Figure 1: At the startof a dust explosion and a passive system of protection, explosive dust is injected into the dust collector to create a flammable cloud. Courtesy: Camfil Farr APC

Identify, address explosion risks to save lives

By Tony Supine & Mike Walters
Camfil Farr APC

The National Fire Protection Association (NFPA) sets standards and codes to protect buildings against fire and explosion risks, and OSHA is enforcing these standards with increasing vigilance. When it comes to combustible dust, several standards must be considered. Combustible dust explosions are a risk in many areas of a plant, but one of the most common locations is the dust collection system. How do you know if your dust collection system complies? What do you do if it doesn't? Are your employees at risk? What are the hazards and how do you identify them?

This article reviews the current status of the OSHA National Emphasis Program for combustible dust, the NFPA standards that address how to prevent or limit explosion hazards, how to identify these hazards, and the types of equipment used to eliminate or control explosion hazards. We will also examine the most common shortfalls to compliance and how to avoid them.

Ten-year retrospective

An explosion at the West Pharmaceutical facility in Kingston, N.C., in January 2003 killed six workers and injured 38 others, including two firefighters. The culprit was inadequate control of dust hazards at the plant. Just a month later, in February 2003, another explosion and fire damaged the CTA Acoustics manufacturing plant in Corbin, Ky., fatally injuring seven workers. Investigators found that resin dust, accumulated in a production area, was likely ignited by flames from a malfunctioning oven, triggering the explosion.

Probably the most famous combustible dust explosion in the past decade—and the one that re-focused the national spotlight on this issue—was the February 2008 accident at the Imperial Sugar Company's Wentworth, Ga., refinery. A dust cloud explosion triggered a fatal blast and fire that killed 13 workers and injured 42 others, generating a storm of media attention and government scrutiny.

These are not the only fatal explosions to occur in U.S. manufacturing plants, though they are the three deadliest to be investigated. More recently, in December 2010, two brothers lost their lives in a chemical explosion at the New Cumberland, W.Va., plant of AL Solutions. And during 2011, three deadly fires and explosions occurred at a Hoeganaes Corp. plant in Gallatin, Tenn. Investigators found that accumulations of fine iron powder in the facility led to the explosions.

In the U.S. alone between 1980 and 2005, the Chemical Safety Board reported 281 explosions caused by ignited combustible dust. These explosions resulted in 199 fatalities and 718 injuries. Combustible dust explosions over the past 10 years in U.S. plants are blamed for well over 100 fatalities and hundreds more injuries.

Sadly, experts believe that all of these accidents were preventable if the companies involved had followed best practices for fire and explosion protection.

Figure 2: About 5 ms later, the dust ignites and the vent is opened. Courtesy: Camfil Farr APC

Explosion protection solutions

There are two general categories of equipment used to comply with NFPA standards for the explosion protection of dust collection systems: passive and active. Passive systems react to the event, while active systems detect and react prior to or during the event.

The goal of a passive system is to control an explosion so as to keep employees safe and minimize equipment damage in the plant. An active system, by contrast, can prevent an explosion from occurring. An active system involves much more costly technology and typically requires recertification every three months.

Passive devices

Explosion venting: Designed to be the "weak" link of the dust collector vessel, an explosion vent opens when predetermined pressures are reached inside the collector, allowing the excess pressure and flame front to exit to a safe area. It is designed to minimize damage to the collector and prevent it from blowing up in the event of a deflagration, thereby reducing the safety hazard.

Flameless venting: Designed to install over a standard explosion vent, a flameless vent extinguishes the flame front exiting the vented area, not allowing it to exit the device. This allows conventional venting to be accomplished indoors where it could otherwise endanger personnel and/or ignite secondary explosions.

Passive float valve: Designed to be installed in the outlet ducting of a dust collection system, this valve utilizes a mechanical barrier to isolate pressure and flame fronts caused by the explosion from propagating further through the ducting. The mechanical barrier reacts within milliseconds and is closed by the pressure of the explosion.

