Combustible Dust: Introduction and the Dust Explosion Pentagon

By Assistant Chief Ronald R. Spadafora, Chief of Fire Prevention

***Editor's Note:** This is Chief Spadafora's last contribution to* WNYF*. He died on June 23, 2018, due to WTC-related illness.*

What is Combustible Dust?

Combustible dust is finely ground organic or metal particles that present an explosion hazard under certain conditions when suspended in air. A dust deflagration or detonation can cause loss of life, serious injuries and destruction of buildings. The U.S. Chemical Safety and Hazard Investigation Board (CSB) identified 281 combustible dust incidents between 1980 and 2005 that led to the deaths of 119 workers, injured 718 and extensively damaged many industrial facilities. A wide variety of materials will burn when in dust form and potentially can generate an explosion. Industry examples include food (sugar, spice, starch and flour), grain, tobacco, plastics, wood, paper, rubber, textiles, pesticides, pharmaceuticals, dyes, coal and metals (aluminum, iron, magnesium and zinc).

Note: Deflagration means "to burn." It has a combustion range from flame to a small-scale explosion. A deflagration is a relatively slow process (subsonic speed) when compared to a detonation. A detonation means "to explode." It is combustion traveling at supersonic speed. A detonation releases more energy than a deflagration during a shorter time period. (The speed of sound is 1,125 feet/second.)

While opening a sawdust bin at a boat manufacturing facility, Salisbury, Maryland, Firefighters were covered in flames. Luckily, the Firefighters received only minor burn injuries to their faces and hands. Photo by Todd Dudek, volunteer Firefighter (Salisbury, MD) and Wildland Firefighter

Primary and Secondary Dust Explosions

Dust explosions can be categorized as either primary or secondary. Primary explosions occur in a confined atmosphere, such as inside a dust collector, silo or cyclone (centrifugal device for separating materials; e.g., solid particles from gases). The shock wave from the primary detonation can compromise/damage the storage vessel, allowing burning dust and gases from the explosion to be expelled into the surrounding area. It also will unsettle dust that may have accumulated on ceiling beams, shelves and floors. As the blast wave propagates throughout the facility, airborne dust fuels the emerging flame, leading to an extensive detonation (secondary explosion) because of the large quantity of dust involved and the high energy of ignition. A secondary explosion can buckle floors, blow down walls and lift the roof of a building. There may be a chain reaction, leading to multiple explosions, resulting in death or serious injury to employees and building collapse.

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A dust explosion is complex. It requires the three components that make up the fire triangle. Additionally, the fuel must be confined within an enclosure and easily dispersed within it. The five components necessary to ignite dust can be referred to as the dust explosion pentagon. They include fuel, ignition source, oxidizer, confinement and dispersion. An examination of these components follows.

Dust Explosion Components

Fuel (Combustible Dust)—There are three major factors that pertain to fuel and its likelihood to burn. The fuel component consists of small, easily suspended particles. They do, however, have a relatively large surface area to mass ratio, compared to larger particles and, therefore, are ignited readily. Moisture is another consideration. The more moisture dust clouds

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Table—Kst Values for Common Metal and Non-Metal Dusts		
Dust	***Size (Microns)***	***Kst Value***
Aluminum powder	22	400
Charcoal	27	117
Cotton	44	24
Magnesium	28	508
Milk powder	165	90
Tobacco	49	12
Wood	43	102

