Hazard Awareness

Secondary Dust Explosions

Lessons from the plastics processing industry

By Donald K. Hayden

SECONDARY DUST EXPLOSIONS in the plastics processing industry resulted in 13 deaths, more than 30 injuries and millions of dollars worth of property damage in 2003. Loss of this magnitude highlights a hazard that is often thought of only as a nuisance housekeeping issue, not as a catalyst for a catastrophic explosion.

This article briefly examines two recent secondary explosions that occurred in the plastics processing industry and caused multiple deaths, injuries and significant property loss. It then reviews the fire triangle and introduces the explosion pentagon and factors that lead to secondary explosions. Basic factors of dust characterization and methods to prevent secondary dust explosions are also discussed.

Two Explosions Highlight Dangers

Much has been written about dust explosions, but two recent explosions highlight the potential consequences of secondary dust accumulation. On Jan. 29, 2003, a massive explosion occcurred at the West Pharmaceutical facility in Kinston, NC (Photo 1). Six employees were killed and dozens more were injured. In addition to the loss of life, this economically depressed town lost more than 200 jobs and millions of dollars worth of property was destroyed [CSB(c)]. On Feb. 20, 2003, just one month later, a similar explosion occurred at the CTA Acoustics plant in Corbin, KY (Photo 2). This explosion claimed seven lives and caused more than 30 injuries [CSB(d)].

The common element in these disasters: Secondary explosions attributed to plastic dust that had accumulated outside of process equipment. In a statement issued on Jan. 28, 2004, by Chemical Safety Board (CSB) Chair Carolyn Merritt, "The explosion at West Pharmaceuticals and a similar incident a few weeks later in Kentucky raise safety questions of national significance. Our investigators have found that both disasters resulted from accumulations of combustible dust. Workers and workplaces need to be protected from this insidious hazard. I can't help but think that if only this hazard had been revealed to West beforehand, we would not be here on the first anniversary of this tragedy analyzing its causes.

"Prompted by these events, the CSB is now examining the number and severity of dust explosions throughout the U.S. over the past several decades. Preliminary results of the study are expected to be available when the West investigation is complete, approximately within the next six months" [CSB(a)].

In an interview conducted by *Industrial Safety & Hygiene News*, Dr. Jerry Poje, a member of CSB, commented on the CTA Acoustics plant explosion. "The accident came less than a month after a similar blast at a Kinston, NC, plant killed six people. The Kinston explosion, and lesser ones in California and Mississippi, [are] believed to have been caused, at least partly, by flammable dust that exploded." Furthermore, Poje notes that "workplace safety experts are increasingly concerned that flammable dust in factories represents the same kind of danger identified two decades ago in grain elevators. Safety standards were adopted after deadly explosions were linked to combustible dust in the silos" ("Combustible Dust Hazards").

Industry Overview

The plastics industry is one of the largest manufacturing sectors in the U.S., accounting for more than $310 billion in annual shipments and 1.4 million jobs. Plastic products play a role in many markets, ranging from packaging and building construction to transportation, consumer and institutional products electronics and more (SPI). An industrial sector of this magnitude, coupled with an underdeveloped awareness of the hazard associated with dust accumulation, complacency and the causes of these recent explosions creates a recipe for repeat disasters.

The number of dust explosions in the plastics processing industry has historically been small relative to the number of facilities; however, percentages and probabilities are of little consolation given the

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Photo 1: Dust explosion killed six and destroyed West Pharmaceutical plant in Kinston, NC, in January 2003.

Photo 2: Dust explosion destroyed production area at CTA Acoustics and caused seven fatalities.

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loss of life and property damage attributed to such explosions. Unless firsthand knowledge of the potential exists, a plastics processing facility can easily conclude that the accumulation of dust outside of process equipment is simply a housekeeping problem which can be swept away (both literally and figuratively).

Secondary dust explosions are not unique to the plastics industry. Many well-publicized dust explosions have occurred in process industries over the past decade. For example, on Oct. 29, 2003, a series of explosions severely burned two workers, injured a third and caused property damage to the Hayes Lemmerz manufacturing plant in Huntington, IN. One of the severely burned men subsequently died. The plant manufactures cast aluminum automotive wheels, and the explosions were fueled by accumulated aluminum dust, a flammable byproduct of the wheel production process [CSB(b)]. On June 8, 1998, at 9:20 am, a series of explosions occurred at a grain elevator facility in Haysville, KS (near Wichita). Seven workers died and 10 were injured.

Plastics fabricators are mentioned in National Fire Protection Assn. (NFPA) Publication 654, *Prevention of Fire and Dust Explosions from Manufacturing, Processing and Handling of Combustible Particulate Solids*, which lists industries that handle combustible particulate solids, either as a process material or as a fugitive or nuisance dust. This indicates that the hazard represented by plastic dust is recognized. The explosions at West Pharmaceutical and CTA Acoustics clearly bring plastics processing into the spectrum of facilities that must acknowledge the hazard posed by the accumulation of dust outside of process equipment.

