FOCUS ARTICLE

The Hazards of Combustible Dusts and Powders

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Dust Explosions: The Nature of the Problem

In the Chemical Process Industries, powdered materials are a common raw material, process intermediate, or final product. It is typical for powders to contain finely divided particles smaller than 500 microns. Small particles by their very nature have a high surface area per unit mass and, if combustible, can propagate a flame through premixed atmospheres. Some 70% of the dusts that are handled in industry can propagate flame. Such flame propagation is called a deflagration and is capable of producing hazardous over-pressures as well as thermal effects.

Process Safety Management (PSM) includes those operating practices that are used to minimize the risk of a fire, explosion, and toxic release. PSM includes addressing the risk of **combustible dust** fires and explosions. It is the expectation of the Occupational Safety and Health Administration that these events be prevented in the workplace. If you receive and process powdered materials (e.g. flour, sugar, artificial sweeteners, and additives), you could have a serious fire or explosion hazard.

Conditions Required for Dust Explosions to Occur

Several conditions must exist simultaneously for a dust explosion to occur (Figure 1):

- The dust must be combustible (as far as dust clouds are concerned, the terms "combustible", "flammable", and "explosible" all have the same meaning and could be used interchangeably);
- The dust must be dispersed (forming a dense cloud in air or another gaseous oxidant);
- The dust concentration must be within the explosible range (above the Minimum Explosible Concentration);
- The available ignition source must have sufficient energy to initiate combustion;
- Sufficient oxygen for combustion must be present; this is normally true in most manufacturing operations;
- The dust must be in a confined area, e.g. within a piece of equipment, room, building, etc.

There are many different ignition sources with sufficient energy to ignite a dust cloud. Some of these include self-heating, electrostatic discharges, electrical sparks, welding and cutting, hot spots and sparks generated by mechanical equipment failure, sparks generated by mechanical impacts, hot surfaces, open flames and burning materials.

The difference between having a flash fire, or an explosion, depends on whether the ignition occurs in a confined area or not. If the ignition occurs inside a confined area such as a piece of equipment or a room, hot burning gases will cause pressurization of the containment. This pressurization will continue until the containment fails, releasing the pressure outward.

If the ignition occurs in an open area, a large fireball will still occur. However, the hot gases are free to expand without interference, and therefore do not create the overpressure seen in an explosion.

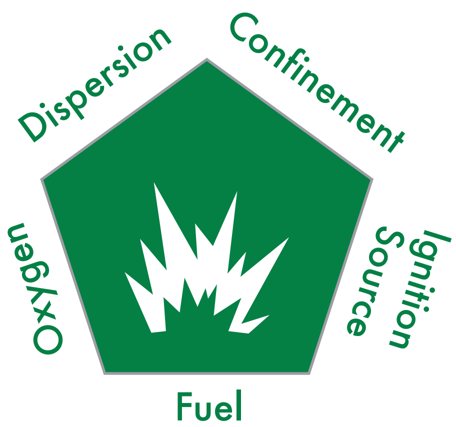

Figure 1 – Conditions required for dust explosions to occur

Assessment of the Dust Explosion Hazard in Your Facility

A systematic approach to identifying **dust cloud explosion** hazards and taking measures to ensure safety must be used. NFPA 652 - Standard on the Fundamentals of Combustible Dust, 2019 Edition states that:

5.4.3.1

Where the explosibility is not known, determination of explosibility of dusts shall be determined according to one of the following tests:

1. The "Go/No-Go" screening test methodology described in ASTM E1226, Standard Test Method for Explosibility of Dust Clouds
2. ASTM E1515, Standard Test Method for Minimum Explosible Concentration of Combustible Dusts
3. An equivalent test methodology

5.4.4.1.

Where dusts are determined to be combustible or explosible, additional testing shall be performed, as required, to acquire the data necessary to support the performance-based design method described in Chapter 6; the DHA described in Chapter 7; the risk assessments described in Chapter 9; or specification of the hazard mitigation and prevention described in Chapter 9.

Go/No-Go Screening Test (ASTM E1226, Standard Test Method for Explosibility of Dust Clouds)

This test determines whether a dust cloud will explode when exposed to a sufficiently energetic ignition source and results in a powder being classified as either "explosible" or "non-explosible". Thus, this test answers the question "Can this dust explode?" If so, then two additional tests are routinely conducted:

Minimum Ignition Energy - MIE (ASTM E2019, Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air)

The MIE test determines the lowest electrostatic energy that can ignite a dust cloud at its optimum ignitable concentration. This test is used primarily to assess the susceptibility of dust clouds to ignition by electrostatic discharges (sparks).

Maximum Explosion Pressure, Maximum Rate of Pressure Rise, Deflagration Index (Kst Value) (ASTM E1226, Standard Test Method for Explosibility of Dust Clouds)

The Maximum Explosion Pressure and Maximum Rate of Pressure Rise values are determined by using a 1-cubic-meter or 20-liter sphere test apparatus. The dust sample is dispersed within the sphere and ignited by pyrotechnic devices. The pressure and rate of pressure rise of the resulting explosion are measured at the sphere wall. The cloud concentration is varied to determine the optimal dust concentration.

