Combustible Dust Basics

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Abstract

From woodworking to metalworking, petrochemicals to fertilizers, any industry that can create or use fine powders as part of their processing must be concerned about the potential for combustion to occur. This is particularly true within the food processing industry, where starches, sugars, flavors, and other powdered substances are frequently used, often in large quantities.

In recent years, several high-profile explosions caused by combustible dust have created the need for greater awareness and oversight of processes involving the materials. Additionally, OSHA has increased enforcement of a National Emphasis Program (NEP) that focuses on combustible dust in the work place.

This paper outlines:

- *The factors associated with the combustion of combustible dust.*
- *Applicable building, fire, and electrical codes and referenced standards.*
- *How the codes impact building and equipment design.*
- *Steps for mitigation where combustible dust is present within a facility.*

Determining Combustibility

The National Fire Protection Association (NFPA) defines combustible dust as "a combustible particulate solid that presents a fire or deflagration hazard when suspended in air, or some other oxidizing medium, over a range of concentrations, regardless of particle size or shape." Using this definition, almost any agricultural product dust has some potential to be classified as a combustible dust. NFPA further defines combustible dust as:

- Finely ground/finely divided organic or metal material – typically 420 micrometers (μm) or smaller. In fact, the finer the dust, the more explosive it can be. Particles that are at 420 μm or smaller in diameter can pass through a No. 40 standard sieve.
- Able to cause an explosion when suspended in air and exposed to a sufficient source of ignition.

The Material Safety Data Sheet (MSDS) for each product should list whether the product is combustible or not. Note that often products are not combustible as a whole but the dust from the material may be.

Given these criteria, the table on the following page identifies some of the food products/ingredients that have combustible dusts.

Table 1:
Examples of Industry Materials where Dust is Combustible

Alfalfa	Apple	Beet root	Carrageen	Carrot	Cocoa bean
Cocoa powder	Coconut shell	Coffee dust	Corn meal	Corn starch	Cotton
Cottonseed	Garlic powder	Gluten	Grass dust	Green coffee	Hops (malted)
Lemon peel dust	Lemon pulp	Linseed	Locust bean gum	Malt	Oat flour
Oat grain	Olive pellets	Onion powder	Dehydrated Parsley	Peach	Peanut meal and skins
Peat	Potato	Potato flour	Potato starch	Raw yucca seed	Rice
Rice flour	Rice starch	Rye flour	Semolina	Soybean	Spice dust
Sugar	Sunflower	Sunflower seed	Tea	Tobacco	Tomato
Walnut dust	Wheat flour	Wheat grain	Wheat starch	Xanthan gum	

Source: OSHA Combustible Dust Bulletin

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Figure 1:
Combustible Dust Pentagon

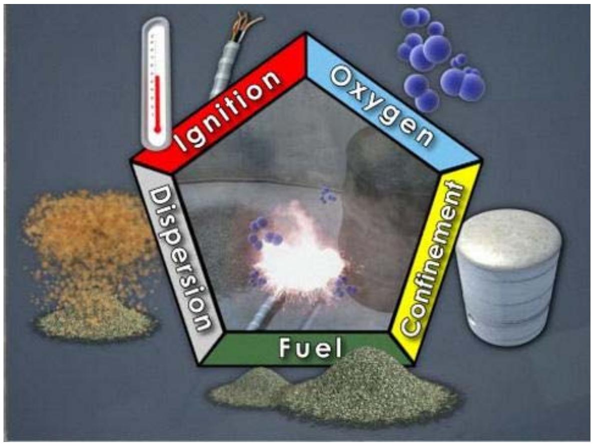


Photo:http://blog.convergencetraining.com/2013/01/oshas-new-combustible-dust-standard.html

The Combustible Dust Pentagon

A dust explosion is different than a fire. To create a fire, three factors are required: Oxygen, fuel, and an ignition source. However, for a dust explosion to occur, two additional factors are needed: The dust must be dispersed at the correct concentration in the air, and it must also be confined in some sort of enclosure, e.g., a silo, dust control filter, bin, conveyor, bucket elevator, or room. This is known as the "Combustible Dust Pentagon." All five elements (oxygen, fuel, heat, dispersion, and confinement) must be present for a combustible dust explosion to occur. If one is missing, it would be difficult to have a dust explosion occur.

