

The John Liner Review

THE QUARTERLY REVIEW OF ADVANCED RISK MANAGEMENT STRATEGIES

VOL. 25 NO. 3

FALL 2011

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During almost any workday, in almost any manufacturing facility, four of the five conditions exist that could precipitate a dust explosion.

Don't Underestimate the Dangers From Combustible Dust

JOHN T. JOB AND JUDY BURNS

There is an old adage: Fool me once, shame on you. Fool me twice, shame on me. When dealing with combustible dust, you do not want to be fooled even one time, and certainly not a second time.

Every few years, the news airs a dramatic story showing video from an explosion in a grain elevator or sugar refinery. Only the aftermath is shown; there are seldom photos of such explosions actually taking place since they happen so quickly. The carnage can be quite sobering but rarely stays in the public consciousness for very long. Seeing first-hand a plant completely leveled and knowing that many serious injuries, and often deaths, resulted from the explosion

of dust suspended in the atmosphere can be terrifying to employees and their families and sobering to risk managers. Combustible dust has become such a major issue that OSHA (Occupational Safety and Health Administration) is in the process of redefining its industry guidelines to set minimum standards on handling dust, many of which will be applied retroactively. Industry and government officials are now recognizing that many types of particulate that were not formerly considered to be combustible will not only burn but will burn quickly enough when suspended in air to create devastating pressure.

Dust is defined as small, dry particles of material. It can be a byproduct of almost any manufacturing

or agricultural process. Common household dust is generally composed of bits of dried skin and hair (from humans and pets); waste products from insects like dust mites; and fiber from clothing, carpeting, draperies, etc. It can also include soot, mold spores and pollen, residue from building products like concrete or plaster, and particles of asphalt and rubber from auto traffic.

Industrial dust is created when materials are processed or when powders are transferred. Depending on the type of material used and the particle size, almost any substance can become a combustible dust under the right combination of factors. During almost any workday, in almost any manufacturing facility, four of the five conditions that could precipitate a dust explosion often exist. It is not at all unusual for there to be a dangerously high concentration of particles of sufficient size to cause an explosion. Frequently, all that is missing is the ignition source. This can come at any time from an unexpected source, such as from a breaking incandescent light bulb or a stray spark from static electricity or metal parts accidentally striking.

Depending on the type of material used and the particle size, almost any substance can become a combustible dust under the right combination of factors.

It is not surprising that things like coal, flour, sugar, spices, grain, tobacco, and textile products create dust that is combustible. After all, these things are dry and will burn when put into contact with a source of ignition. Ironically, many products that might not be considered to be flammable create combustible dust given the right conditions. Among these are metal dust from aluminum, bronze, iron carbonyl, magnesium, and zinc. Plastic dust from PVC, melamine, polyethylene, and many other types of synthetics are also sources of combustible dust.

Food processing facilities and other manufacturing operations need specialized equipment to help rid the processing atmosphere of dangerous dust.

Simple housekeeping alone is not enough to handle the volume of particulate matter that can be created during just one day in a high-dust-producing or powder-handling facility. Brooms and standard industrial vacuum cleaners can be effective, but only if they are regularly used before dangerous levels of dust accumulate. Once dust accumulations reach dangerously high levels, use of brooms and conventional vacuums can create an especially hazardous situation. A standard vacuum cleaner can actually explode if heavy accumulations of dust are sucked into the closed container. In addition, the exhaust airstream from a vacuum cleaner can stir up dust into the air from raised horizontal surfaces, creating a dust cloud that can fill much of the room that is being cleaned. Sweeping heavy accumulations down to the main floor level from elevated platforms can also create dangerous dust clouds, as can the use of compressed air to “blow down” such dust. Dust clouds can be susceptible to ignition by electrical sparks generated by unshielded motors or lights and even ringing alarm bells.

Determining Explosibility

Testing laboratories go through a complicated procedure to determine the explosibility of a given substance. There are several values that are calculated. First is the minimum explosive concentration (MEC), which tells how much (or how little) of the substance is needed in a given volume of air to cause an explosion. The second factor is how much energy (spark) is needed to ignite that sample: the minimum ignition energy (MIE). The third is the Pmax, which is the maximum explosion pressure of a dust cloud at the worst-case concentration. The final factor is the Kst value, which has to do with the worst-case rate of pressure rise under testing conditions, which is an indication of maximum flame speed.