Anatomy of a Secondary Dust Explosion

NFPA describes dust as a particle less than 420 microns or 16.5 mils in size. For comparison, a grain of salt is approximately 500 microns. Plastic dust of this particle size can come from many sources within a facility. It can be a product of a process or byproduct. Accumulations of dust can occur during transfer, storage, mixing and general handling operations. Sawing, machining and other abrasive processes can also generate plastic dust. Grinding—an operation common to many plastics processing facilities—can generate significant quantities of dust across a wide spectrum of particle sizes, and this dust can readily disperse and rapidly accumulate if not adequately controlled.

The main prerequisite for a disastrous secondary explosion is the accumulation of sufficient quantities of combustible dust outside process equipment, as it provides fuel for the development of a large secondary dust explosion (Eckhoff). Dust explosions usually occur as a series. Frequently, the initial deflagration (or primary explosion) is rather small in volume but intense enough to jar dust from beams, ledges and other surfaces, or even to rupture small pieces of equipment (such as dust collectors) within buildings.

Subsequently, a much larger—or secondary—dust explosion can propagate (Plamer). Primary and secondary explosions often occur so close in time that they may be heard as one explosion or as a series of explosions that sounds like rolling thunder. The first explosion sends an air shockwave, or a pressure front, at approximately 1,000 feet per second that causes accumulated dust to become airborne. The pressure front is followed by a flame front traveling at 10 feet per second. The flame front ignites airborne dust as it progresses through the structure; once initiated, it becomes a continuous series of explosions as long as adequate fuel and confinement are present. The result is a chain of secondary explosions that moves with destructive force throughout the facility causing major structural damage (Noyes).

The chance of a dust cloud igniting is affected by many variables, including the size of the particles, dust concentration, impurities present, oxygen concentration and the strength of the source ignition. The only way to determine a plastic dust's potential for explosibility is to test it.

Dust Cloud Explosion Test

Three tests can be used to determine the fire and explosion properties of a powder when it is suspended in the form of a dust cloud: explosion classification, minimum ignition energy and dust explosion severity (Ebadat).

The explosion classification test should be the first test performed to determine whether the dust cloud is combustible. In this test, a flame is propagated through a suspended powder to determine whether the dust cloud can initiate and sustain an explosion. This test is commonly performed using a Hartmann apparatus. Results are classified into one of two groups. Group A are powders that when suspended ignite and propagate a flame; Group B powders do not ignite when suspended. About 90 percent of powders belong to Group A. For powders classified in this group, the minimum ignition energy and dust explosion severity tests are recommended to fully characterize the explosibility of the dust. For powders categorized as Group B, additional tests are not normally required unless specific circumstances, such as exposure to higher-than-ambient temperatures, exist (Ebadat).

The minimum ignition energy test is used to determine the minimum energy required to ignite a suspended powder. In this test, a powder sample is placed in a dispersion tube and dispersed into a dust cloud. Two electrodes within the tube are connected to a series of capacitors and a voltage source. A spark of known energy is introduced into the tube; if the powder ignites, the spark energy is reduced to a level where the dust cloud no longer ignites. The lowest energy at which the spark ignites the cloud is the minimum ignition temperature (Ebadat).

The third test, which, as noted, is essential for Group A dust, is the dust explosion severity test. In this test, the dust is suspended in a 20-liter spherical explosion chamber and the cloud is ignited. Pressure transducers linked to the chamber measure the pressure before, during and after the explosion to determine the explosion severity. The data can be used to determine the maximum explosion pressure and the maximum rate of pressure rise (Ebadat).

Explosion Pentagon

Five elements must occur simultaneously for a dust explosion to occur (Stephan). The model for a dust explosion expands on the well-known fire triangle (Figure 1), in which fuel, oxygen and an ignition source are required for a fire. The two additional conditions necessary for a dust explosion are suspension, which creates a dust cloud, and confinement. These two additional elements create an explosion pentagon (Figure 2).

Like the fire triangle, removing any one element from the pentagon would prevent an explosion from propagating. However, if suspension is the only element removed from the pentagon, the potential for an explosion is eliminated, but the elements for fire—ignition, fuel and oxygen—remain. Therefore, efforts to prevent explosions outside process equipment should focus on the fuel side of the pentagon (Stephan).

Preventing Secondary Explosions

Preventing dust explosions is a combination of many factors (Figure 3). The possibility of a secondary dust explosion, however, is a factor of dust accumulation outside of process equipment. If this element is controlled through a program that includes source capture, inspection and repair of leaking equipment, routine housekeeping and training to develop employee awareness, the potential for a secondary explosion can be eliminated. "In other words, the possibility of extensive secondary explosions can be eliminated if the outside of process equipment and shelves, beams, walls and floors of workrooms are kept free of dust" (Eckhoff).