Environmental factors have a big impact on the chemistry of a dust explosion. High oxygen content, high air temperature (in the form of a spark or flame), and high air turbulence can increase the risk of a combustible dust explosion.

Measuring Combustibility

Some of the dusts listed in Table 1 are a bigger danger than others. There are three key indices used to quantify explosiveness:

1) Minimum Ignition Energy (MIE). The MIE is the smallest amount of heat or electrical energy that is needed to ignite a dust/air mixture. The smaller the value, the more volatile the dust is. There are a number of physical characteristics that influence a product's MIE:

- Chemical composition. Organics and metals have lower MIE.
- Particle size. The smaller the particle, the lower the MIE.
- Moisture content. The lower the moisture, the lower the MIE.

Table 2 lists MIE's for some common food product dusts. Remember, the lower the MIE, the more volatile the product is.

Table 2:
Minimum Ignition for Some Food Products

Product (dusts)	MIE (millijoules)
Corn	45-100
Wheat	50 -100
Oats	>500
Barley	50 – 100
Soybeans	50 -100
Starch (rice)	>30
Starch (wheat	10 – 30
Sugar	<10

Note that the MIE for any given product will be smaller as the dust particle gets smaller. For example, a whole corn kernel has a high MIE; corn dust has a much lower MIE.

2) Minimum Explosion Concentration (MEC). Often called the Lower Explosive Limit (LEL), the MEC is "the minimum concentration of combustible dust suspended in air, measured in mass per unit volume that will support a deflagration" (OSHA). Measured in oz. /ft.^{3}, MEC is dependent on the size of the particle, the temperature of the ignition source, and the amount of oxygen in the air. As a rule of thumb, a cloud density in which the visibility of a 25-watt light bulb is less than six feet is sufficient to create an explosion.

The MEC is the measure of the dispersion factor in the Combustible Dust Pentagon. If the amount of dust in the air per cubic foot is greater than the MEC, explosive conditions are present.

3) Deflagration Index (K_{St}). The deflagration index, measured in bar-meters per second, indicates how big an explosion would be by measuring the maximum rate of pressure rise for most favorable dust/air mixture to create an explosion. In general, the larger the K_{St} value is, the more violent the explosion. The K_{st} value is used to size explosion deflagration venting and pressure relief apparatus. The higher the K_{st} value, the larger the deflagration vent area is needed. Two factors influence the deflagration index: chemical composition (organic, metals) and particle size (the smaller the particle, the higher the K_{St}). Due to this possible variation, the deflagration index values can vary by situation. Testing should be done on the exact material being processed to accurately determine its K_{St}.

Table 3 lists some common organic and metal dust K_{St} values.

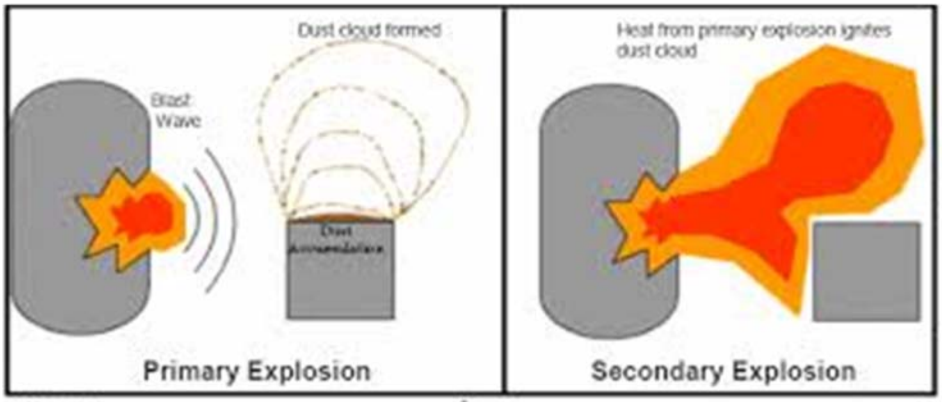
Table 3:
K_{St} Values for Organic and Metal Dusts

