Combustible Dust Explosions - Causes and Prevention

An Online Continuing Education Course for Engineers

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Combustible Dust Explosions - Causes and Prevention

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Introduction

When you hear about an explosion, what comes to mind first? If you're like most people, you think of a bomb, or natural gas. It's hard for many people to comprehend how an explosion can be caused by dust; but dust explosions occur quite frequently.

A dust explosion is the rapid combustion of fine particles suspended in the air, often but not always in an enclosed location. Dust explosions can occur where any dispersed powdered combustible material is present in high enough concentrations in the atmosphere or other oxidizing gaseous medium such as oxygen. Dust explosions are a frequent hazard in underground coal mines, in grain elevators, and other industrial environments.

Figure 1 – Aftermath of grain elevator explosion, Westwego, LA

According to Dr Julian Hought of risk management specialists, HFL Risk Services, an estimated 2,000 dust explosions occur each year in Europe. There are approximately 50 reported dust explosions in the UK alone – that's roughly one every single week. A staggering 24 per cent of them occur within the food industry. In fact, dry ingredients such as flour, custard powder, instant coffee, sugar, dried milk, potato powder, soup powder and cocoa powder have been responsible for 120 deaths in the past 30 years.

The worst dust explosion in American history occurred at a grain elevator in Westwego, Louisiana on December 22, 1977, killing 36 people. Although the cause of the explosion is still unknown, experts believe that a spark of ignition, either from machinery or static electricity, led to the explosion.

The blast destroyed 48 of the 73 giant silos used to store soybeans, wheat and oats at the plant. Most of the men that died were trapped in a two-story, cinder block office building that was crushed when a nearby 25-story grain elevator exploded.

Because of the tragedy in Westwego, three major safety regulations were implemented to grain elevators nationally and abroad. Now, hundreds of heat sensors are installed so that if a machine overheats, the workers will know right away. Pressure sensors were added to help reduce the thermal expansion of grain dust, and offices and control rooms have been moved to remote locations on plant sites.

Elements of a Dust Explosion

There are four or five* necessary conditions for a combustible dust explosion:

1. A combustible dust
2. The dust is suspended in the air at a sufficiently high concentration
3. There is an oxidant (typically atmospheric oxygen)
4. There is an ignition source
5. *Confinement of the dust cloud.

*In some traditional analyses of dust explosions, confinement is considered a fifth requirement. It is not an essential condition for an explosion, but confinement increases the intensity of the explosion. The catastrophic dust explosions that make news headlines occur in confined buildings or silos.

You may recognize the first three conditions listed above as the elements in the familiar “Fire Triangle”. The addition of the latter two elements to the fire triangle creates what is known as the "explosion pentagon" (see Figure 2)

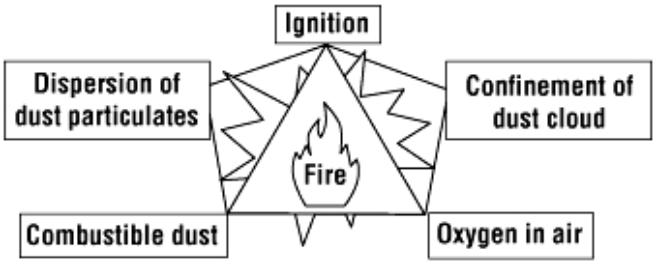


Figure 2: Dust Fire and Explosion Pentagon

If one of the elements of the explosion pentagon is missing, a catastrophic explosion cannot occur. Two of the elements in the explosion pentagon are difficult to eliminate: oxygen (within air), and confinement of the dust cloud (within processes or buildings). However, the other three elements of the pentagon can be controlled to a significant extent, and will be discussed further in this course.

It's important to note here that the conditions for a combustible dust explosion listed above are a bit oversimplified. Conditions must be "just right" for an explosion to occur. Not only must the dust be combustible, but it must release enough heat when it burns to sustain the fire. Additionally, the dust must have a particle size capable of spreading the flame.

Not only must the dust be suspended in air, but it must be at the right concentration. If the concentration is too high or too low, the dust will not ignite. Below a certain value, the lower explosive limit (LEL), there is simply insufficient dust to support the combustion at the rate required for an explosion. A combustible concentration at or below 25% of the LEL is considered safe. Similarly, if the fuel/air ratio increases above the upper explosive limit (UEL), there is insufficient oxidant to permit combustion to continue at the necessary rate.