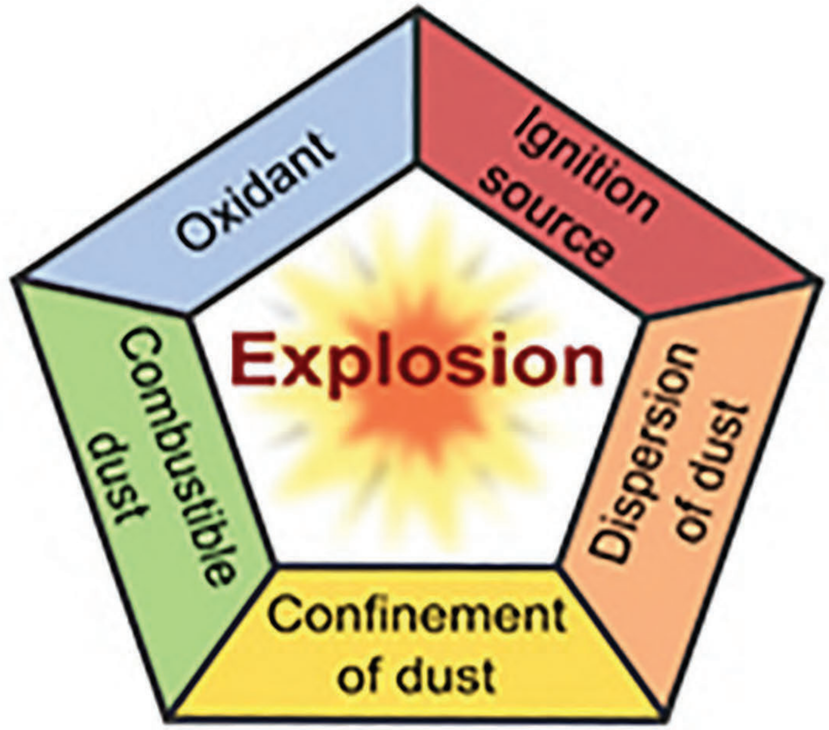
absorb, the more difficult they are to ignite. Moisture also reduces the severity of the explosion. The final fuel factor is its Kst value, a measure of the relative energy of a dust explosion. The higher the Kst value, the more energy the dust particles will generate.

A dust cloud's explosive power is measured via the dust's deflagration index (rate of pressure rise). The National Fire Protection Association (NFPA) classifies dusts according to their explosiveness and corresponding Kst rating. Class 0 dusts (silica, for example) have a 0 Kst rating. They are not subject to explosion. Any dust with a Kst value greater than 0 can burn. Class I dusts (grains, sugar, coal, iron) have weak explosion characteristics and ratings below 200 Kst. Class II dusts (cellulose, wood, flour) have strong explosion characteristics that are within a Kst range of 200 to 300. Class III dusts (magnesium, aluminum) have very strong explosion features and are rated greater than 300 Kst.

A micron is a unit of length. One micron = 0.000039 inch. Combustible dusts with an average particle size smaller than 420 microns are considered to be explosive. The particle size of table salt is approximately 100 microns. Dust explosions do not need large amounts of fuel to spread.

Ignition Source—The ignition source is what actually causes the other components of the pentagon to combust and create a dust explosion. It can be static electricity, open flame, a lit cigarette, sparks from metal parts scraping against each other or overheated machinery. This pentagon component can be contained to some degree by removing any open flames or potential for sparks to be created. It is also important to ensure machinery is clean and not getting too hot when it is operating. It is practically impossible, however, for a facility to completely remove the risk for an ignition since it can be caused by such varied sources. The key factor to predicting a dust particle's likelihood to ignite is its minimum ignition energy (MIE). Dusts that have low MIE are more easily ignited than dusts that have higher MIE.

Oxidant—A fire needs oxygen to be able to burn and this pentagon explosion component is present everywhere. It is in the air workers are breathing in the facility. Reducing the oxygen content increases the amount of energy required to ignite the combustible dust and may prevent ignition.



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Determining the minimum oxygen content (MOC) is an important strategy used to prevent explosions in process systems by lowering the oxygen concentration to the point at which dust cloud explosion no longer can be supported. Since oxygen is a component of air and necessary for workers to survive, it is the hardest component to remove from the explosion pentagon.

Confinement—When dust is contained within an enclosed area, it causes issues with confinement. The space can be as large as a warehouse or factory. Dust particles can remain suspended in confined air for many days, causing the density of the dust cloud to be constantly increasing. When the dust ignites, the confinement will cause intense pressure to build and push the explosion throughout the facility. Confined dust explosions have had the power to lift roofs from buildings, knock over load-bearing walls and buckle solid concrete floors. Environmental issues prevent manufacturers from releasing accumulated dust into the outside air, which means it stays confined inside the building. The minimum explosive concentration (MEC) is the minimum concentration of combustible dust and air needed for an explosion to occur. The MEC is analogous to the lower flammable limit for gases/vapors in air.

Dispersion—This occurs when the accumulated dust is spread out over the air and creates a dust cloud. This can be caused when daily activities disturb accumulated dust and send it airborne, such as using compressed air to clean. Another cause of dust dispersion occurs when a small primary combustion occurs and emits shock waves throughout the facility. These vibrations can knock down dust that had settled on rafters, beams, pipes or HVAC ductwork and spread it throughout the air. Once it has been dispersed, this dust can change from the initial fire to an explosion almost immediately. A dust layer depth of 1/32 inch (0.8 mm) or greater covering an area more than five percent above the floor can create this phenomenon. ■

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