
- A reduction in the severity of a loss.
- It will help ensure compliance with regulatory standards.
- It will help bring management and employees together to solve a common problem.

A dust hazard assessment should be performed as a normal course of business. As the process changes, the hazard assessment should be updated through a management of change program.

Senior management must drive the program and initiate the program from top management down. Hazard assessment is not a delegated responsibility. Senior management should take an active part in the program and process and incorporate hazard assessment into the corporate or plant safety culture.

Who Should Be Involved In The Hazard Assessment Team?

The makeup of the assessment team will depend upon the size or complexity of the process. The team may be as small as a few people were as many as 8 to 12. The team should be limited to the fewest number of people to provide an effective analysis. However, once the analysis is performed and documented, all levels of management, including the plant manager or CEO, should perform a review and upon their acceptance, sign the document.

Most teams have three basic roles. There should be a team leader to act as the facilitator. This person should be the main contact between the members, management, and employees. A scribe should be designated to formally document the discussions and techniques being used. It is important to document the process and methodology used by the team. The remaining members of the team will contribute to the study. Team members may be experts in the process, maintenance managers, safety managers, operators, or department managers. Ultimately, top management is responsible for the success or lack of success in the assessment.

Preparation For The Hazard Assessment

The analysis and review should fit the process and conform with RAGAGEP. The analysis will include three primary steps: preparing for the review, performing the review, documenting the results.

When preparing for the review, the team should gather and discuss possible sources of information to be used during the assessment. A conceptual plan should be outlined. The outline should identify the scope and goals of the team, team member responsibilities, schedules and deadlines, desired outcomes, communication procedures, and other requirements of the team. Relevant information should be gathered and assessed.

The scope of the study should be clearly identified. The portions of the process to be evaluated should be clearly agreed to by the team before work begins. This may require breaking the process into separate hazard assessment parts to cover the entire process. The scope may also identify specific consequences to be addressed in the study. This study could be specific to PPE, property protection, exposure protection, business continuity, or other significant consequence.

Team members should be selected based upon the specific area of expertise they bring to the team. Each team member should be utilized to maximize their potential. Some team members may address multiple areas of expertise. It is important that the team members work together to create a synergistic effect.

When the team is initially assembled, an outline of the objectives should be presented. The process should be reviewed in detail so that all members have a common basis for the study. Flowcharts, flow diagrams, and piping and instrument diagrams (P&IDs) should be available for all members.

A total facility walk down should be performed after the overview meeting. The walk down should allow adequate time for questions and comments between team members. If the facility is not yet in operation, visiting another operating facility at another location may be helpful.

Hazard Identification Methods

Performing the review should identify hazards. These hazards should consider physical characteristics of the process and where breakdown in the process may occur. Causes of a dust explosion should be identified. Each cause should be quantified as to the severity and probability, how the cause is a hazard, location, and ways to mitigate an explosion or undesired effect.

The selection of an appropriate hazard identification method should incorporate two separate and distinct steps. The first step is to identify the process hazards. The second step is to evaluate whether the existing or proposed safeguards are adequate to control those hazards.

A hazard is a physical, chemical, particle size, or orientation characteristic that has the potential for causing harm to people, property, business continuity, or the environment. Undesirable consequences should be identified. In the case of dust hazards, dust explosion and/or flash fire may be the primary consequence.

After the consequences are defined, the team can identify the systems, processes, and plant characteristics that may be of interest in the hazard analysis. It is important that the hazard identification technique be thorough and that all important hazards are identified. The team should not discount hazards simply because the design or installation meets applicable codes or standards. Codes and standards are minimum requirements and the team must understand that if the design does not extend beyond what is required in a code or standard, the process has been installed using a minimum permitted criteria. It is not an optimal installation with regard to protection safeguards. The team should not discount hazards based upon an installation meeting minimum codes.

Past experiences of the process may provide important clues to hazards. Operators and maintenance employees should be interviewed for their thoughts and input. Even if they are not specifically on the team, the team can profit from their experiences.