The maximum rate of pressure rise is used to calculate the Deflagration Index (K_{st}) value of the dust cloud. The K_{st} value and the maximum explosion pressure can be used in the design of dust explosion protection measures such as explosion relief venting, suppression, and containment. This test answers the question "How serious are the consequences if a dust cloud is ignited?"

The concentration of dust in the cloud is important. An explosible dust cloud resembles a dense fog. Although such concentrations are not normally expected to be present within processing buildings, explosible dust clouds are regularly formed inside the material handling/processing equipment; for example, when bins are being filled, when powders are pneumatically conveyed, or when accumulated dust is removed from filters in a dust collector.

The particle size of the dust influences the explosibility of a dust cloud. Powders include pellets (sizes greater than about 2 mm), granules (approximate sizes between 2 and 0.5 mm), and dust particles (sizes less than about 0.5 mm). The finer the particles, the greater the surface area per unit mass; thus, the more explosible a given dust is likely to be. When the cloud is composed of a range of particle sizes from fine to coarse, the fines play a prominent part in ignition and explosion propagation. For friable materials, the presence of dusts should be anticipated in the process stream, regardless of the starting particle size of the material. For example, materials such as sugar and phenolic flake will create dust in handling operations.

The moisture content of a product will also affect the explosion risk. A dry dust would contain less than 5% moisture. Dry dusts of small particle size would be more easily ignited and would produce more violent explosions. Moisture within or on the particle surface reduces both the likelihood of flame propagation and the rate of propagation. Moisture acts as a heat sink in reducing the effectiveness of flame transfer from one particle to another. Moisture also can cause agglomeration of fine particles and increase the "apparent" particle size.

NFPA 652 also requires that a Dust Hazard Analysis (DHA) be conducted. In addition to evaluation of the materials, the DHA must also include examination of powder and dust operations to identify areas of the facility where combustible dust clouds could exist under normal and/or abnormal conditions. This would include examination of the processing equipment, building and building compartments. The DHA shall be performed or led by a qualified person.

Actions taken as a result of the DHA include those that control and mitigate the hazards. Potential actions are described in the following paragraphs.

Safety from dust cloud explosions includes taking measures to avoid an explosion (explosion prevention) or designing facilities and equipment so that in the event of an explosion personnel and processes are protected (explosion protection). The selection of explosion prevention and/or protection measures is based on:

- How much information is available on the sensitivity of the powder(s) to ignition and the resulting explosion severity;
- The nature of the processes and operations in which dust is handled or created;
- The level of employee knowledge and appreciation regarding the consequences of a dust explosion and adherence to the preventive measures (**employee training**);
- Environmental and societal effects of a dust explosion; and
- Business interruption resulting from a dust explosion.

Explosion Prevention and Protection Measures

The risk of an explosion is minimized when one of the following measures is ensured:

- An explosible dust cloud is never allowed to form;
- The atmosphere is sufficiently depleted of oxidant (normally the oxygen in air) that it cannot support combustion;
- All ignition sources capable of igniting the dust cloud are removed; and/or
- People and facilities are protected against the consequences of an explosion by "protection measures" such as explosion containment, explosion suppression, or explosion relief venting.

Secondary Explosions and Good Housekeeping

A technically well-designed plant does not guarantee safety, if those who operate it do not understand the hazards involved and the precautions designed to control them.

A majority of the most serious dust explosions over the years have not been caused by the primary explosion inside equipment, but from a secondary explosion within the building. This occurs if a small initial event causes a pressure wave to propagate into the workplace, disbursing dust deposits around the room into a cloud, and that secondary dust cloud ignites. This can happen in a series of connected rooms and result in catastrophic building failure.

Housekeeping activities must ensure that secondary fuel sources are not available. Of key importance is evaluation of dust release points and exhaust ventilation needs. It is much easier to replace a gasket, refit a manway, or install local dust collection systems, etc., than to spend the time cleaning up the dust that has escaped.

Safeguard Reliability

All safeguards intended to prevent dust explosions must be recognized, understood, and rigorously maintained by employees and management staff. Operators should be aware that signs of overheating, excessive vibration, or noises indicating mechanical malfunction or misalignment need prompt attention before a small smoldering dust deposit leads to a serious explosion. Likewise, protective safeguards such as explosion relief vents or abort gates must be appropriately designed, inspected or tested, and maintained to ensure proper operation. A routine inspection and testing program should be developed and implemented for all safety-critical systems and devices.

The tests below may be required to provide additional information necessary for ensuring a sound basis for safety.

Minimum Ignition Temperature of a Dust Cloud – MIT Cloud (ASTM E1491, Standard Test Method for Minimum Auto-ignition Temperature of Dust Clouds)

This test determines the lowest temperature capable of igniting a dust dispersed in the form of a cloud. The MIT Cloud is an important factor in evaluating the ignition sensitivity of dusts to such ignition sources as heated environments, hot surfaces, electrical devices, and friction sparks.