Back draft damper: A mechanical back draft damper is positioned in the inlet ducting. It utilizes a mechanical barrier that is held open by the process air and is slammed shut by the pressure forces of the explosion. When closed, this barrier isolates pressure and flame fronts from being able to propagate further up the process stream.

Flame front diverters: These devices divert the flame front to the atmosphere and away from the downstream piping. Typically, these devices are used between two different vessels equipped with their own explosion protection systems. The flame front diverter is used to eliminate "flame jet ignition" between the two vessels that could overpower the protection systems installed.

Actives devices

Chemical isolation: Designed to react within milliseconds of detecting an explosion, a chemical suppression system can be installed in either inlet or outlet ducting. Typical components include explosion pressure detector(s), flame detector, and a control panel. This system creates a chemical barrier that suppresses the explosion within the ducting, reduces the propagation of flame through the ducting, and minimizes pressure increase within connected process equipment.

Chemical suppression: Whereas chemical isolation is used to detect and suppress explosions within the ducting, chemical suppression protects the dust collector itself. It is often used, together with isolation, when it is not possible to safely vent an explosion or where the dust is harmful or toxic. The system detects an explosion hazard within milliseconds and releases a chemical agent to extinguish the flame before an explosion can occur.

Fast acting valve: Designed to close within milliseconds of detecting an explosion, the valve installs in either inlet or outlet ducting. It creates a mechanical barrier within the ducting that effectively isolates pressure and flame fronts from either direction, preventing them

Figure 3: Almost immediately, the flame is extended away from the dust collector and into a safe area. Courtesy: Camfil Farr APC

from propagating further through the process.

High-speed abort gate: The gate is installed in the inlet and /or outlet ducting of a dust collection system and is used to divert possible ignition hazards from entering the collector, preventing a possible explosion from occurring and preventing flame and burning debris from entering the facility through the return air system. A mechanical barrier diverts process air to a safe location. Abort gates are activated by a spark detection system located far enough upstream to allow time for the gate to activate.

When planning explosion protection, don't overlook additional devices and materials that can help reduce fire risk within the dust collection system. For spark-generating applications, a range of features and technologies is available, from flame-retardant and carbon anti-conductive filter media to spark arrestors in the form of drop-out boxes, perforated screens, or cyclone devices installed at the collector inlet. Fire sprinkler systems may also be required with some installations.

A dust collector that uses vertically mounted filter cartridges can also reduce fire and explosion risks. With horizontally mounted cartridges, dust becomes trapped in the pleats in the upper third of the filters. This trapped dust can burn even if the filter media is fire retardant. Horizontal cartridges are also exposed to all of the dust entering the collector, coarse and fine. This leads to premature failure from abrasion and leaks. These leaks can go unnoticed for quite some time while fine combustible dust is blown into your facility. Vertically mounted filters use baffle systems to segregate much of the dust into the hopper, which reduces the load on the filters and helps eliminate these problems.

Avoid pitfalls

A variety of situations can place a facility at risk, but there are some common denominators. The ones we have most commonly encountered in our field experience are:

Complacency about maintaining the status quo: "I've been here for years and we've never had a problem" is an all-too common refrain. This mind-set stems in part from a common misconception that the facility's dust is not explosive because it has not had an event, when in fact the opposite may be true. In some cases, it may take years for dust to accumulate to explosive levels as seen in the CTA Acoustics event.

To understand the risks, let's review the five elements that comprise what is known as the "dust explosion pentagon":

- combustible dust
- an ignition source
- oxygen in the air
- dispersion of the dust in sufficient concentration to be explosive
- containment of the dust cloud within a confined or semi-confined vessel or area.

All five of these elements may exist in an industrial facility, but all must be present at the same time for an explosion to occur. If there is no containment, it is still possible for a flash fire to erupt if elements 1-4 are present simultaneously.

