Dust Explosion Pentagon

Protecting Your Process

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CONTENT

ABSTRACT

A dust explosion is the rapid combustion of fine particles suspended in the air within an enclosed location. Dust explosions can occur where any dispersed powdered combustible material is present in high-enough concentrations in an atmosphere containing oxygen.

The Dust Explosion Pentagon provides an illustration and definition of the necessary components present simultaneously to cause the explosion. It consists of five elements: dispersion of fine particles in the mixture, combustible powder, oxygen, confinement of the mixture and source of ignition. The avoidance of possible disaster requires that at least one of the elements is removed from the equation.

It is easier to visualize and comprehend the concept, if one reviews a typical descriptive pentagon.

This paper will provide an overview and general guide to elimination of the hazard by removal of at least one of the necessary elements from the equation.

COMBUSTIBLE DUST

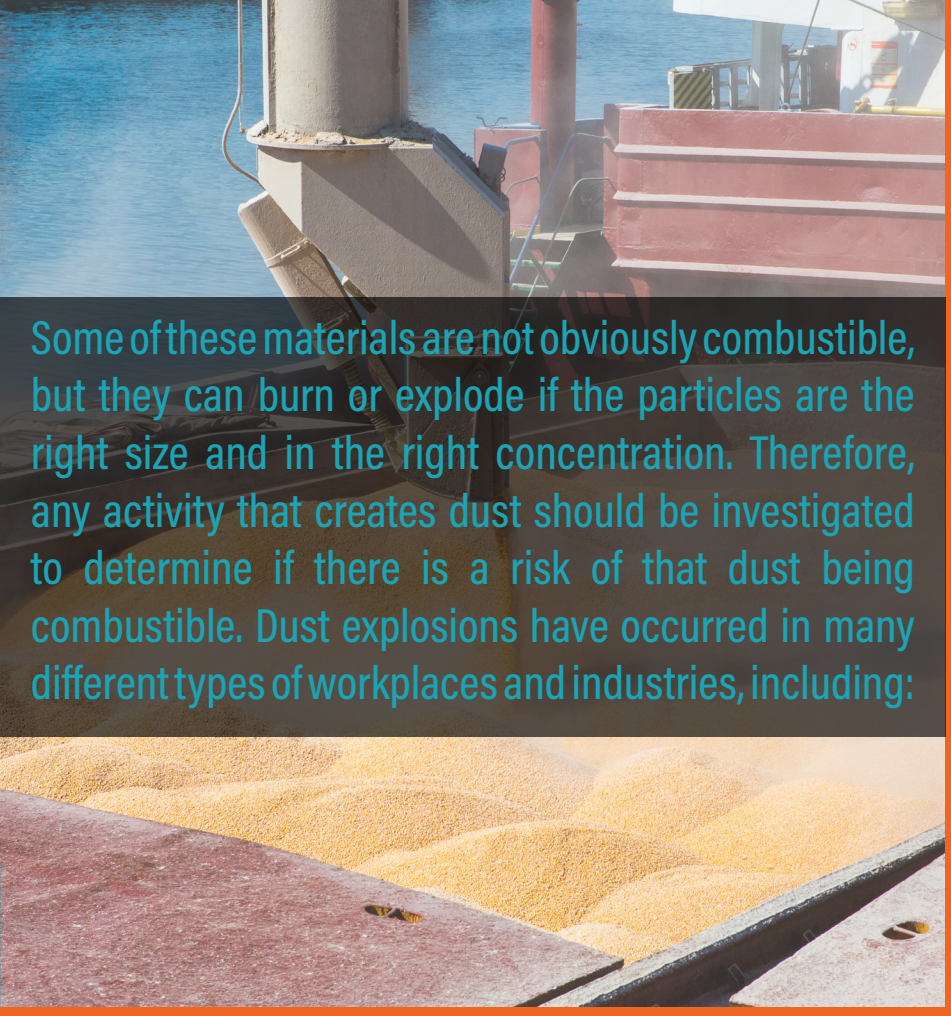
Combustible dust, as defined by OSHA, is a solid material composed of distinct particles or pieces, regardless of size, shape or chemical composition, which can present a fire or deflagration hazard when suspended in air or some other oxidizing medium over a range of concentrations.

