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Dust explosions

Combustible Dust in Industry: Preventing and Mitigating the Effects of Fire and Explosions

Safety and Health Information Bulletin

SHIB 07-31-2005

This Safety and Health Information Bulletin is **not** *a standard or regulation, and it creates no new legal obligations. The Bulletin is advisory in nature, informational in content, and is intended to assist employers in providing a safe and healthful workplace. Pursuant to the* Occupational Safety and Health Act, *employers must comply with hazard-specific safety and health standards promulgated by OSHA or by a state with an OSHA-approved state plan. In addition, pursuant to Section 5(a)(1), the General Duty Clause of the Act, employers must provide their employees with a workplace free from recognized hazards likely to cause death or serious physical harm. Employers can be cited for violating the General Duty Clause if there is a recognized hazard and they do not take reasonable steps to prevent or abate the hazard. However, failure to implement any recommendations in this Safety and Health Information Bulletin is not, in itself, a violation of the General Duty Clause. Citations can only be based on standards, regulations, and the General Duty Clause.*

Purpose

This Safety and Health Information Bulletin (SHIB) highlights:
Hazards associated with combustible dusts;

Work practices and guidelines that reduce the potential for a combustible dust explosion, or that reduce the danger to employees if such an explosion occurs; and,

Training to protect employees from these hazards.
Background

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Organic Dust Fire and Explosion: Massachusetts (3 killed, 9 injured)

In February 1999, a deadly fire and explosion occurred in a foundry in Massachusetts. The Occupational Safety Health Administration (OSHA) and state and local officials conducted a joint investigation of this incident. The joint investigation report[1] indicated that a fire initiated in a shell molding machine from an unknown source and then extended into the ventilation system ducts by feeding on heavy deposits of phenol formaldehyde resin dust. A small primary deflagration occurred within the ductwork, dislodging dust that had settled on the exterior of the ducts. The ensuing dust cloud provided fuel for a secondary explosion which was powerful enough to lift the roof and cause wall failures. Causal factors listed in the joint investigation report included inadequacies in the following areas:
Housekeeping to control dust accumulations;
Ventilation system design;
Maintenance of ovens; and,
Equipment safety devices.



Organic Dust Fire and Explosion: North Carolina (6 killed, 38 injured)

In January 2003, devastating fires and explosions destroyed a North Carolina pharmaceutical plant that manufactured rubber drug-delivery components. Six employees were killed and 38 people, including two firefighters, were injured. The U.S. Chemical Safety and Hazard Investigation Board (CSB), an independent Federal agency charged with investigating chemical incidents, issued a final report[2] concluding that an accumulation of a combustible polyethylene dust above the suspended ceilings fueled the explosion. The CSB was unable to determine what ignited the initial fire or how the dust was dispersed to create the explosive cloud in the hidden ceiling space. The explosion severely damaged the plant and caused minor damage to nearby businesses, a home, and a school. The causes of the incident cited by CSB included inadequacies in:
Hazard assessment;
Hazard communication; and
Engineering management.
The CSB recommended the application of provisions in National Fire Protection Association standard NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids, as well as the formal adoption of this standard by the State of North Carolina.

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Organic Dust Fire and Explosion: Kentucky (7 killed, 37 injured)

In February 2003, a Kentucky acoustics insulation manufacturing plant was the site of another fatal dust explosion. The CSB also investigated this incident. Their report[3] cited the likely ignition scenario as a small fire extending from an unattended oven which ignited a dust cloud created by nearby line cleaning. This was followed by a deadly cascade of dust explosions throughout the plant. The CSB identified several causes of ineffective dust control and explosion prevention/mitigation involving inadequacies in:
Hazard assessment;
Hazard communication;
Maintenance procedures;
Building design; and,
Investigation of previous fires.

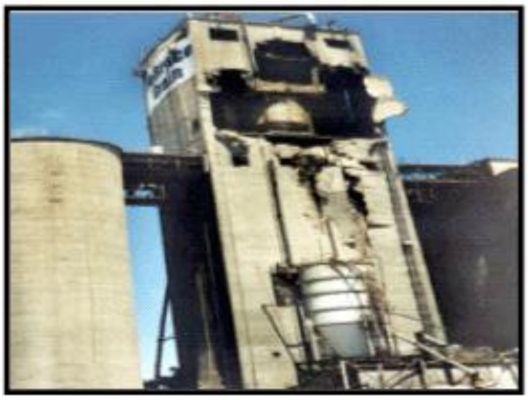
Metal Dust Fire and Explosion: Indiana (1 killed, 1 injured)

Finely dispersed airborne metallic dust can also be explosive when confined in a vessel or building. In October 2003, an Indiana plant where auto wheels were machined experienced an incident which was also investigated by the CSB. A report has not yet been issued, however, a CSB news release[4] told a story similar to the previously discussed organic dust incidents: aluminum dust was involved in a primary explosion near a chip melting furnace, followed by a secondary blast in dust collection equipment.