Dust type	K_{st} Value
Barley Grain	240
Rice Starch	190
Pectin	162
Soy Bean Flour	110
Milk Powder	90
Wood Dust	102
Coal Dust	85
Magnesium	508
Aluminum Powder	400

Primary and Secondary Explosions

What makes a combustible dust explosion more dangerous than a fire is how violent it is and how rapidly it can spread. A fire will not spread without fuel: If no new fuel is available, the fire will die out. A combustible dust explosion, however, can be self-perpetuating. When an explosion occurs, a heated shock wave is sent out in all directions. The shock wave will knock additional dust off of horizontal surfaces, causing it to be dispersed in the air. If the dust is at the right concentration, a secondary explosion will occur, causing further damage. The secondary explosion can cause a tertiary explosion, and so on. Secondary explosions generally cause more damage than the initial explosion because they cover more area.

Figure 2:



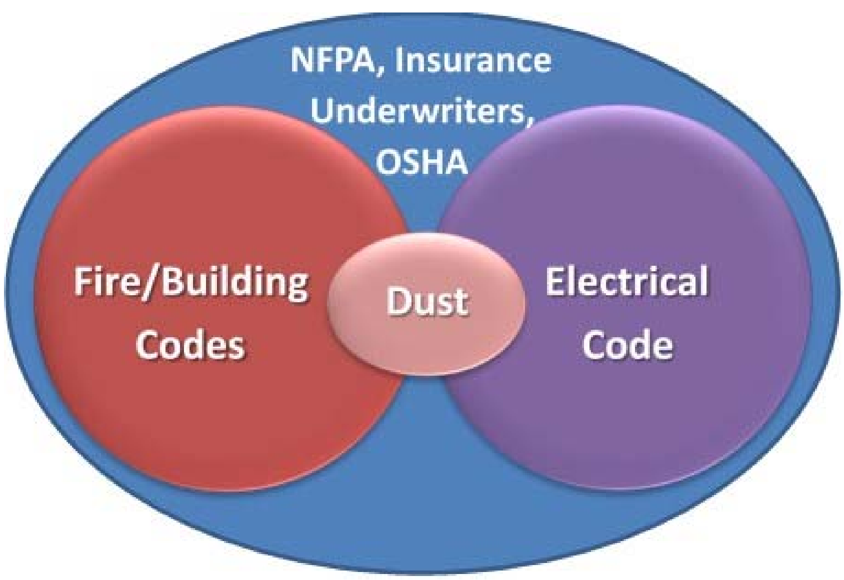
https://www.osha.gov/dts/shib/shib073105.html

Secondary explosions occur when a primary explosion in some piece of processing equipment dislodges or encounters "fugitive dust" that has accumulated and dispersed throughout the facility. This fugitive dust, if ignited, causes additional explosions which actually can be more severe than the original explosion, due to increased concentrations and quantities of dispersed combustible dust.

Combustible Dust Hazard and Applicable Codes

Figure 3 shows the relationships between the building, fire and electrical codes as they apply to combustible dust. NFPA standards apply for combustible dust when referenced from any of the applicable codes. In addition, the Occupational Safety and Health Administration (OSHA) has released a National Emphasis Program (NEP) that is also currently enforced. The NEP generally follows building, fire and electrical codes, but has a few nuances that may alter the process and building design. The OSHA website www.osha.gov contains the details on the combustible dust NEP.