The presence of this dust, both in open and unseen areas, can present a grave hazard to employees, employers and facilities as explosions can be catastrophic.
Essentially, a combustible dust is any fine material that has the ability to catch fire and explode when mixed with air.

Many materials can become combustible under specific situations.
Combustible dusts can be from:

- **Most solid organic materials**
- **Some nonmetallic inorganic materials**
- **Agricultural products: egg whites, powdered milk, cornstarch, sugar, flour, grain, potato, rice, etc.**
- **Metals: aluminum, bronze, magnesium, zinc, etc.**
- **Chemical dusts: coal, sulphur, sugar, flour, grain, wood, etc.**
- **Pharmaceuticals**
- **Pesticides**
- **Rubber**
- **Textiles**
- **Plastics**

There are many, many more types of materials that may become a combustible dust.[1]



Some of these materials are not obviously combustible, but they can burn or explode if the particles are the right size and in the right concentration. Therefore, any activity that creates dust should be investigated to determine if there is a risk of that dust being combustible. Dust explosions have occurred in many different types of workplaces and industries, including:

Grain elevators

Food production

Chemical manufacturing

(e.g., rubber, plastics, pharmaceuticals)

Lumber Mills

Woodworking facilities

Metal processing

(e.g., zinc, magnesium, aluminum, iron)

Recycling facilities

(e.g., paper, plastics, metals)

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. 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 circumstances, there is the potential for a serious explosion to occur.

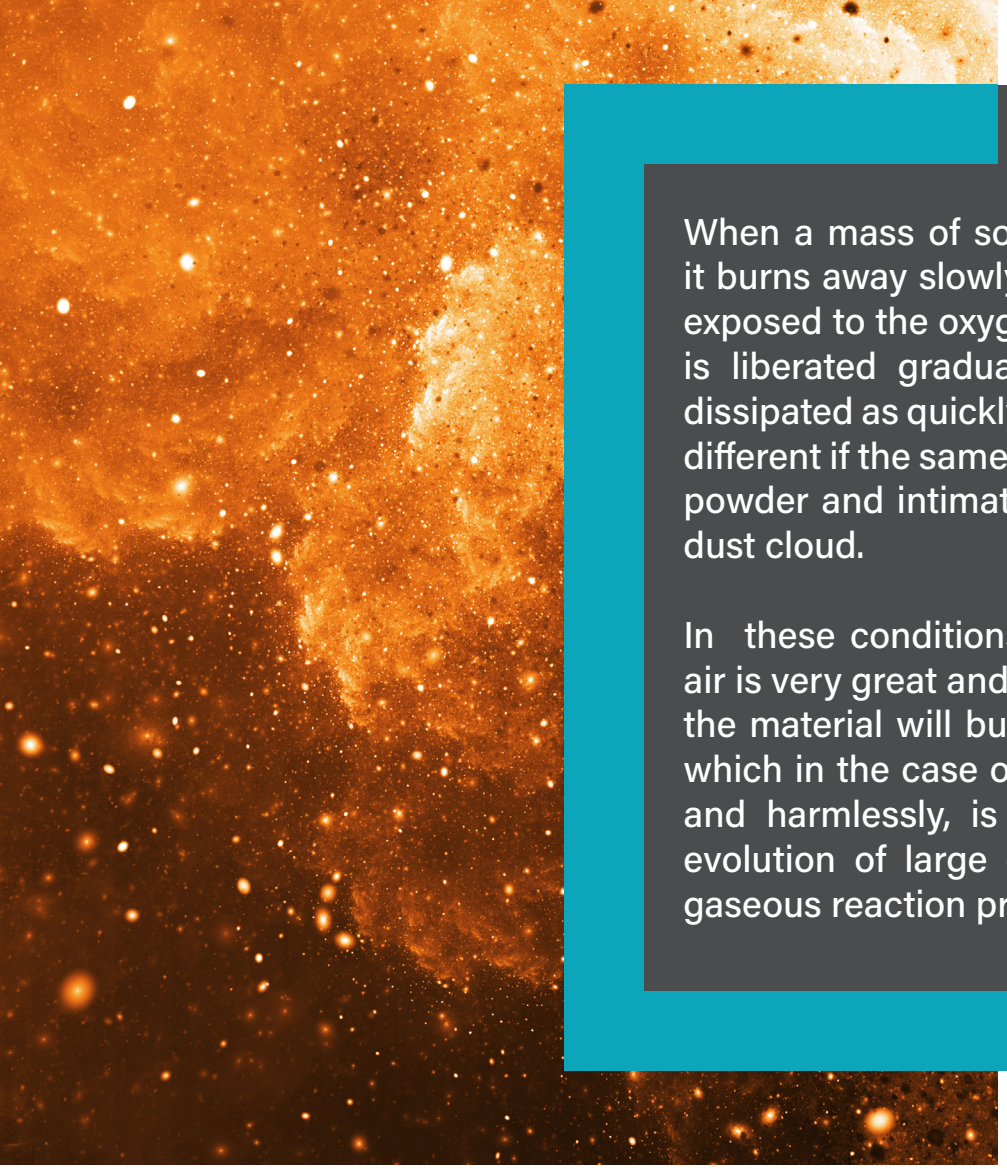
The build-up of even a very small amount of dust can cause serious damage.