Standard-sized sieves are used to measure the particle size distribution for most samples tested. Sometimes only the fines are explosion tested, if there is potential for isolation of fines. “Fines” is an industry term for very fine particles that remain after sieving or otherwise sorting particles. Frequently, it is recommended that a dust sample be explosion tested “as-received,” since this more closely represents actual conditions in the facility.

To calculate the MEC, a precise weight of the

sample is placed into a special testing apparatus. Then, a controlled puff of air disburse the particles in the chamber and a spark is applied via an electrode. The same quantity of material is tested with the spark at two different heights in the chamber. If the sample ignites, then a lesser weight of the material is tested. Then, successively smaller samples are tested until the sample fails to ignite. This is repeated four times to assure accuracy. The test results from the two different electrode heights are averaged for the smallest sample that ignited at each height. The ratio of the average quantity of material to the volume of air returns the MEC.

The MIE is calculated much the same way, using the same apparatus and the same procedures. This time, the variable is the amount of energy that is applied through the electrode. A weight of eight times the MEC is used. A precisely measured burst of energy is applied, and the minimum energy applied to create a flame propagation of at least 4 inches is determined. Successive trials are conducted until the sample fails to ignite. Again, averages of a number of tests determine the final result.

The Pmax is calculated by placing a sample in a specialized explosion-testing chamber called a 20-liter sphere. The air from the chamber is evacuated to 0.4 bar absolute. Then, the apparatus automatically pressurizes the air in the container to 20-bar gauge. At this point, a special valve quickly injects the dust sample into the container, using a nozzle that insures that the sample is evenly distributed within the chamber.

Next, a chemical igniter is triggered at a precise time after the dust is released. Other special equipment measures the pressure released by the explosion. The test is performed three times for accuracy, and the mean of the maximum rate of pressure rise and the maximum pressure rise is calculated.

The Kst value of combustible dust is a more complicated calculation that involves determining the ratio of the maximum pressure to the maximum rate of pressure rise in a testing situation. This is the nominal factor that is usually used in connection with the combustibility of dust. So, substances with a very low Kst value create only a weak explosion, while a higher Kst value will create a more dramatic and destructive explosion. There are only two substances with a Kst of 0: sand and silicon.

For simplicity, four classes are used to determine the strength of explosions, ST Classes:

ST 0	No explosion	KST = 0
ST 1	Weak explosion	KST > 0 and \leq 200
ST 2	Strong explosion	KST > 200 and \leq 300
ST 3	Very strong explosion	KST > 300

Exhibit 1 shows Kst values and explosion classes for a few common substances.

So, you can see from this chart that sugar, which gets a lot of publicity from explosions, is only a bit more explosive than soap, which we do not generally think of as explosive. Aluminum and magnesium,

Exhibit 1

Substance	Kst	Explosion Class
Magnesium	508	ST 3 – Very Strong Explosion
Aluminum powder	400	ST 3 – Very Strong Explosion
Cellulose	229	ST 2 – Strong Explosion
Corn starch	202	ST 2 – Strong Explosion
Sugar	138	ST 1 – Weak Explosion
Polyethylene	134	ST 1 – Weak Explosion
Charcoal	117	ST 1 – Weak Explosion
Soap	111	ST 1 – Weak Explosion
Milk powder	90	ST 1 – Weak Explosion

however, being metals, which we don't think of as particularly flammable, are both highly explosive under the right conditions. All of the conditions — the particle size, the concentration of small particulate suspended in the air, and the proximity or probability of an ignition source — must be considered in the careful, comprehensive evaluation of dust hazards in a given facility.

Often efforts are focused only on dealing with primary explosion dangers, while the risk of a secondary explosion is overlooked or minimized.

Primary or Secondary Explosion

Damage can result from two different types of explosions. A primary explosion is determined by proximity to the initial ignition source. An example would be a spark occurring in a dust collector that causes the dust within the collector bag to ignite. A secondary explosion is triggered in a remote location by a wave or flame front that propagates back away from the primary explosion site to a second site. An example would be flames following a dust trail from the dust collector back through exhaust ductwork into the main plant. Secondary explosions are generally much more devastating and widespread, since they are usually in an unprotected or inadequately protected area. Often a sense of false security is perceived when explosion prevention measures are in place in some so-called high-risk areas, but not in adjacent, equally risky areas. While dust collectors, explosion venting, and other mechanisms can be useful, they are sometimes inadequately designed, poorly maintained, or circumvented for convenience or through ignorance of the dangers.