Minimum Ignition Temperature of a Dust Layer – MIT Layer (ASTM E2021, Standard Test Method for Hot Surface Ignition Temperature of Dust Layers)

This test determines the lowest temperature capable of igniting a dust layer of standard thickness (5 to 12.7 mm). The MIT Layer is used in evaluating the ignition sensitivity of powders to ignition by hot surfaces, as in ovens and dryers and on motors. The lower of the two MIT values is used to specify the maximum surface temperature for Class II equipment as required by the National Electrical Code®, NFPA 70.

Self-Heating (Prevention of Fires and Explosions in Dryers, Institute of Chemical Engineers, 1990)

Ignition of bulk powders can occur by a process of self-heating when the temperature of the powder is raised to a level at which the heat liberated by the exothermic oxidation or decomposition reaction exceeds the heat losses, resulting in a "runaway" increase in temperature.

The minimum onset temperature for self-ignition of a powder depends mainly on the nature of the powder and on the size of the container. If these variables are known, a reliable assessment of the onset temperature for self-ignition and also the induction time to self-ignition can be made by appropriate small-scale laboratory tests:

- Bulk Powder Test: Simulates bulk powder in IBCs, bags, and hoppers
- Aerated Powder Test: Simulates fluidized bed processing
- Powder Layer Test: Simulates powder deposits on dryer walls/surfaces and tray drying
- Basket Test: Simulates large-scale storage or transport conditions

Minimum Explosible Concentration - MEC (ASTM E1515, Standard Test Method for Minimum Explosible Concentration of Combustible Dusts)

The MEC test determines the lowest concentration of dust cloud in air that can give rise to flame propagation upon ignition.

Electrostatic Volume Resistivity (General Accordance with ASTM D257, Standard Test Methods for DC Resistance or Conductance of Insulating Materials)

Volume Resistivity is the primary criterion for classifying powders as low, moderately, or highly insulating. Insulating powders have a propensity to "create" and retain electrostatic charge and can produce hazardous electrostatic discharges.

Electrostatic Chargeability (General Accordance with ASTM D257, Standard Test Methods for DC Resistance or Conductance of Insulating Materials)

Electrostatic Chargeability is a measure of the propensity of powder particles to become charged when flowing through piping or ductwork or when handled in containers. This test provides data that can be used to develop appropriate material-handling guidelines from an electrostatic hazards point of view.

Limiting Oxidant Concentration - LOC (EN 14034-4, Determination of the Limiting Oxygen Concentration of Dust Clouds)

The LOC test determines the minimum concentration of oxygen (when displaced or diluted by an inert gas such as nitrogen, argon, carbon dioxide, or steam) that would be capable of supporting combustion or explosion. The LOC test is used to determine the required extent of inert-gas dilution and to set oxygen concentration alarms or interlocks in inerted vessels. The LOC is inert gas specific and this test should be conducted using the appropriate inert gas.

For further information, please download and review the DEKRA Strategic Combustible Dust Guide: A Strategic Guide to Characterization and Understanding Handling Dusts and Powders Safely

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David E. Kaelin, Sr., B.S.Ch.E., Mr. Kaelin has over 35 years of experience in the specialty chemical manufacturing industry and 25 years specializing as a Process Safety Engineer. He has participated in the design and construction of numerous chemical processing facilities and provided support and training in all areas of PSM. As a Process Safety Engineer, he has led process hazard analysis, risk assessments and facility siting reviews. At the corporate level he has created and taught courses in PSM and hazard recognition methods. Mr. Kaelin is an expert in the application of hazard recognition techniques including: HAZOP, FMEA. What-If, Fault Tree Analysis, Risk Screening and Checklist. He is an active member of AIChE, and NFPA.

DEKRA Process Safety

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Process Safety Management (PSM) Programs

- Design and creation of relevant PSM programs
- Support the implementation, monitoring, and sustainability of PSM programs
- Audit existing PSM programs, comparing with best practices around the world
- Correct and improve deficient programs

Process Safety Information/Data (Laboratory Testing)

- Flammability/combustibility properties of dusts, gases, vapors, mists, and hybrid atmospheres
- Chemical reaction hazards and chemical process optimization (reaction and adiabatic calorimetry RC1, ARC, VSP, Dewar)
- Thermal instability (DSC, DTA, and powder specific tests)
- Energetic materials, explosives, propellants, pyrotechnics to DOT, UN, etc. protocols
- Regulatory testing: REACH, UN, CLP, ADR, OSHA, DOT
- Electrostatic testing for powders, liquids, process equipment, liners, shoes, FIBCs

Specialist Consulting (Technical/Engineering)

- Dust, gas, and vapor flash fire and explosion hazards
- Electrostatic hazards, problems, and applications
- Reactive chemical, self-heating, and thermal instability hazards
- Hazardous area classification
- Mechanical equipment ignition risk assessment
- Transport & classification of dangerous goods

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