In a closed vessel such as a cartridge dust collection system, an explosion typically begins when an ignition source enters the dust collector. This ignition source can come from many things and in most cases is never identified. When a pulse cleaning event occurs, a suspended cloud of combustible dust is present in high concentration within the collector.

Though some incidents involve a single explosion, it is more common for a series of deflagrations to occur. The initial explosion can dislodge ignitable dust hidden on overhead surfaces or other areas over a large area and trigger secondary explosions that can be ignited from the initial explosion or from other ignition sources. It is these secondary explosions that have historically caused the

Figure 4: The smoke and dust quickly clear. The entire event took just 150 ms. Courtesy: Camfil Farr APC

majority of injuries and damage to property.

The level of hazard can change from day to day and even from moment to moment—whether due to the introduction of a new process, a temporary lapse in housekeeping, or a static electricity discharge caused by improper grounding. It takes ongoing vigilance and management of change to identify conditions in your plant that might cause a potential safety problem.

Failure to conduct a hazard analysis (also called a risk evaluation): This is probably the biggest oversight that we see. The NFPA states that a hazard analysis is needed to assess risk and determine the required level of fire and explosion protection. The analysis can be conducted internally or by an independent consultant, but either way the authority having jurisdiction will ultimately review and approve the findings.

When it comes to explosion protection, the first step in a hazard analysis is to determine if your dust is explosive. Most commercial test laboratories offer a low-cost test to establish whether a dust sample is combustible. If the test is positive, then the explosive index (Kst) and the maximum pressure rise (Pmax) of the dust should be determined by ASTM E 1226-10, Standard Test Method for Explosibility of Dust Clouds.

Your dust collection equipment supplier needs the Kst and Pmax values in order to correctly size explosion venting or suppression systems. Failure to provide this information will increase your costs, since the supplier will use worst-case estimates of the Kst and Pmax values or may even refuse to provide the equipment. The liability to the manufacturer and to the equipment purchaser is too high to ignore the life safety objectives.

The fact is, any dust above 0 Kst is now considered to be explosive, and the majority of dusts fall into this category. If OSHA determines that even a very low Kst dust is present in a facility with no explosion protection in place, a citation will result. This is one of the biggest changes to occur with the reintroduction of the OSHA NEP in 2008.

Shopping for price over quality: Every plant engineer is acquainted with the benefits of basing purchasing decisions on life-cycle cost—sometimes called “total cost of ownership”—over choosing equipment with the lowest price tag. A dust collector is no exception. A well-designed dust collection system can pay for itself rapidly in energy and maintenance savings, costing far less to operate than a unit with a low initial price.

As documented both in full-scale testing and field experience, in the event that a dust explosion occurs in the collector, a low-end model will more than likely require total replacement. A collector made of thicker-gauge metal with higher vessel strength, however, will survive an explosion and can often continue in service with only the explosion vent and filter cartridges needing to be replaced.

Use of noncompliant devices: A close cousin to the “price versus quality” issue involves the use of noncompliant or uncertified explosion protection devices. As an example, sometimes products, such as back flap dampers, may be reverse-engineered by suppliers that do not have any expertise in explosion protection or have chosen not to perform the required testing to satisfy the standards and/or the performance-based provisions. No testing exists to prove that the device will comply with current standards.

If an OSHA inspector finds this situation in the field, the plant will have to replace the device and may be subject to a fine. Worse yet, if a combustible dust problem should occur, there is no guarantee that the device will perform as expected.

Housekeeping deficiencies: In its October 2011 update on the Combustible Dust NEP, OSHA reported that one common violation

More information at PlantEngineering.com:

There is more information on the topic of combustible dust collection and safety available at ***www.PlantEngineering.com***. Among the items available online:

* A detailed list of the agencies involved in monitoring the safety of dust collector systems. Among those agencies are OSHA, NFPA and the U.S. Chemical Safety Board.

* A list of relevant NFPA standards that cover combustible dust issues.

encountered during inspections involved "hazardous levels of dust accumulation in the workplaces due to poor housekeeping practices." In the authors' experience, as a rule of thumb, if an OSHA inspector can run his finger across a dusty surface or see a footprint, that is considered a citable condition.