Often efforts are focused only on dealing with primary explosion dangers, while the risk of a secondary explosion is overlooked or minimized. In a major event in 2003 at an Indiana factory producing aluminum wheels, a primary explosion occurred in a dust collector outside the plant. In an effort to

salvage scrap aluminum, a mechanical separator was used to sort metal pieces by size. The sorted pieces were then remelted in a large furnace inside the plant. A byproduct of the separation process was the creation of a great deal of fine aluminum dust. The reclamation system was very poorly maintained, with large quantities of dust leaking back into the plant, causing deep accumulations on overhead rafters and ductwork. Infrequent cleanings by untrained personnel, as well as leaking ductwork, were found to be contributing factors. Additionally, in spite of a history of small dust fires, factory management had largely ignored the hazard and apparently did not realize the escalating nature of the problem. Unfortunately, several workers were injured and one mechanic working near the remelting furnace was killed when the shock wave from the primary explosion dislodged dust accumulations on rafters and other horizontal surfaces, creating a cloud of fuel that then ignited, probably due to a flame front that propagated back into the main factory through the damaged ductwork. There was no warning, and personnel were unable to escape the flash fire that consumed the fuel and the oxygen in the area. The series of small fires and dust leaks should have served as warning signals of the impending danger.

Poor maintenance or other so-called cost saving measures are often much more costly in the long run than actually doing the job properly or using the correct equipment and procedures. For example, failing to change dust collection bags at the recommended frequency or using a substitute or "off-brand" bag (i.e., not recommended by the manufacturer) can be dangerous. Also, trying to use in-house personnel to remove dangerously large accumulations of dust can intensify the potential for disaster. Adding additional pickup points to a dust collection system without increasing the airflow rate can create dangerous accumulations inside ductwork and inside the work area.

Lack of Awareness

The major problem for plant managers, risk managers, and employees is the lack of awareness about the dangers of combustible dust. Even parties who deal daily with the issue just do not understand the magnitude of the danger. In years past, factories dealt with the problem of dust by simply opening windows

or doors or installing exhaust fans, thus reducing the concentrations of particles in an enclosed area. Employees might have used a kerchief or dust mask to keep from breathing in dust, but to them, the dust was considered a nuisance, not a hazard. Until environmental standards were established to limit them, streams of dusty air were allowed to be directly discharged outdoors. Today's factories are tightly sealed to prevent the release of pollutants, and to reduce heating and cooling costs. Environmental regulations continue to further limit the levels of particulate that industrial facilities are allowed to discharge into the atmosphere. So, the problem of combustible dust is increasing at a rate that is alarmingly high. The public does not understand that most dusts can generate an explosion that is as powerful as methane. Dust is a fuel that can burn so quickly that escape is impossible. Being caught in a combustible dust flash fire or explosion is almost always deadly.

Perfect Storm

In 2000, there was a popular movie called *The Perfect Storm*, and the term has crept into our vernacular. The term refers to a group of adverse conditions that converge into the worst possible result, be it a natural disaster, a political controversy, or any other undesirable event. Risk managers in all areas of industry need to consider this: Given the right conditions, almost any material can create an explosion or flash fire due to the combustible dust generated in the facility. A perfect storm of dust is created when a sufficient concentration of particulate material of sufficiently small size is suspended in an enclosed area where a source of ignition can cause the rapid combustion of the dust. Removing or interrupting any one of the conditions — fuel, concentration, suspension in air, confinement, and ignition source — can greatly reduce the hazard or prevent a serious incident.

Mitigation of dust is growing as an industry issue, but there is still a tremendous amount of uncertainty both about the danger and the cost associated with the problem of combustible dust. There are several governmental and industry agencies that are scrambling to develop new comprehensive guidelines for dealing with combustible dust. OSHA is reportedly nearing completion of its new regulations. These will be the most far reaching, since they have the force of government behind them. However, industry groups,

such as the Chemical Safety Board and the National Fire Protection Association (NFPA), are also focusing a great deal of effort on the problem. The current version of NFPA 654, which was updated in 2006, is presently the most comprehensive and will probably be the “gold standard” for dust control, with OSHA adapting the existing rules to include more personal safety issues.