Related Experience in the Grain Handling Industry

In the late 1970s a series of devastating grain dust explosions in grain elevators left 59 people dead and
49 injured. In response to these catastrophic events, OSHA issued a "Grain Elevator Industry Hazard Alert" to provide employers, employees, and other officials with information on the safety and health hazards associated with the storage and distribution of grain.

In 1987, OSHA promulgated the Grain Handling Facilities standard (29 CFR 1910.272), which remains in effect. This standard, other OSHA standards such as Emergency Action Plans (29 CFR 1910.38), and updated industry consensus standards all played an important role in reducing the occurrence of explosions in this industry, as well as mitigating their effects. The lessons learned in the grain industry can be applied to other industries producing, generating, or using combustible dust.



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Elements of a Dust Explosion

Elements Needed for a Fire (the familiar "Fire Triangle"):

1. Combustible dust (fuel);
2. Ignition source (heat); and,
3. Oxygen in air (oxidizer).

Additional Elements Needed for a Combustible Dust Explosion:

4. Dispersion of dust particles in sufficient quantity and concentration; and,
5. Confinement of the dust cloud.

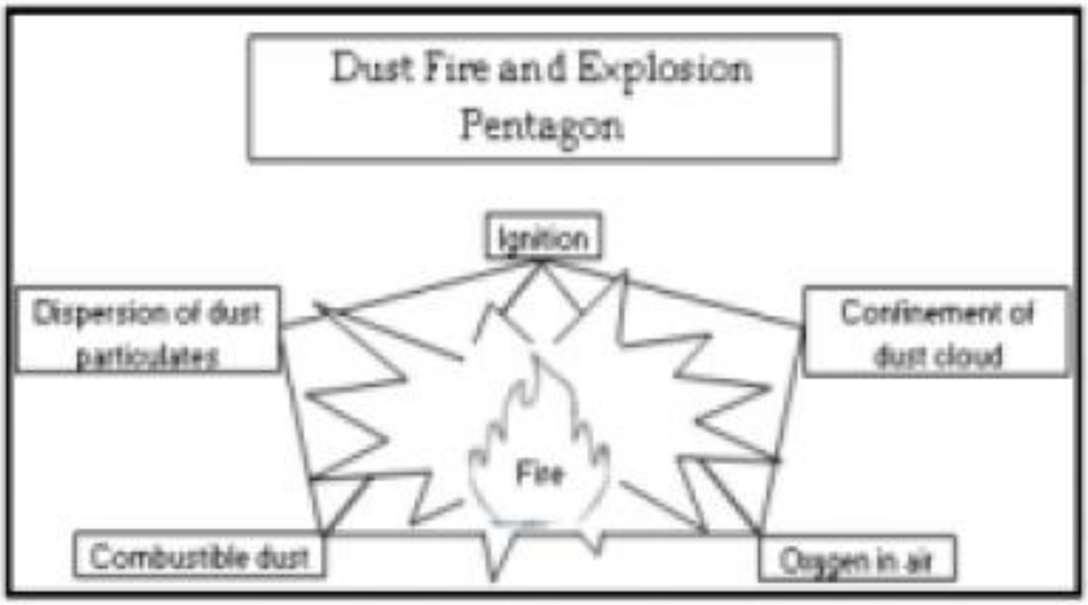

Figure 1

The addition of the latter two elements to the fire triangle creates what is known as the "explosion pentagon" (see Figure 1). If a dust cloud (diffused fuel) is ignited within a confined or semi-confined vessel, area, or building, it burns very rapidly and may explode. The safety of employees is threatened by the ensuing fires, additional explosions, flying debris, and collapsing building components.

An initial (primary) explosion (see Figure 2) in processing equipment or in an area were fugitive dust has accumulated may shake loose more accumulated dust, or damage a containment system (such as a duct, vessel, or collector). As a result, if ignited, the additional dust dispersed into the air may cause one or more secondary explosions (see Figure 2). These can be far more destructive than a primary explosion due to the increased quantity and concentration of dispersed combustible dust.