Recommendations from outside consultants, insurance carriers, fire marshals, audit teams, and others should be evaluated. These outside organizations have additional experiences beyond your facility and process. Capitalizing on their input may be advantageous.

Checklists are a very good tool to use in identifying hazards and they are available from many sources. Checklists from associated hazardous processes may be useful to identify points which may also be found in your facility or process.

The physical characteristics of the materials handled should be fully and clearly identified. Physical characteristic of dust may vary even within the same process envelope. A grinder may produce a given particle size, however, there is a strong potential for smaller particles sizes to also be produced. Some of these small particles may become airborne and land on building and equipment surfaces. Even the off-specification materials should be evaluated as part of the hazard analysis.

After the hazards have been identified, they should be listed in the assessment reports. A ranking system should be used to identify the severity and frequency of the consequences.

Analysis Procedure

The analysis procedure should cover all aspects of the hazard. The procedure should also identify undesired consequences and protection features installed. Alternatives that could reduce or eliminate the hazard should be identified. Some considerations to be incorporated into the review include:

<u>Site selection</u>
Site identification is possibly one of the most important factors in mitigating major loss. Hazardous processes involving dust should be made based upon separation from any other process or exposure. An upset and consequential dust explosion in a process may have major consequences. These consequences will be exponentially increased when other operations or areas of the plant facility become involved. This process site should be selected so that in the event of a catastrophic explosion, people, surrounding equipment, surrounding critical processes, areas significant to the business continuity of your operation, and neighbors to your facility are not impacted.

<u>Equipment Hazards</u>
Equipment hazards should be identified. Some hazards may include mechanical sparking, introduction of foreign materials, frictional heat, or bearings which may overheat. Some of the more difficult equipment hazards are those hazards not as readily observed, such as mechanical failure, breakdown, or overheating.

Electrical Sources

Electrical sources are readily identifiable, such as electrical energy for motors, conveyors, and material moving equipment.

One of the first considerations is to identify the electrical classification of the area or room volume. NFPA70, the National Electrical Code (NEC), Chapter 5, Special Occupancies, addresses hazardous locations. It defines the classification of several special occupancies, such as flammable liquids, gases and vapors; combustible dusts; and other materials. It is meant to integrate with other NFPA standards that more fully address the particular occupancy. For electrical issues, the NEC defines what electrical devices are permitted in a given area. The definitions located in section 500.2 are important to know when addressing special occupancies. This section defines terms such as dust ignition-proof, dust tight, and purged and pressurized.

Section 500.5 defines the classification of special occupancies. When discussing combustible dusts, most are classified as Class II locations. Class II locations are those that are hazardous because of the presence of combustible dust.

Safety Related Equipment

There is a high probability that there are many safety related features built into your process. Some of these may be instrumentation interlocks to shut down the process upon upset or operations outside of given parameters. Fire protection systems may be installed to detect or discharge fire extinguishing agents. Fire sprinklers, deluge systems, or vessel explosion suppression systems may be installed. Explosion venting may be installed to direct a blast to a safe location.

Human Factors

Human factors will vary as to the process and the amount of human intervention required. Modern systems depend on automation to perform many tasks. Process sensors send critical data to a control room operator and will limit the amount of human intervention needed within the process enclosure. Despite the technological level involved in the process, an operator is ultimately responsible for the process. Operators and maintenance personnel may be required to enter the enclosure to inspect equipment, make adjustments, provide maintenance, or make repairs. Operator intervention must be factored into the assessment. For almost every human activity there is a positive and a negative factor.

Housekeeping

Good housekeeping cannot be stressed enough in any industry, but even more so in occupancies where dust is present. Regular housekeeping should be provided in facilities that handle dust. Walls, floors, ledges and other surfaces should be vacuumed, broom-swept, water-washed or cleaned regularly so no dust accumulates. Keep elevated accumulations to a minimum. Avoid the practice of blowing down dust with compressed air.