In this article, we hope to raise awareness of the problem associated with dust. We will do this by describing examples of good (management) intentions that resulted in wasted capital on solutions that addressed only part of the problem or failed to reduce the inherent hazard of the process. First, a little background.

There are several governmental and industry agencies that are scrambling to develop new comprehensive guidelines for dealing with combustible dust.

Disciplines Involved

There are several disciplines that deal with dust hazards, and each has its own set of goals, guidelines, and mechanisms. Industrial hygienists and safety engineers look at the health hazards associated with ingesting, absorbing, or inhaling particulate matter or toxins. They generally look for ways to keep these noxious substances from entering the human body. Protective equipment such as respirators, dust masks, and safety suits are tools that an industrial hygienist might recommend. OSHA guidelines are particularly important, since human safety is its primary concern.

Industrial engineers design the equipment and processes that create dust as a byproduct. They can try to configure the machines to produce less dust or to alter the size of the dust particles that are necessarily created in the processing of materials. Sometimes the selection of a less hazardous material can be a part of the industrial process design. For example, the process of powder transfer (paint) can sometimes be adjusted to use a different solvent or a smaller or larger particle

size that yields an equivalent quality product while releasing less combustible dust into the atmosphere. The use of robotic equipment can help to reduce the hazards to human health, but it does nothing to reduce the danger to assets from the combustible dust that is created during the transfer of paint or powder to surfaces. In fact, the use of robots could inadvertently provide the necessary spark to ignite a cloud of paint overspray. Often hydraulic systems rather than electrical motors are used to power robots, but sparks still can be accidentally created.

Mechanical engineers usually design heating, ventilation, and cooling (HVAC) systems, but they can also design dust removal equipment that can help prevent dangerous levels of dust from accumulating. Exhaust fans, ductwork, conveyors, and collectors are mechanisms that can be used to lessen the hazard. But often, just the act of moving materials can exacerbate the problem. A trail of dust that settles into ductwork can act like a fuse leading from a match to a powder keg.

Fire protection engineers have traditionally looked at the ways to detect and suppress a fire or explosion once it has happened. The tools that they use are detection systems (pressure, heat, smoke, and flame) and suppression systems (water or chemical spray systems, dry chemicals, and gaseous agents). There are several goals associated with the use of these systems. First is the early detection of a problem, in order to allow the safe evacuation of personnel from the area of a fire and to summon help in the form of a fire brigade or other emergency personnel. Second is to quickly bring the fire under control or at least surround it and stop its spread. This will limit damage and protect personnel and fire fighters by keeping the fire manageable. Explosion suppression systems work even faster to detect and suppress an explosion before dangerous pressure waves and flame fronts propagate.

Fire protection engineers are also trained to look for dangerous conditions that can be conducive to triggering a fire or explosion. Vapor generated from flammable liquids and the buildup of dust on horizontal surfaces are just two issues that fire protection engineers are trained to recognize. In doing housekeeping surveys, fire protection engineers look for potential dangers from storage, process, and maintenance deficiencies. Insurance underwriters and risk managers rely on the findings of loss prevention surveys performed by fire protection engineers to reduce the

possibility of a serious event.

Fire protection engineers rely on NFPA standards as well as other building and fire codes for their assessments. Since NFPA 654 will figure prominently in any new guidelines from OSHA, this gives fire protection engineers a strategic edge in the recognition and mitigation of combustible dust hazards. They are already familiar with the code and understand the need for comprehensive planning to deal with dust. The American Institute of Chemical Engineers (AIChE) Center for Chemical Process Safety's Guidelines for Hazard Evaluation, which is referenced in several NFPA standards, will also be used by fire protection engineers to ensure that combustible dust hazards are well managed at industrial plants.

Explosion Mitigation

A specialty that is getting more recognition lately is explosion mitigation. This is a rapidly growing industry that looks not only at ways to prevent an explosion but also, should an event occur, ways to suppress it or channel the pressure and flame fronts in a direction that causes the least amount of danger to personnel and minimizes property damage.

Because there is often a considerable amount of overlap between traditional engineering disciplines, there can be gaps in the comprehensive evaluation of the hazards. Also, depending on the discipline involved, there can be some degree of professional bias about exactly what is important. So, a comprehensive approach to the problem of dust requires that all aspects of the hazard be considered. Here are some basic steps to be taken.