Primary and Secondary Explosions

Dust explosions may be classified as being either "primary" or "secondary" in nature. Primary dust explosions (see Figure 3) may occur inside process equipment or similar enclosures, and are generally controlled by pressure relief through purpose-built ducting to the external atmosphere. Secondary dust explosions (see Figure 3) are the result of dust accumulation inside a building being disturbed and ignited by the primary explosion, resulting in a much more dangerous uncontrolled explosion inside the workplace. Historically, fatalities from dust explosions have largely been the result of secondary dust explosions.

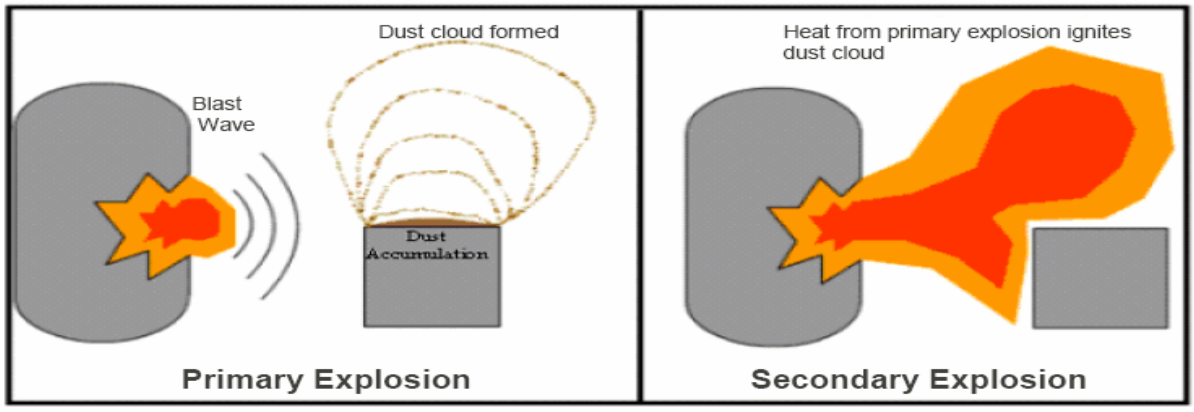


Figure 3 – Primary and Secondary Explosions

Sources of Dust

Many common materials, which are known to burn, can generate a dust explosion such as coal and sawdust. In addition, many otherwise mundane organic materials can also be dispersed into a dangerous dust cloud, such as grain, flour, starch, sugar, powdered milk, cocoa, coffee, and pollen. Powdered metals (such as aluminum, magnesium, and titanium) can form explosive suspensions in air, if finely divided.

Explosive dust can arise from activities such as transporting grain, and grain silos have often been demolished violently. Mining of coal leads to coal dust, and flour mills likewise have large amounts of flour dust because of milling. A gigantic explosion of flour dust destroyed a mill in Minnesota on May 2, 1878, killing 14 workers at the Washburn A Mill, and another 4 in adjacent buildings. A similar problem occurs in sawmills and other places dedicated to woodworking.

Although not strictly a dust, paper particles emitted during processing - especially rolling, unrolling, calendaring/slitting, and sheet-cutting - are also known to pose an explosion hazard. Enclosed paper mill areas subject to such dangers commonly maintain very high air humidities to reduce the chance of airborne paper dust explosions.

To support rapid combustion, the dust must consist of very small particles with a high surface area to volume ratio, thereby making the collective or combined surface area of all the particles very large in comparison to a dust of larger particles. Dust is defined as powders with particles less than about 500 micrometres in diameter, but finer dust will present a much greater hazard than coarse particles by virtue of the larger total surface area of all the particles.

Below is a list of some materials that can become combustible under specific situations. This is only a small sampling. There are much more types of materials that may become a combustible dust.