CONFINEMENT

A hazardous mixture of dust particles in air can, upon ignition deflagrate, detonate, or explode. In addition to the familiar fire triangle of oxygen, heat, and fuel (the dust), dispersion of dust particles in sufficient quantity and concentration can cause rapid combustion known as a deflagration if the combustion propagation outwards is slower that the speed of sound. If the combustion propagation is faster than the speed of sound it is detonation.

In order to have an explosion, there must be confinement of the flame propagating in the dust-air mixture. If the event is confined by an enclosure such as a building, room, vessel, or process equipment, the resulting pressure rise may cause an explosion. Confinement is the final element making up the dust explosion pentagon. With confinement of the propagating flame front, pressure will rise which may cause rupture of the enclosure.

It is important to note that complete confinement (e.g., four walls, floor, and a roof) is not necessary for dust explosions to reach destructive pressures. Any confinement can lead to pressure rise, acceleration of the flame, or pressure piling, which can all increase the explosion violence. Although the explosion protection approach of venting reduces the amount of confinement, care is needed to size vent panels appropriately to avoid equipment failure.



DISPERSION

When a mass of solid combustible material is heated it burns away slowly owing to the limited surface area exposed to the oxygen of the air. The energy produced is liberated gradually and harmlessly because it is dissipated as quickly as it is released. The result is quite different if the same mass of material is ground to a fine powder and intimately mixed with air in the form of a dust cloud.

In these conditions the surface area exposed to the air is very great and if ignition now occurs the whole of the material will burn with great rapidity; the energy, which in the case of the mass was liberated gradually and harmlessly, is now released suddenly with the evolution of large quantities of heat and, as a rule, gaseous reaction products.

Although an intimate mixture of a flammable dust and air may burn with explosive violence, not all mixtures will do so. There is a range of concentrations of the dust and air within which the mixture can explode, but mixtures above or below this range cannot. The lowest concentration of dust capable of exploding is referred to as the lower explosive limit and the concentration above which an explosion will not take place as the upper explosive limit. The lower explosive limits of many materials have been measured. They vary from 10 grams per cubic meter to about 500 grams per cubic meter. For most practical purposes it may be assumed that 30 grams per cubic meter is the lower explosive limit for most flammable dusts. Though this may seem to be a very low concentration, in appearance a cloud of dust of such a concentration would resemble a very dense fog.

The upper explosive limits are not well defined and have poor repeatability under laboratory test conditions. Since the upper explosive limit is of little practical importance, data for this parameter is rarely available. The most violent explosions are produced when the proportion of oxygen present is not far removed from that which will result in complete combustion. The range of the explosive concentrations of a dust cloud is not simply a function of the chemical composition of the dust; the limits vary with the size and shape of the particles in the dust cloud.