1. Always assume the dust is combustible unless a test proves otherwise. Wishful thinking often leads us to assume that the dust created at our facility is the same as some dust that was tested in the past and shown not to be explosive, or even noncombustible. Be aware that combustible dust tests that have become international standards now include larger ignition sources. Dusts with large particle sizes may have been considered noncombustible in the past, but might no longer be classified as such. Consider all variables, including possible contamination with other types of dust particles that could alter the combustibility of a substance, such as fly ash and coal dust mixtures in boiler houses. Be aware that the finest particles

will take the longest to settle and will most easily concentrate at roof level.

2. If dust hazard data are available (MSDS, industry information, etc.), then cautiously use the data as a basis for broadly classifying the dust hazard. But be very careful to compare the particle size and moisture content of the material handled at your facility before blindly using generic dust hazard data. Even daily variations can affect the hazard.
3. If reliable dust hazard data are not available, or if the composition of your dust is mixed, then engage a professional testing organization to test actual samples of your dust. If fines can be segregated at your facility (i.e., in bag-type dust collectors), then these should be tested as well. If the fines will be very dry, then the sample should be dried before testing. Use only an experienced testing lab to both collect and test the samples.
4. Evaluate the hazard. If a vessel that contains combustible dust (dust collector, elevator, bin, silo, dryer, etc.) is not equipped with explosion protection (venting to outdoors, explosion suppression, built to withstand explosion, etc.), then a dust explosion could cause the vessel to rupture. If such a vessel is located in a room with considerable combustible dust accumulations on horizontal surfaces (especially overhead), then a secondary room explosion could occur. If interlocks or maintenance procedures are lacking, then an ignition source is much more likely. The most devastating explosion incidents have included the above three deficiencies.
5. Minimize the hazard. Shut down the processing and clean up the dust accumulations before dust accumulations in a room exceed 1/16 to 1/32 inches thick. The safest way is to use a water washdown, but vacuum systems that are appropriate for hazardous areas also provide a very safe method. Next, consider upgrading the dust collection and powder transfer systems to minimize dust escape and the expense of frequent cleanup. Long term, look for ways to locate equipment susceptible to explosions outdoors or in rooms with limited access which are designed to safely vent

an explosion. Conversion to all vacuum-transfer systems requires larger fans but can minimize the frequency of labor-intensive cleanup sessions. Larger fans can also prevent fallout into ducts and conveyers to minimize the potential for propagation of flame throughout the system.

Very often the best approach to the problem of combustible dust is a multidisciplinary tactic. However, the overriding factor in the successful handling of any type of dust hazard is the careful management and coordination of the various disciplines involved. Below, we offer a few real-life examples where good intentions — and good money — were expended to help reduce a known hazard, but the results were less than desirable.

Simple Measures Are Inherently Safer

A boat manufacturing facility on the East Coast experienced several fires resulting from the ignition of wood dust accumulations inside the overhead ducts used to remove sawdust generated at workstations throughout the plant. These fires were generally confined to the inside of the metal ductwork because full automatic sprinklers at roof level quickly contained the fires. But during each event, smoke filled much of the facility and water discharged from sprinklers damaged equipment and in-process materials. Cleanup and repairs took several days, requiring extra shifts to maintain delivery schedules. After the second fire, plant management opted to invest considerable capital in two dry chemical fire-extinguishing systems.

The inherently safer solution would have been to replace the fan drawing air through the ductwork with a larger unit. This fairly low-cost improvement could have allowed management to save the capital invested in the dry chemical systems. By moving the dust-laden air through the system at a faster rate, the particles would remain suspended in air, allowing essentially all of the dust to reach the outdoor bag-type dust collector. The higher airflow rate would reduce the concentration of dust suspended in air within the ductwork, making ignition within the ducts much less likely.

Ultimately, management did replace the fan with a larger unit, making the system inherently safer by safely relocating dangerous dust concentrations to an outdoor dust collector. This eliminated the powder trail leading from the dust collector back inside to

the plant, dramatically reducing the probability of propagating a fire or explosion back into the plant. Also, the need to shut down production to clear the ductwork several times a year was eliminated. To ensure dust fallout is not recurring, duct interiors are now checked at least annually or anytime production changes or modifications are made.