- agricultural products such as egg whites, powdered milk, cornstarch, sugar, flour, grain, potato, rice, etc.
- metals such as aluminum, bronze, magnesium, zinc, etc.
- chemical dusts such as coal, sulphur, etc.
- pharmaceuticals
- pesticides
- rubber
- wood
- textiles
- plastics

Sources of Ignition

There are many sources of ignition, and a naked flame need not be the only one. Common sources of ignition include:

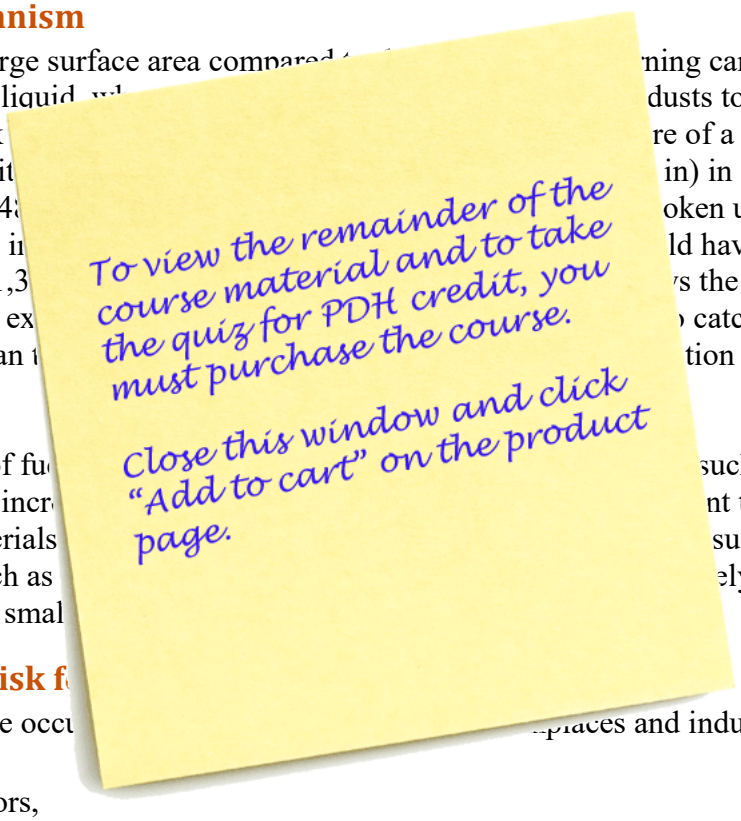
- electrostatic discharge (e.g. an improperly installed conveyor belt, which can act like a Van de Graaff generator)
- friction

- electrical arcing from machinery or other equipment
- hot surfaces (e.g. overheated bearings)
- fire

However, it is often difficult to determine the exact source of ignition when investigating after an explosion. When a source cannot be found, ignition will often be attributed to static electricity. Static charges can be generated by external sources, or can be internally generated by friction at the surfaces of particles themselves as they collide or move past one another.

Explosion Mechanism

Dusts have a very large surface area compared [illegible] ning can only occur at the surface of a solid or liquid, wh[illegible] dusts to be much more flammable than bulk [illegible] re of a combustible material with a densit[illegible] in) in diameter, and have a surface area of 0.04[illegible] oken up into spherical dust particles 50 µm i[illegible] ld have a surface area of 120 square metres (1,3[illegible] s the material to burn much faster, and the ex[illegible] catch on fire with much less energy than t[illegible] tion within the material.



When this mixture of fu[illegible] such as a warehouse or silo, a significant incr[illegible] nt to demolish the structure. Even materials [illegible] such as aluminum), or slow burning (such as [illegible] ely divided, and can be ignited by even a smal[illegible]

Workplaces at Risk f[illegible]

Dust explosions have occu[illegible] places and industries, including:

- Grain elevators,
- Food production,
- Chemical manufacturing (e.g. , rubber, plastics, pharmaceuticals),
- Woodworking facilities,
- Metal processing (e.g. , zinc, magnesium, aluminum, iron),
- Recycling facilities (e.g. , paper, plastics, metals), and
- Coal-fired power plants.

Dusts are created when materials are transported, handled, processed, polished, ground and shaped. Dusts are also created by abrasive blasting, cutting, crushing, mixing, sifting or screening dry materials. The buildup of dried residue from the processing of wet materials can also generate dusts. Essentially, any workplace that generates dust is potentially at risk.

Therefore, any activity that creates dust should be investigated to see if there is a risk of that dust being combustible. Dust can collect on surfaces such as rafters, roofs, suspended ceilings, ducts, crevices, dust collectors, and other equipment. When the dust is disturbed and under certain