OXIDANT

The oxidant is normally atmospheric air at close to atmospheric pressure. However, air with a reduced oxygen content can still allow an explosion to take place. The limiting oxygen concentration for a dust explosion is typically in the range 5–15% by volume.

This risk assessment recognizes that dust explosions can occur in air at pressures considerably greater than atmospheric pressure, as well as below atmospheric, if there is still sufficient oxygen. Also, that for some applications the oxidant can be a chemical other than oxygen, e.g. chlorine.

Oxidant reduction and elimination can be accomplished by inerting with displacement or blanketing with Nitrogen, Carbon Dioxide or other inert gas. That method can be used within a storage and processing within container confinement or for pneumatic conveying and transport aimed at air elimination.

IGNITION SOURCE

Although mixtures of dust and air within the flammable range are capable of explosion, they will not explode unless they are ignited in some way. Once a source of ignition is presented to the flammable mixture, flame will propagate throughout the cloud. The mode of ignition of a dust cloud is typically a flame, hot surface, static electricity discharge, an electrical spark or a mechanically generated frictional spark or heat. The minimum condition necessary to initiate a dust explosion with certain modes of ignition can be measured. One of the tests performed is KST deflagration.

Dust explosion classes ST1, ST2 & ST3 KST value and PMAX are explosive properties measured in the laboratory to quantify the severity of a dust explosion.

Dust Explosion Class	Kst (bar.m/s)*	Characteristic*	Examples**
St 0	0	No explosion	Silica
St 1	> 0 and < or = 200	Weak explosion	Charcoal, sulfer, sugar, and zinc
St 2	> 200 and < or = 300	Strong explosion	Cellulose, wood flour, and poly methyl acrylate
St 3	> 300	Very strong explosion	Aluminum, magnesium, and anthraquinone

The actual class is sample specific and will depend on carying characteristics of the material such as particle size and moisture.

**OSHA CPL 03-00-008 - Combustible Dust National Emphasis Program*

***NFPA 68, Standard on Explosion Prevention by Deflagration Venting*

HAZARD ASSESSMENT

There are many variables that must be considered - the particle size of the dust, the method of dispersion, ventilation system characteristics, air currents, ignition sources, confinement of the dust cloud, physical barriers, and so on. As a result, the often quoted "rule of thumb" about dust accumulation (such as being able to write in the dust, or the dust being the thickness of a paperclip, dime or quarter, or the amount of visibility through a dust cloud) is not always reliable. Best practice is to keep the workplace as dust free as possible.

Hazard assessment has become mandatory in 2020. Starting September 7, 2020, OSHA requires manufacturers to perform DHA (Dust Hazard Analysis) per NFPA 652, 2019.

Conduct a risk assessment and look specifically for dust explosion possibilities.
Below are some questions that may help:

Processes

- Do you manufacture or use any materials (and their by-products) that can become a dust?
- Do you have processes such as abrasive blasting, cutting, grinding, sieving, polishing, cleaning, or other tasks that create dust?

Research/Information

- Have you researched if the dust present is combustible?
- Are there documented cases reported in literature about the materials in your workplace being associated with a combustible dust explosion?

Note: *It is very important to research the materials and products used in your workplace. Stating the possibility of a combustible dust hazard is a new requirement on the Safety Data Sheet (SDS). Older Material Safety Data Sheets (MSDSs) may not provide the same information so additional research may be necessary.*

Ignition sources

- Do you have ignition sources (e.g., sparks, fire/flames, stoves, kilns, or welding flames)?
- Can dust enter or accumulate on electrical enclosures or equipment?
- Does your workplace have a no-smoking policy? Are there measures to isolate smoking and ignition sources away from production areas?

Housekeeping

- Do you know if there are open areas and overhead structures where dusts may accumulate?
- Have you looked for "hidden" areas where dust may accumulate (e.g. behind false ceilings, inside ventilation or conveyor equipment, in ducts, on support beams, etc.)?
- Do you have a housekeeping program to regularly remove dust?
- Do you have a dust collection system in place?
- If yes, does your dust collection system conform to local requirements (e.g. fire code)?