Figure 3:
The Relationship Between Various Codes and Standards and Combustible Dust



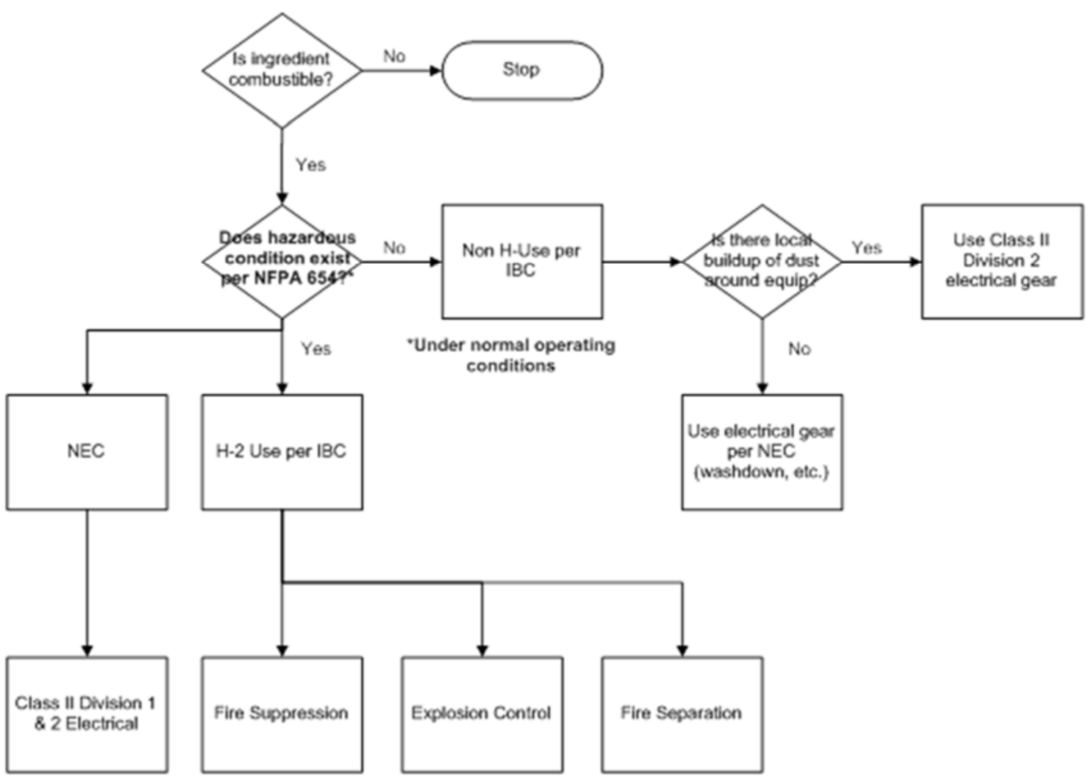
Surprisingly, building and fire codes do not directly address combustible dust. Building codes simply state that buildings and structures that pose a deflagration hazard must be classified as H-2 hazardous occupancy – but do not indicate when a deflagration hazard exists. On the other hand, fire codes authorize the local Fire Marshal to enforce NFPA 61 (Standards for the prevention of fires and combustible dusts explosions in food processing facilities), NFPA 68 (Standard on explosion protection by deflagration venting), as well as NFPA 654 (Standards for manufacturing, processing, and handling of combustible particulate solids) when they deem a deflagration hazard is present.

Conversely, the National Electric Code (NEC) is very specific as far as dust classification and requirements. NEC Article 500 covers the requirements for electrical equipment and wiring for Class I, II, III, Divisions 1 and 2. NEC Article 500.4 references NFPA 499 for classifications of combustible dust areas, and NEC Article 502 identifies Class II locations in which combustible dust is present under normal conditions.

A Code Road Map

Because it is somewhat of a gray area in determining when a deflagration hazard is present, it is the responsibility of local authorities to evaluate and enforce the hazard. To help determine if a deflagration hazard exists, look at the following flow diagram (Figure 4):

Figure 4:
Code & Standard Flow Diagram for Combustible Dust



1. First, determine if the ingredient being handled is combustible. See the definition in the "Measuring Combustibility" section.