Housekeeping activities should be initiated whenever dust is spilled or released. In the event of a system upset or deflagration, dust located on elevated walls or ledges may be shaken loose and may form a cloud as it drops to the floor. Other areas of concern are where dusts are introduced into the production stream, such as where bags of material are poured into a reactor or vessel.

A documented, planned inspection process should be implemented to evaluate cleanliness, dust accumulation rates and housekeeping frequency required to maintain dust accumulations below threshold amounts. Areas and spaces that cannot be accessed should be sealed to prevent dust accumulations. One recent severe explosion involved dust that had accumulated above a drop ceiling. If no dust accumulations are present, the chance of a dust explosion or deflagration is significantly reduced.

External and Environmental Factors

External factors should be identified and evaluated. The external factors which could impact your facility may be substantial. Natural hazards may play a significant factor when dealing with dusts. The relative humidity at a given time may be a factor. There are some studies which suggest grain elevator explosions occur when the relative humidity is low. Lightning storms may be an external factor which would impact your process. You may want to shut down your process prior to the arrival of a lightning storm. Earthquakes may dislodge dust accumulations from high building members and create a dust cloud. Your team should look at external factors very closely.

Analysis Methods

Commonly used hazard evaluation procedures use various methods to evaluate hazards. Each method uses a thorough, orderly, systematic approach to determine what may go wrong in the process. OSHA identifies several methods in the Process Safety Management (PSM) standard for chemical industries. Your team should identify and select the appropriate method which is best suited for the hazard and complexity of the process. Sometimes, more than one method may be used and multiple assessments may be performed.

The primary methods identified in PSM also may be used for combustible dust assessment. The primary methods used are well documented by OSHA as well as the Center For Chemical Process Safety.

<u>What-if</u>
The what-if analysis technique is a brainstorming approach. Experienced people familiar with the process ask questions based upon an event and subsequent consequences. This method is particularly helpful if the team members are experienced. If not, the results may be incomplete or inaccurate.

<u>What-if / Checklist Analysis</u>
The What-if / Checklist Analysis is designed to identify hazards as they pertain to types of incidents that may occur in a process or activity. This experienced-based technique requires well versed and knowledgeable team members. The team will use established checklists and apply the what-if scenarios to the process. The checklist provides a systematic approach and may lead to additional discussion and identification of additional hazards. Conversely, if the checklist is not complete, significant hazards could be overlooked.

<u>Hazard And Operability Study (HAZOP)</u>
The HAZOP study was developed to identify and evaluate safety hazards in a process plant, and to identify operability problems. The purpose of a HAZOP study is to carefully review the process and operation in a systematic fashion to determine whether deviations from the design and operation may lead to undesirable consequences. Guide words are used to lead the team through process parameters. The team discusses deviations from normal operations, their possible causes, and the consequences of the deviation. If the consequences are significant, or the safeguards are not adequate, the team may recommend corrective action.

The primary advantage of HAZOP is the brainstorming which comes out of the meetings. The discussions should stimulate creativity and generate new ideas. The interaction between team members of diverse backgrounds and experiences build upon one another.

<u>Failure Mode And Effects Analysis (FMEA)</u>
The purpose of an FMEA study is to identify a single system or single piece of equipment. This study focuses on the hardware. The FMEA is concerned about the process and the equipment, and does not normally study human behavior or operations procedures System failures are studied and at each failure point, recommendations are generated to increase equipment reliability and improve the safety of the process.

<u>Fault Tree Analysis (FTA)</u>
The Fault Tree Analysis focuses on a single event or main system failure. The purpose of an FTA is to identify combinations of equipment failures and human errors that may result in a failure event. This analysis method is primarily used for systems with high redundancy.

The FTA utilizes a graphic model that displays various combinations of equipment failures and human errors. The FTA relies heavily on Boolean logic gates to describe how equipment failures will impact the system train. Boolean logic is an algebra mathematical system which uses true or false statements. Based on the true or false condition, a path is selected in a flow chart of the system or process being evaluated. The analysis focuses on preventative measures for a single basic cause to reduce the likelihood of loss.