With this solution implemented, the dust explosion hazard was effectively transferred to an area that already had explosion venting and fire protection in place. The outdoor dust collector already had adequate explosion venting that released to the open air. Fire protection, consisting of a single sprinkler head inside the top of the unit, was adequate to suppress any fire quickly. Since the dust collector was located 50 feet from the plant and clean air was exhausted outdoors, the potential for propagation of a fire or explosion back into the plant was determined to be minimal. Installing the larger fan created this opportunity to reduce maintenance and housekeeping costs while making the plant inherently safer.

This Way Out

A cellulose grinding facility in the Midwest suffered a devastating secondary dust explosion that essentially leveled the plant. When the plant was rebuilt, an explosion expert was hired to design explosion protection for the cellulose grinding equipment and rooms. The grinding equipment was located in several rooms that were separated from the main plant by fire- and pressure-resistant walls. Plant safety policy prohibited these grinding rooms from being occupied while the equipment was energized. This policy was enforced by the installation of switches on the access doors that would power down the equipment if the doors were opened.

Unfortunately, due to inadequate knowledge of the effects of pressure piling, each grinding system consisted of a high-strength cyclone connected to a low strength bag-type dust collector. For convenience and speed in rebuilding, schedule-40 pipe (12 and 16 inches diameter) was used as the ductwork connecting the cyclone and bag-type dust collectors in each grinding stage. It was only a matter of time before sparks created in one of the grinders ignited suspended dust in the cyclone. Since the cyclones and ducts were designed to contain an explosion, the flame and pressure fronts had no safe outlet. These forces were directed into the bag-type dust collectors at very high

speeds. Due to the high dust-to-air concentration during operation and chronic dust fallout in the ducts, the initial explosion or flash fire had ample fuel as it propagated into the bag-type dust collectors.

Although the bag-type dust collector was equipped with open louvers that provided ample explosion vent area, the collector shell ruptured violently due to the pressure-piling effects. In addition, since the rotary valves at the base of each cyclone were not designed to stop pressure and flame fronts, the initial flash fire or explosion propagated into all grinding stages that were operating at the time. Three of the four bag-type dust collectors were destroyed, and some more minor damage affected connected weigh hoppers and conveyer shells. Explosion vent panels on the exterior walls of the grinders released but did not provide enough vent area to prevent structural damage to the steel roof deck, which had to be rebuilt. Months of expensive down time resulted, even though management had done what it thought was needed to minimize the dust explosion damage.

In this case, the solution was the installation of explosion vents on all units including cyclones and connecting ducts, which release into the rooms. The bag-type dust collectors were replaced with much stronger units that vented directly outdoors through large exhaust ports. Rotary valves were replaced with ones designed to resist explosion pressures and flame-front passage (metal to metal contact at blade tips).

A simple process-hazard study revealed that essentially all ducts operated above the minimum explosive concentration for the cellulose dust in air. So, even after the dust fallout problems were minimized by equipment changes, the inherent hazard of the system continued to be of prime concern, driving personnel behavior and management policies. Failure to adequately assess the MEC resulted in the inadvertent creation of the perfect storm that plant management *thought* it was preventing. Although the damage was substantially less than during the explosion that essentially destroyed the first plant, it was still much higher than plant management had envisioned.

Plug and Play Isn't Enough

A paperboard processing facility in the Midwest replaced its very old cyclone dust collectors with a modern paper scrap and dust collection system.

However, they apparently installed the equipment without a professionally designed plan that comprehensively addressed the hazards and physical conditions. The old cyclones were located near the end of the paperboard trim lines and exhausted air outdoors, through the roof. Paper dust accumulations had to be cleaned from roof areas several times each year due to the inefficiency of this system to remove fines. The dust explosion hazard of this old system was minimal thanks to this inefficiency.

The new collectors were located in a separate cutoff room and consisted of a primary cyclone to remove larger pieces from the airstream and bag-type dust collectors to remove fines. Unfortunately, explosion venting was not provided on the bag-type dust collectors, which were capable of producing combustible paper dust clouds during operation. The walls of the newly enclosed room created confinement that could have resulted in explosive pressures building up in the room.