2. If the dust is combustible, review NFPA 654 to determine if a deflagration hazard exists. NFPA 654 has two methods for determining the deflagration hazard: one based on a series of calculations, and the second that is called the "Layer Depth Criterion Method", which is the easier of the two. The latter method states that "a dust flash fire or dust explosion hazard exists when the dust layer thickness measured external to process equipment exceeds 1/32" (approximate thickness of a paperclip) and covering at least 5% of the total floor area." Note that the thickness can be increased if the material bulk density is less than 75 lbs/cubic foot.

> Essentially, these two steps say that if the dust is determined to be combustible and conditions are such that there is a dust coating of 1/32" over 5% of the floor area of the room, conditions exist that will require the building, HVAC, and electrical components to be constructed in a manner consistent with the definition of Hazardous Use (H-2) as described in the building and fire code. Additionally, Class II, Division 1 and 2 electrical standards will be needed.
>
> If the dust is neither combustible nor present in a high enough quantity, H-2 classification is not required. Other parameters such as washdown construction or USDA regulations will be the determining considerations for the building, HVAC and electrical design.

Determining Hazardous Use is a complex process. Therefore, it is essential to gain consensus with the local building and fire officials on the classification and compliance requirements for the specific project. (With any project conditions, the Authority Having Jurisdiction (AHJ) will have final say on whether the operation will be classified as a hazardous occupancy.)

Note that in figure 4, there might be situations where Hazard Use is not required but Class II electrical gear is. For example, suppose an area around a blender is extremely dusty but takes up less than 5% of the room floor space. The area immediately around the blender may require Class II Division 2 lights and fixtures, but these would not be required anywhere else on the floor.

Combustible Dust and Design Parameters

The building, electrical, mechanical equipment and process equipment design parameters are all greatly affected if it is determined that an H-2 Use building or room exists.

- Building Design. When a deflagration hazard is present with combustible dust, the following H-2 Occupancy Construction Requirements must be met:

    - Fire separation between the hazardous occupancy and the adjacent areas. (2 to 4 hour fire resistance rating based on occupancy)
    - Explosion control (venting or prevention)
    - Reduced emergency egress travel distances
    - Compliance with NFPA 654 and NFPA 61*
    - Increased fire suppression requirements

- Electrical Design. Electrical classification for Hazardous Dust is defined differently than the building code. The NEC works on the premise that the farther from the source, the lesser the hazard. Within a 20 foot "bubble" or sphere of the source, Class II, Division 1 electrical components are required. For

* NFPA 61, Chapter 6, Section 6.2.1 (enclosure requirements) of this standard states that where a dust explosion hazard exists in rooms, buildings, or other enclosures under "normal" operating conditions, such areas shall be provided with explosion relief venting distributed over the exterior walls (and roof, if applicable) in accordance with NFPA 68, *Standard on Explosion Protection by Deflagration Venting*. (Note: If equipment is malfunctioning, it is not considered "normal" operating conditions under this evaluation.)

the next 10 feet, Class II Division 2 is required. Beyond this initial 30 feet, any appropriate electrically classified equipment can be used.

Note that a typical Totally Enclosed Fan Cooled (TEFC) motor qualifies as a Class II Division 2 motor. TEFC motors are regularly specified for wash down or wet areas.

The NEC is referenced for wiring methods, enclosure types, permitted conduits, lighting, receptacles and rated devices. See Figure 5 below for a graphical representation of the electrical classifications.