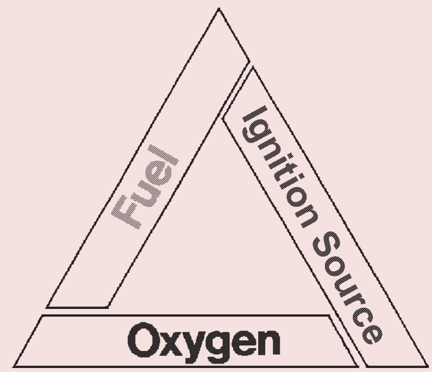
Controlling dust at the source via established work practices and local exhaust ventilation if necessary is the initial step in preventing dust accumulation outside process equipment. Effective dust extraction should be provided in areas where dust routinely occurs as a part of normal operations. This includes areas such as material conveyance vacuum pump rooms and grinding operations.

A second element in preventing dust accumulation includes routine inspection of process and auxiliary equipment to identify leaks by which dust can escape. Inspections should be conducted frequently enough to identify system leaks before surfaces can become covered. According to Stevenson, for most dust a layer as thin as 1/32 of an inch (0.79mm) is sufficient to create an explosion hazard. If leaks are identified, they should be corrected as soon as possible, stopping the process if necessary because considerable quantities of dust can accumulate outside process equipment over time due to minor but steady leaks (Stevenson).

Routine housekeeping is a third step in preventing dust accumulation. However, the methods and tools used to control accumulation of plastic dust concentrations outside process equipment must be selected carefully because inappropriate methods could produce the final link of the explosion pentagon—thereby creating the conditions required for an explosion.

Figure 1

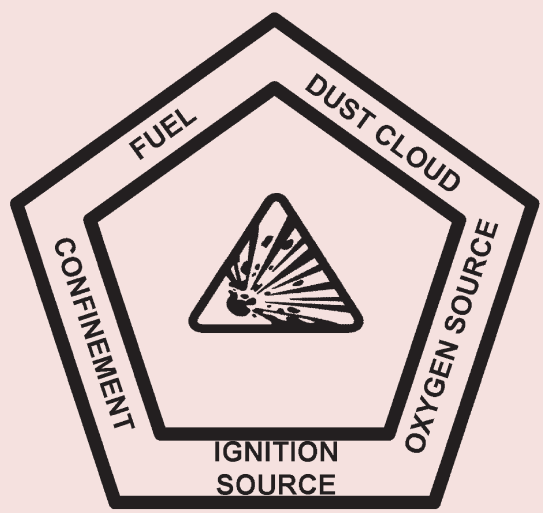
Fire Triangle



Source: Adapted from NFPA.

Figure 2

Explosion Pentagon



Source: Adapted from CSB.

Preventing Secondary Dust Explosions

•Control dust at the source with work practices and local exhaust ventilation.

•Routinely inspect and repair leaking equipment from which dust can escape and accumulate.

•Develop and implement a routine housekeeping program focused on preventing the accumulation of dust outside of process equipment.

•Develop and implement initial and refresher training which ensures that employees are knowledgeable of the hazard and their role in preventing dust accumulation outside of process equipment.

NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing and Handling of Combustible Particulate Solids, states that sweeping or blowing down with steam or compressed air produces dust clouds and shall be prohibited.

If vacuum cleaners are used, they must be explosion-proof and designed for use in environments where explosive dust is present. Standard commercial or industrial vacuuming system should not be used. According to NFPA 654, vacuum cleaners used for cleaning combustible dust "shall at a minimum be listed for use in Class II hazardous locations." If hand tools are used for cleaning and housekeeping, they should be nonsparking conductive tools. Brooms and brushes used for cleaning should be made from a natural fiber material. Synthetic fibered bristles for brooms and brushes and scoops made of plastic should be avoided due to the potential of these materials to generate static sparks. Preventing dust clouds during cleaning and housekeeping should be emphasized as well.

Employee training is the fourth element in this preventive process. Employees must be made aware of the hazards associated with explosive dust accumulation. According to NFPA 654, initial and refresher training shall be provided that ensures employees are knowledgeable of the following topics:

1) hazards of their workplace;
2) general orientation, including plant safety rules;
3) process description;
4) equipment operation, safe start-up and shutdown, and response to upset conditions;
5) necessity for proper functioning of related fire and explosion protection systems;
6) equipment maintenance requirements and practices;
7) emergency response plans.

Although a facility may have never experienced a secondary explosion, this does not indicate that the potential does not exist. Perhaps the five conditions necessary for an explosion have not yet occurred simultaneously. Thus, effective employee training is critical. One uninformed employee can unknowingly initiate the sequence of events that completes the five sides of the explosion pentagon, leading to disaster.

Conclusion

Plastics products are an integral part of daily living and the plastics processing industry represents a critical component to both local and the global economies. Secondary dust explosions in the process industry are not new, but recent disasters involving plastics processing facilities highlight a hazard that exists in a specific sector of the process industry and reaffirms the hazard to the process industry in general. Acknowledgement of this hazard and application of measures to prevent dust accumulation—including control at the source, inspection and repair, housekeeping and employee training—are critical to preventing subsequent disasters. Dust accumulation outside of process equipment is much more than a nuisance housekeeping issue. ■

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