Documentation Of The Assessment

Documentation of the assessment is an integral part of the process. It will identify all members involved in the process, and their role. As the assessment progresses, the documentation should identify all steps taken, including methodologies that do not work for a variety of reasons. This will allow future assessment teams to review the work done and understand why a particular assessment path was selected.

When a new process is being developed, good documentation will help justify the original design of the system. It can be a tool used in the management of change process.

The assessment should become a part of the information training for all operators. Operators may discover inherent hazards with the system which could help them prevent going into a failure mode. Documentation made available to operators will aid in communicating essential information. Operators will be able to build on this information for future assessments.

A good hazard assessment may be used in the development of an effective emergency response program. The identified loss scenarios will enable emergency responders to appreciate the loss potential of the process. It will assist their planning efforts to ensure that adequate manpower and equipment responds and that they are deployed to critical points around the facility. For large facilities with significant loss potential, staging areas may be set up away from the facility to reduce response time of relief crews or multiple alarm responders.

The analysis should identify response considerations such as additional PPE, special extinguishing agents, in addition to identifying ineffective response protocols.

Documentation of the assessment should be maintained for the life of the process. When the assessment is updated, the previous assessment should be maintained in its entirety. This will provide historical information on the process and may be used in an incident investigation in the event of a catastrophic loss event.

The final documentation package should include a sheet listing all team members. Each team member should sign the document showing their agreement. In addition to the team members, all corporate managers should sign the document showing that they have reviewed the procedures, that the procedures are complete, and that they agree with the final results. Depending upon your corporate structure and the magnitude of the process being assessed, the plant manager and each department manager should review, agree to, and sign the document. This accountability structure ensures that top management is aware of the relative hazards of their facility. In the event of a major catastrophic loss they will be part of the accountability chain. By understanding the hazards and consequences, they will be better able to evaluate acceptable risk tolerances and they will be in a better position to allocate budgets for improvements when they are requested.

A complete documentation package for a process will include the design package, the construction documentation, calculations for various system components, sources of replacement equipment, and process assessments. It is important to identify the various portions of the documentation so that it may be easily retrieved in the future. Documentation should be stored electronically and backup copies should be maintained offsite for redundancy.

Implementing The Recommendations Of The Assessment

The hazard assessment will include significant information about your process. It will include information regarding design criteria, construction details, process equipment, operating procedures, hazard identification, PPE, process safety considerations, fire protection systems, and many more key concerns for the safe operation of the process. The properly documented assessment will be an encyclopedia of information.

The assessment documentation will assist in developing meaningful recommendations to enhance the safe operation of the process. Based upon the severity of consequences, key areas of deficiency may be identified and those areas may be a focus for future improvement.

Top management will be able to respond to the identified items in the hazard assessment. Resources may be allocated within the existing corporate structure or additional resources may be obtained to address the key components identified as priority items in the hazard assessment.

Risk managers may use the hazard assessment documentation to ensure adequate insurance and risk mitigation techniques are in place. This is extremely important when significant exposures are present. An explosion event in a combustible dust area may impact plant output in other departments and even in other interdependent plants within the organization.

The assessment documentation may also be used to incorporate items into the business continuity procedures for the corporation. The business continuity plan for your organization identifies key considerations to maintain business operations in the event of major catastrophic loss.

Emergency plans should be updated to reflect the findings of the assessment. Additional manpower may be considered for the emergency response team. Additional job functions may be needed to address some of the considerations with the combustible dust process. Public-sector responders may be interested in the results of the hazard assessment. It will enable them to increase the number of fire engines, ladder trucks, rescue vehicles, and ambulances needed for the initial dispatch. Your local hospital may have additional supplies on hand to respond to the challenges of critically burned patients.

The hazard assessment will be an invaluable tool in communicating the hazards to operators and other employees who may be impacted by a system failure in the combustible dust handling process area.