Figure 5:
Class II Division 1 & 2 “Bubbles” around Combustible Dust Source

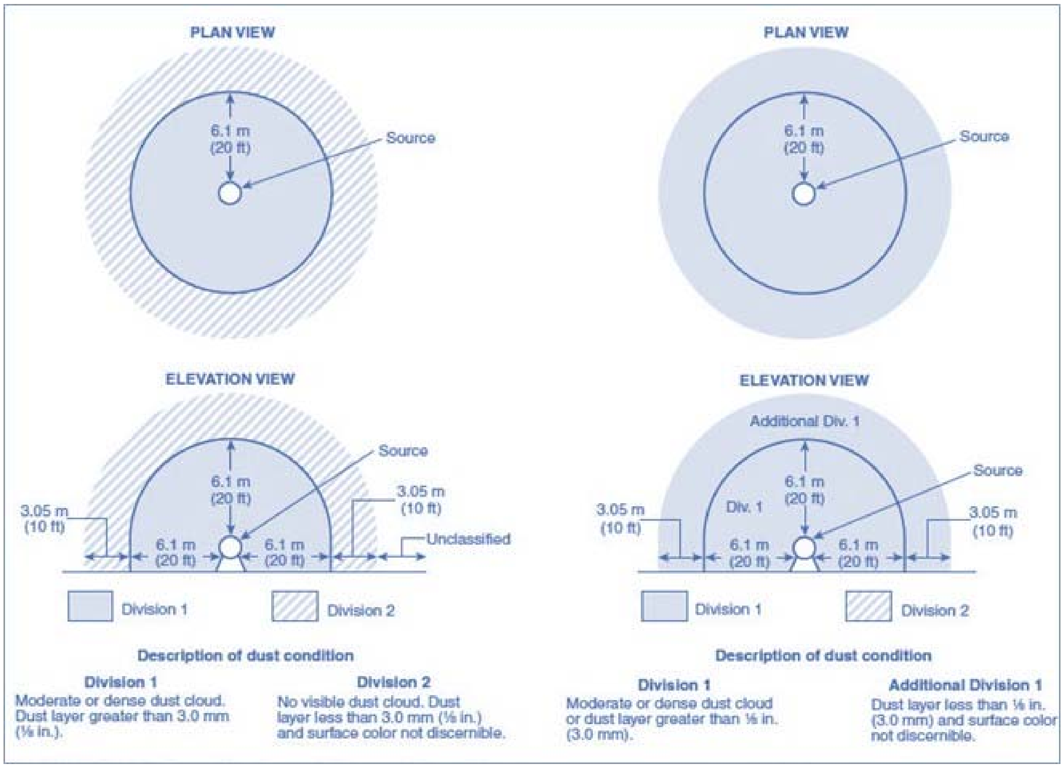


Image: NFPA.org

- Mechanical Design. Mechanical equipment that is located in a Class II Division 1 location requires a Class II Division 1 motor, heaters that do not have an open flame, and instrumentation that does not produce a spark, arc or heat. Class II Division 2 locations require Totally Enclosed, Fan Cooled (TEFC) motors, heaters that do not have an open flame, and instrumentation rated for location or in a dust tight enclosure (NEMA 4X).

- Process Equipment Design. Process equipment follows the same rules as the mechanical equipment as far as motors and other electrical gear is concerned. Bulk conveying equipment like bucket lifts, belt conveyors, and screw conveyors have additional design requirements because they convey or confine the dust producing products. Typically, they have to have some kind of pressure relief or deflagration vent as part of their design. Large spray dryers, fluid bed dryers and Filtermat® dryers are often equipped with fire suppression equipment.

Dust collectors and odor control devices are often required to have a deflagration vent and/or fire suppression equipment as part of their design.

All the explosion suppression methods will fall into one of three categories:

- Venting. This is the most cost effective and convenient of the three methods. A duct is attached to the equipment and run to a safe location outside the building to control the direction and size of the explosion. The duct is designed to withstand the force of the blast and allows almost instantaneous relief of the pressure. One drawback to this method is that it allows the explosion to occur, resulting in a high probability of damage to equipment. Two options for venting are shown in Figure 6.

Figure 6:
Equipment Venting

Image: www.cmctechnologies.com/au/item227.htm

Figure 7:
Typical Chemical Suppressant System Installation

- Suppression. Some situations may not lend themselves readily to venting so chemical suppression may be a better solution. Suppression involves injecting a chemical suppressant into the process equipment to smother the fire or explosion before it can occur. The blue spheres shown in Figure 7 are pressurized and filled with a chemical suppressant. A rupture disk or pressure sensor is inserted in the pipe attaching the spheres to the piece of equipment. When a buildup of pressure that indicates that an explosion is about to occur, a valve opens releasing the suppressant into the equipment, stopping the explosion. This release happens almost instantly; a typical time is 0.06 seconds from detection to release.