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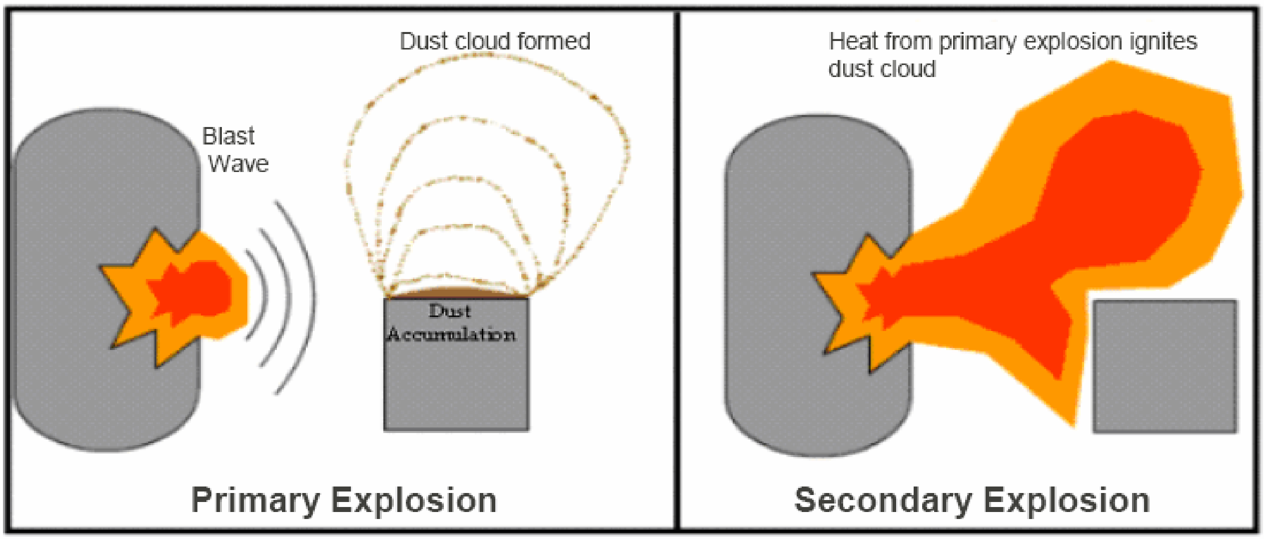

Figure 2

If one of the elements of the explosion pentagon is missing, a catastrophic explosion can not 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 document.

Facility Dust Hazard Assessment

A combustible dust explosion hazard may exist in a variety of industries, including: food (e.g., candy, starch, flour, feed), plastics, wood, rubber, furniture, textiles, pesticides, pharmaceuticals, dyes, coal, metals (e.g., aluminum, chromium, iron, magnesium, and zinc), and fossil fuel power generation. The vast majority of natural and synthetic organic materials, as well as some metals, can form combustible dust. NFPA's Industrial Fire Hazards Handbook[5] *states that "any industrial process that reduces a combustible material and some normally noncombustible materials to a finely divided state presents a potential for a serious fire or explosion."*

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Facility Analysis Components

Facilities should carefully identify the following in order to assess their potential for dust explosions:
Materials that can be combustible when finely divided;
Processes which use, consume, or produce combustible dusts;
Open areas where combustible dusts may build up;
Hidden areas where combustible dusts may accumulate;
Means by which dust may be dispersed in the air; and
Potential ignition sources.
The applicable Federal, state, and local laws and regulations must be identified and followed. The two predominant model fire codes which have been adopted by many jurisdictions in this country are the International Code Council's International Fire Code® and NFPA's Uniform Fire Code®. Both of these model codes reference many of the NFPA consensus standards related to dust explosion prevention and mitigation which are discussed below. In the absence of a legal mandate to comply with these consensus standards, they should be considered a very useful source of guidance on this topic.

Dust Combustibility

The primary factor in an assessment of these hazards is whether the dust is in fact combustible. Any "material that will burn in air" in a solid form can be explosive when in a finely divided form.[6] *Combustible dust is defined by NFPA 654 as: "Any finely divided solid material that is 420 microns or smaller in diameter (material passing a U.S. No. 40 Standard Sieve) and presents a fire or explosion hazard when dispersed and ignited in air." The same definition is used for combustible metal dust in NFPA 484, Standard for Combustible Metals, Metal Powders, and Metal Dusts. One possible source for information on combustibility is the Material Safety Data Sheet (MSDS) for the material. In some cases, additional information such as test results will be available from chemical manufacturers.*

Different dusts of the same chemical material will have different ignitability and explosibility characteristics, depending upon many variables such as particle size, shape, and moisture content. Additionally, these variables can change while the material is passing through process equipment. For this reason, published tables of dust explosibility data may be of limited practical value. In some cases, dusts will be combustible even if the particle size is larger than that specified in the NFPA definition, especially if the material is fibrous.[7]

Industrial settings may contain high-energy ignition sources such as welding torches. In these situations, test methods for dust ignition and explosion characteristics from ASTM International (originally the American Society for Testing and Materials) would be of value. A discussion of these test methods is in reference 8, and the relevant OSHA and other standards are listed in the "Sources of Additional Information" section of this document.