Maintenance operations may use some of the items identified in the dust hazard assessment to schedule maintenance frequencies. Departmental shutdown frequencies may be scheduled based upon identified hazards. Spare parts may be maintained on-site or within a close geographical proximity for immediate delivery.

Management Of Change (MOC)

After the process is in operation, items may be identified which require a change. For the most part, these items should be minor in nature. Any change initiated into the process, whether it be a physical change in equipment, a change in the process, a change in particle size, or any other change may constitute a significant system change. To control these changes, a documented Management of Change (MOC) program should be implemented.

A change occurs whenever there is a replacement which is not a "replacement in kind." An example may be the replacement of a motor which is not of the same power rating. It could be changing a grinder with one of a larger or smaller size. Any physical replacement of equipment which is not identical should initiate an MOC.

Likewise, any process changes should initiate an MOC. If the process engineer changes the temperature in any part of the process, changes the amount of time the material is in any portion of the process, changes the pressure at which the process operates, or introduces a new additive, an MOC should be initiated.

Prior to any change in the process taking place, a detailed analysis and evaluation of the proposed process change should be performed. When a problem with the system is identified and needs to be changed or corrected, a formal written request should be submitted to the assessment team. This initiation may be a suggestion for improvement, a requirement to replace a part which is obsolete, or for any other reason. If the MOC process is not initiated, it is possible that changes will not be brought to the attention of management and the hazard assessment team.

The team is responsible for approving the change, and should evaluate each suggestion as well as perform an initial review. This review will determine if the suggestion will be continued, or if it is not accepted, indicate the imminent undesirable characteristic of the suggestion. Up to this point, there may be a limited number of individuals involved in the review. If accepted, the change request should be escalated to a more formal status, documented in more detail, and submitted to the entire assessment team.

The assessment team should conduct a thorough desktop review to determine the feasibility of the change. The entire team should agree upon the effectiveness and safety of the change prior to its implementation. Each team member should signed the accepted sheet of the request and provide any positive or negative comments as they see fit.

Once accepted, the procedure manuals should be updated to reflect the changes. Any applicable limits in the operating procedures should be documented so the operators do not exceed the new limits, procedures, or methods. A notification and training procedure should be implemented so that all affected parties fully understand the change. Operators should be trained in any new procedures or methods in the process.

Once the review, notification, and training is completed, the change may be implemented. The implementation process will depend upon the degree of change which has been initiated. Some changes will require a slow ramp up to full capacity so the life changes may be studied during a gradual implementation. Once this step is completed, all documentation should be formally updated and prior editions of the procedures should be retired. Retired procedures should be maintained so that future employees may go back and track the progression of the process.

Benefits of a Good Combustible Dust Assessment

A dust hazard may exist wherever a combustible dust is handled. It may also exist as a result of handling and processing large pieces of material. Dust may be produced in small amounts as a by-product of the process. Following good engineering practice will help identify dust accumulations before they become a hazard.

The combustible dust assessment is a complex process and is not a quick walk-through of your facility. The team approach will help look for multiple weaknesses in the process that a single person may overlook.

Performing a thorough combustible dust assessment cannot guarantee that loss incidents will not occur. No assessment can identify every single hazard or possible loss occurrence. However, a well conducted and documented assessment will help reduce incidents over the life of the process. Incidents that do occur may have reduced consequences, produce less property damage, less business interruption, and fewer employee injuries.

Those involved in the assessment will have a deeper understanding of the process and the inherent hazards associated with it. Those reviewing the assessment for training and educational opportunity will learn from the assessment, have a better understanding of the process, and may prevent loss incidents by using the gained knowledge to operate the process in a safer manner. It can be used to educate the plant emergency response team as well as public responders who will respond to your facility.

The cost to conduct, maintain, and update an in-depth dust assessment may be considerable. Management may not be able to quantify the dollar value of the assessment based on incidents prevented. However, in hindsight after a loss event, they will be able to quantify the cost of not performing an adequate, in-depth assessment.

Management's willingness to expend the resources to prevent losses, injury, and death will stand as a testament to their dedication to safety.

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