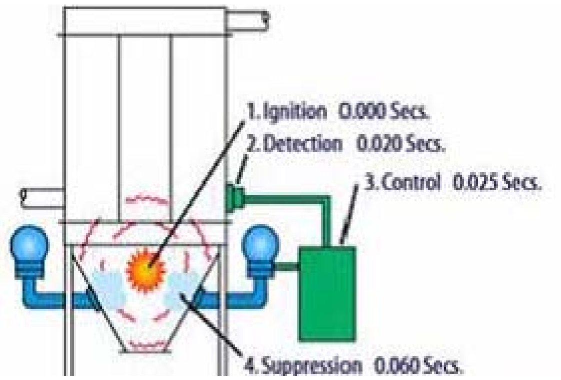


Image: www.advancedsafetysystems.com

Figure 8:
Isolation

Suppression is a more expensive option than venting but it decreases or eliminates an equipment damage potential. If the suppressant is released into the equipment, the equipment has to be cleaned up and the suppressant system replaced. An ongoing cost to have the system inspected on an annual basis will also be incurred.

- Isolation. This involves isolating the explosion to prevent it from spreading. The most common way is a mechanical or chemical isolation method. It uses an extremely fast-acting barrier to halt the spread of the explosion or flame. The picture to the right shows how the system is designed.

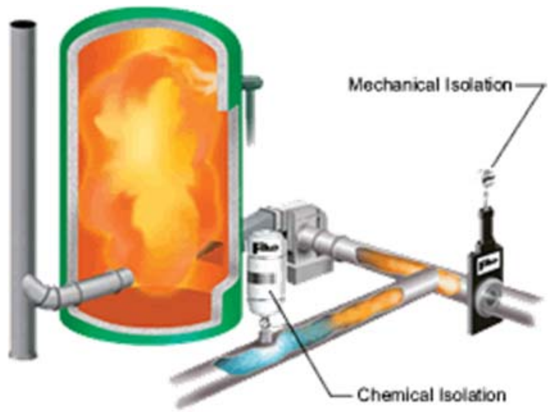


Photo: ww.fire-chief.com/explosion-suppression/

Preventing/Mitigating Dust Explosions

Dust explosions can be prevented by following these recommended practices:

- Controlling points of ignition. Ensure that all electrical equipment in a Hazardous Use area is rated Class II, Division 1 or 2. Properly ground equipment and install static electricity prevention devices. Implement a Hot Work permit program to regulate open flames and items which could spark. Control smoking and separate heated surfaces from dusts.

  Most equipment manufacturers understand the requirements for fire suppression and have added it to their design. The responsibility of the owner or consultant is to identify the explosion risks and make sure the equipment vendor installs the appropriate measures as part of his design.

- Minimize dust buildup. Proper housekeeping is key to effectively eliminating the possibility of a dust explosion. Dust collection should be installed at any possible dusty area. A preventative maintenance program for the dust collection system (changing filters, inspecting bearings, etc.) should be followed rigorously. Good housekeeping practices, including thorough and regular cleaning of the process area, is easy to implement and a cost effective way to control dust. The goal is never to allow the 1/32” build up in any area of the facility including floors, ducts, lights, and any other horizontal surfaces.

Combustible Dust Basics

Summary

Combustible dust hazards have always been around in the food industry but only recently has an emphasis been put on designing buildings, mechanical equipment, process equipment, and electrical components to prevent hazardous situations. OSHA has placed more importance on mitigating combustible dust risks by increasing their inspectors' education and scope of inspections to include dust hazards.

To properly implement a safe combustible dust mitigation and explosion prevention program, food industry safety and operations personnel need to develop an understanding of which dusts are combustible, be aware of the combustion pentagon, have housekeeping programs in place to mitigate dust build up and make sure building and equipment designs meet the applicable codes and standards.

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