The most dangerous component of the installation was the use of clear plastic bags duct-taped to the bottom chute on the bag-type dust collectors. These bags were used to collect paper dust as it settled out of the dust collector. Unintentionally, the plastic bag served as an easily ruptured vessel that would facilitate release of this accumulated fuel. A small initial explosion in the bag-type dust collector could easily propagate into the room and be fueled by the fines collected in the plastic bag. These fines would be thrown into suspension by the pressure front and then ignited by the flame front. Explosion damage to the concrete-block walls of the room was likely due to the amount of fuel in the bags. These walls were fire rated, but not explosion resistant. No explosion venting was provided on the room since all four walls were interior to the plant.

These dust collectors were located too far from an outside wall or roof to design cost-effective explosion venting releasing outdoors. The most cost-effective solution was to install explosion suppression on the bag-type dust collectors. Any protection design would also need to address isolation on the inlet and outlet ducts, since clean air was returned to the plant. Although the concentration of fines in this new paper scrap and dust collection system remained well below the MEC, the bag-type dust collectors could produce combustible clouds when the reverse pulse of air system operated to clean the bags. This

occurred every few seconds and depended on pressure drop or timer setting.

Failure to recognize the combustible dust hazard prevented plant management from implementing the most cost-effective solution, because they were not provided with all the hazard information up front. Retrofitting will be much more costly and creates a much less than optimal situation. Ideally, these bag-type dust collectors *should* have been installed on the roof, with adequate explosion venting and explosion-resistant rotary valves on their bottom chutes. Personnel exposure to injury during dust collection bag changing could have been greatly reduced. The cost of wall construction could have been reduced or eliminated. Dust escape into the new room also could have been reduced.

The new dust collection system does reduce personnel exposure to airborne dusts at the trimming lines. It also reduces dust emissions into the environment and the need to regularly clean the roof. But the lack of a clear plan that included a comprehensive evaluation of the dust hazards led to the unnecessary and ineffective expenditure of capital. The dust explosion hazard was actually increased. So far, no serious incident has taken place, but plant management is faced with unexpected capital costs and damage potential that should have been easily addressed during the initial installation.

Coffee and Alcohol Don't Mix!

An explosion at a pharmaceutical plant points out the need for detailed management-of-change programs. The processing involved mixing powders with cooled alcohol and water, in a specific order, to ensure worker safety and product consistency. However, at some point the steps were reordered, mostly to facilitate the dilution of the powder in the alcohol before adding the water, which slowed the dissolution process. Unfortunately, there was not a formal management-of-change program in place, so the steps were reordered, but apparently no one actually thought through the process. Luckily, for some time, no incidents occurred. However, during one batch process, workers decided to take a coffee break after charging the mixing vessel with alcohol. They left the alcohol in the vat, where it warmed to room temperature (above its closed-cup flash point), creating dangerous levels of explosive vapor in the tank. The workers returned from their break

and dumped the charging powder into the warmed alcohol. Apparently, the static charge created by powder particles flowing across one another and out of their container was sufficient to create a spark that ignited the flammable vapors. The mixing chamber was damaged, as were some nearby walls. The two workers were severely injured. Roof-level sprinklers controlled the residual fire in the mixing vessel.

A formal management-of-change program would have required that the reordering of the process be approved according to specific guidelines. The dangerous practice of mixing the powder in the pure alcohol was potentially lethal, but as long as the temperature of the alcohol was low, the danger was negligible. Consideration could have been given to finding an optimal mixture of alcohol and water that would have allowed for the powder to dissolve while minimizing the explosion potential.

Conclusion

In dealing with the dangers from combustible dust, it is imperative that a comprehensive plan be in place to adequately evaluate the hazard as well as to mitigate the danger. Without fully testing the dust and understanding the process, it is not possible to know exactly what needs to be done. Relying on MSDS information may mislead managers into thinking that a danger does not exist. Just knowing the Kst of a substance is not enough information for determining risk. A well-designed dust mitigation plan includes many factors and may include input from a number of disciplines. But the coordination

of the disciplines requires a working knowledge of several sets of standards and guidelines, along with a thorough process-hazard analysis.

Even more important is that any plan ensures that capital expended toward the mitigation of combustible dust hazard results in effective and adequate protection. Too many times, a series of warning events is ignored, or, even worse, a secondary event occurs in the wake of mitigation attempts that have gone bad. Don't be fooled even once by combustible dust, and you won't have to worry about being fooled a second time. Always treat combustible dust with the same respect and care that you would give to any combustible substance or flammable fuel.

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Volume 25, Number 3; Fall 2011.

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