Education & Training

- Are employees aware of combustible dust and its hazards?
- Do employees follow housekeeping rules and take steps to reduce dust and remove ignition sources?
- Have employees been trained and educated on safe methods for cleaning?

HAZARD PREVENTION

Eliminate

- Where possible, avoid horizontal surfaces (such as window ledges, beams, light fittings, etc.) where dust can accumulate.
- Eliminate "hidden" areas where dust can accumulate unnoticed.
- Do not use brooms or compressed air hoses to clean surfaces. Only use vacuums approved for dust collection.
- Only use a dust collection / dust extraction system that is designed to eliminate or control combustible dust. Using most models of fans typically stirs the dust, adding dust particles into the air and worsening the situation.

Substitute

- Install smooth ceilings and other surfaces (instead of a rough finish) to minimize dust accumulation and to make cleaning easier.

Engineering

- Use an appropriate dust extraction and collection system with the inlet located as close to the dust producing process as possible. Follow required standards and codes when installing these systems. Locate dust collectors outdoors, where possible.
- Direct explosion venting away from areas where there may be employees.
- Use appropriate electrical and ventilation equipment.
- Keep all mechanical and electrical equipment in good repair.
- Keep static electricity under control, which includes the bonding and grounding of equipment. Check all bonded and grounded equipment regularly to ensure the bonds are in good condition.
- Check equipment that may wear (e.g., bearings) as they may generate heat and become an ignition source.
- Remove open flames, sparks, friction, heat sources, and other sources of ignition.
- Select and use intrinsically safe tools or machinery.
- Put covers around pipes and cables, or embed pipes and cables in the walls, where possible, to reduce surfaces where dust can accumulate.

Administration

- Develop and implement a combustible dust inspection and control program which outlines how often inspections will occur and how dust will be controlled.
- Develop a hot work permit system for activities such as welding and cutting.
- Develop an ignition control program to eliminate or reduce sources of ignition. Keep ignition sources away from dusty areas or use suitable controls.
- Educate all employees about combustible dusts, the hazards, and how they can help eliminate the risk of fire and explosions.
- Inspect for dust at regular intervals.
- Establish a housekeeping program that will remove dust regularly.
- Use proper equipment and techniques when cleaning dust. Care must be taken to minimize dust clouds, and only use vacuums approved for dust collection.
- Regularly inspect machines, ducts, and ventilation systems for dust. Repair or clean promptly.

SUMMARY

The basic requirements for a dust explosion to occur is that combustible dusts are suspended in air and are ignited. In practice, for a dust explosion to occur, a number of conditions must be met including:

- The dust must be combustible and release enough heat when it burns to sustain the fire.
- The dust must be capable of being suspended in air.
- The dust must have a particle size capable of spreading the flame.
- The concentration of the dust suspension must be within the explosible range.
- An ignition source must be in contact with the dust suspension.
- The atmosphere must contain sufficient oxygen to support and sustain combustion.
- There is a form of confinement or enclosure that allows pressure to build.
- Hazard assessment and prevention tools are essential in ensuring safe, explosion free operations.
- OSHA non-compliance results in General Duty Clause Violation citations under the Combustible Dust NEP.
- There are several NFPA Standards dealing with Prevention, Assessment and Prevention of the Fires and Explosions in the manufacturing facilities.
    - NFPA 61 Agricultural and Food Processing
    - NFPA 654 Manufacturing, Handling and Processing of Combustible Particles
    - NFPA 484 Combustible Metals
    - NFPA 655 Sulfur Fires
    - NFPA 664 Wood Processing and Woodworking

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Combustible Dust

Does your company or firm process any of these products or materials in powdered form?

If your company or firm processes any of these products or materials, there is potential for a "Combustible Dust" explosion.