Even diligent cleanup of floors and work surfaces is not sufficient if more elevated areas are neglected: Dust accumulation on rafters and other horizontal overhead surfaces or on top of machinery is a frequent culprit. Also, the NFPA recently tightened its definition of hazardous surface dust (in NFPA 654), defining it as any dust layer of 1/64 in. (0.4 mm) or greater, compared to a previous limit of 1/32 in. (0.8 mm) of dust.

When it comes to the dust collector, a simple but important housekeeping requirement is to change filters when airflow through the system reaches a differential pressure limit as prescribed by the manufacturer or when the pressure drop across the collector is negatively affecting the ability of the dust collection system to capture the dust, thus allowing it to escape into the facility.

Another housekeeping misstep is storing dust in the dust collector's hopper. The hopper should be equipped with a device that discharges the dust into a separate drum or storage container after it is pulsed off the filters during the cleaning process. Equally important, this storage container must be emptied regularly, or dust can back up into the hopper. Dust sitting in a hopper creates a potential fire or explosion risk, and may also affect performance of the dust collection system.

Misconceptions about "open" style dust collectors: There is a fairly widespread misconception that open-type dust collection systems, such as those incorporated into downdraft tables and booths, are not a hazard. While these collectors admittedly differ from traditional dust collectors in that they do not take the form of a tightly contained vessel, at least four of the five ingredients of the explosion pentagon may still be present: combustible dust, an ignition source, oxygen, and dispersion of the dust in sufficient concentration to pose a hazard.

Thus, there is still a risk of flash fire directed by a pressure front—a potentially fatal risk, given that workers are in close proximity in these environments. If you are using an open-type dust collector, you must still test and evaluate the combustibility of the dust and equip the area with fire and/or explosion protection equipment as required.

The mistake of over-engineering: The problems and pitfalls described thus far involve not doing enough in one way or another. But sometimes plant engineers err on the side of doing too much—the error of over-specification, which results in explosion protection solutions that may be needlessly expensive and time-consuming to maintain and monitor.

The NFPA allows real-world destructive test data to be used in place of its own standard calculations, provided the dust collection supplier can provide adequate data to prove that the collection system is designed to meet a specific set of criteria for a given situation. The use of real-world destructive test data is thus a permissible and sometimes overlooked strategy.

Conclusion

There is no universal agreement about the best way to tackle the combustible dust problem. Some concur with the CSB position that OSHA needs to accelerate efforts to produce and enforce its own standard, citing a long-standing precedent with the grain industry.

Explosions in grain bins used to be one of the biggest safety problems in the U.S. In 1987, following a series of deadly explosions, OSHA promulgated a Grain Handling Facilities Standard that remains in effect today. This standard has yielded major improvements in combustible dust safety in these facilities.

According to OSHA, "The lessons learned in the grain industry can be applied to other industries producing, generating, or using combustible dust."

Others argue that more stringent and perhaps consolidated dust standards from the NPFA, diligently enforced by OSHA and local authorities, would be preferable to a separate OSHA standard. What everyone does seem to acknowledge is that more drastic action is necessary to prevent combustible dust tragedies from continuing to occur.

Until such action is mandated, a certain degree of self-regulation is called for. Every plant engineer can choose to be part of the problem or part of the solution. By following the guidelines in this article, and securing the help of engineering consultants and equipment suppliers with a proven track record in combustible dust applications and performance-based solutions, you can minimize risk factors and maximize combustible dust safety in your facility. PE

Supine *has held numerous positions with Camfil Farr APC including research and development manager, technical director, and currently plant manager.* ***Walters****, a registered professional engineer with 30 years' experience in air pollution control and dust collection systems, is a senior engineer with the company. The authors can be reached at 800-479-6801 or 870-933-8048; e-mail filterman@farrapc.com; website www.farrapc.com.*