Agricultural Products
Egg white
Milk, powdered
Milk, nonfat, dry
Soy flour
Starch, corn
Starch, rice
Starch, wheat
Sugar
Sugar, milk
Sugar, beet
Tapioca
Whey
Wood flour

Agricultural Dusts
Alfalfa
Apple
Beet root
Carrageen
Carrot
Cocoa bean dust
Cocoa powder
Coconut shell dust
Coffee dust
Corn meal
Cornstarch
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 dust
Olive pellets
Onion powder
Parsley (dehydrated)
Peach
Peanut meal and skins
Peat
Potato
Potato flour
Potato starch
Raw yucca seed dust
Rice dust
Rice flour
Rice starch
Rye flour
Semolina
Soybean dust
Spice dust
Spice powder
Sugar (10x)
Sunflower
Sunflower seed dust
Tea
Tobacco blend
Tomato
Walnut dust
Wheat flour
Wheat grain dust
Wheat starch
Xanthan gum

Carbonaceous Dusts
Charcoal, activated
Charcoal, wood
Coal, bituminous
Coke, petroleum
Lampblack
Lignite
Peat, 22%H_20
Soot, pine
Cellulose
Cellulose pulp
Cork
Corn

Chemical Dusts
Adipic acid
Anthraquinone
Ascorbic acid
Calcium acetate
Calcium stearate
Carboxy-methylcellulose
Dextrin
Lactose
Lead stearate
Methyl-cellulose
Paraformaldehyde
Sodium ascorbate
Sodium stearate
Sulfur

Metal Dusts
Aluminum
Bronze
Iron carbonyl
Magnesium
Zinc

Plastic Dusts
(poly) Acrylamide
(poly) Acrylonitrile
(poly) Ethylene (low-pressure process)
Epoxy resin
Melamine resin
Melamine, molded (phenol-cellulose)
Melamine, molded (wood flour and mineral filled phenol-formaldehyde)
(poly) Methyl acrylate
(poly) Methyl acrylate, emulsion polymer
Phenolic resin
(poly) Propylene
Terpene-phenol resin
Urea-formaldehyde/cellulose, molded
(poly) Vinyl acetate/ethylene copolymer
(poly) Vinyl alcohol
(poly) Vinyl butyral
(poly) Vinyl chloride/ethylene/vinyl acetylene suspension copolymer
(poly) Vinyl chloride/vinyl acetylene emulsion copolymer

Dust Control Measures

The dust-containing systems (ducts and dust collectors) are designed in a manner (i.e., no leaking) that fugitive dusts are not allowed to accumulate in the work area.

The facility has a housekeeping program with regular cleaning frequencies established for floors and horizontal surfaces, such as ducts, pipes, hoods, ledges, and beams, to minimize dust accumulations within operating areas of the facility.

The working surfaces are designed in a manner to minimize dust accumulation and facilitate cleaning.

Ignition Control Measures

Electrically-powered cleaning devices such as vacuum cleaners, and electrical equipment are approved for the hazard classification for Class II locations.

The facility has an ignition control program, such as grounding and bonding and other methods, for dissipating any electrostatic charge that could be generated while transporting the dust through the ductwork.

The facility has a Hot Work permit program.

Areas where smoking is prohibited are posted with "No Smoking" signs.

Duct systems, dust collectors, and dust-producing machinery are bonded and grounded to minimize accumulation of static electrical charge.

The facility selects and uses industrial trucks that are approved for the combustible dust locations.

Prevention Measures

The facility has separator devices to remove foreign materials capable of igniting combustible dusts.

MSDSs for the chemicals which could become combustible dust under normal operations are available to employees.

Employees are trained on the explosion hazards of combustible dusts.

Protection Measures

The facility has an emergency action plan.

Dust collectors are not located inside of buildings. (Some exceptions)

Rooms, buildings, or other enclosures (dust collectors) have explosion relief venting distributed over the exterior wall of buildings and enclosures.

Explosion venting is directed to a safe location away from employees.

The facility has isolation devices to prevent deflagration propagation between pieces of equipment connected by ductwork.

The dust collector systems have spark detection and explosion/deflagration suppression systems.

Emergency exit routes are maintained properly.

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