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Electrical Classification

The facility analysis must identify areas requiring special electrical equipment classification due to the presence (or potential presence) of combustible dust. The OSHA Electrical standard (29 CFR Part 1910
Subpart S) contains general requirements for electrical installations in hazardous areas. Detailed requirements for equipment and wiring methods are in NFPA 70, the National Electrical Code®. However, NFPA 70 does not define combustible dusts.

Further guidance on area classification is contained in NFPA 499, Recommended Practice for the Classification of Combustible Dusts and of Hazardous (classified) Locations for Electrical Installations in Chemical Process Areas. This document uses the same definition of combustible dust as NFPA 484 and NFPA 654. The overall dust hazard designation for electrical requirements is Class II. This is further broken down into Divisions which represent the probability of dust being present at any given time. Additionally, each dust is assigned a group (E, F, or G), representing the dust types (metal, carbonaceous, and other, respectively) with different properties. For instance, group E dusts are electrically conductive and electric current can pass through a layer of such dust under favorable circumstances, causing short circuits or arcs.

Other Hazard Analysis Considerations

The amount of dust accumulation necessary to cause an explosive concentration can vary greatly. This is because there are so many variables – the particle size of the dust, the method of dispersion, ventilation system modes, air currents, physical barriers, and the volume of the area in which the dust cloud exists or may exist. As a result, simple rules of thumb regarding accumulation (such as writing in the dust or visibility in a dust cloud) can be subjective and misleading. The hazard analysis should be tailored to the specific circumstances in each facility and the full range of variables affecting the hazard.

Many locations need to be considered in an assessment. One obvious place for a dust explosion to initiate is where dust is concentrated. In equipment such as dust collectors, a combustible mixture could be present whenever the equipment is operating. Other locations to consider are those where dust can settle, both in occupied areas and in hidden concealed spaces. A thorough analysis will consider all possible scenarios in which dust can be disbursed, both in the normal process and potential failure modes.

After hazards have been assessed and hazardous locations are identified, one or more of the following prevention, protection and/or mitigation methods may be applied. The references and information sources at the end of this document will assist in the decision process for the methods suitable to specific work sites. Additional guidance and requirements may be available from local or state fire and building code officials as well as OSHA Area or Regional Offices.

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Control

NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids, contains comprehensive guidance on the control of dusts to prevent explosions. The following are some of its recommendations:
Minimize the escape of dust from process equipment or ventilation systems;
Use dust collection systems and filters;
Utilize surfaces that minimize dust accumulation and facilitate cleaning;
Provide access to all hidden areas to permit inspection;
Inspect for dust residues in open and hidden areas, at regular intervals;
Clean dust residues at regular intervals;
Use cleaning methods that do not generate dust clouds, if ignition sources are present;
Only use vacuum cleaners approved for dust collection;
Locate relief valves away from dust hazard areas; and
Develop and implement a hazardous dust inspection, testing, housekeeping, and control program (preferably in writing with established frequency and methods).
The OSHA ventilation standard, 29 CFR 1910.94, contains ventilation requirements for certain types of operations (such as abrasives, blasting, grinding, or buffing) which involve dusts, including combustible dusts. Additionally, 29 CFR 1910.22(a)(1) requires employers to keep work places and other areas clean, which includes the removal of dust accumulations.

Ignition Control

NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids, also contains comprehensive guidance on the control of ignition sources to prevent explosions. The following are some of its recommendations:
Use appropriate electrical equipment and wiring methods;
Control static electricity, including bonding of equipment to ground;
Control smoking, open flames, and sparks;
Control mechanical sparks and friction;
Use separator devices to remove foreign materials capable of igniting combustibles from process materials;
Separate heated surfaces from dusts;
Separate heating systems from dusts;
Proper use and type of industrial trucks;
Proper use of cartridge activated tools; and
Adequately maintain all the above equipment.
The use of proper electrical equipment in hazardous locations is crucial to eliminating a common ignition source. The classification of areas requiring special electrical equipment is discussed in the Facility Dust Hazard Assessment section above. Once these areas have been identified, special Class II wiring methods and equipment (such as "dust ignition-proof" and "dust-tight") must be used as required by 29 CFR 1910.307 and as detailed in NFPA 70 Article 500. It is important not to confuse Class II equipment with Class I explosion-proof equipment, as Class II addresses dust hazards, while Class I addresses gas, vapor and liquid hazards.

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The use of industrial trucks is regulated by OSHA's Powered Industrial Trucks standard (29 CFR 1910.178). Hazardous atmospheres including dust concentrations are addressed in paragraph (c) of this standard.

Where coal-handling operations may produce a combustible atmosphere from flammable dust, employers covered by the Electric Power Generation, Transmission, and Distribution standard must eliminate or safely control ignition sources. See 29 CFR 1910.269(v)(11)(xii).

Damage Control

NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids, contains comprehensive guidance to minimize the danger and damage from an explosion. The following are some suggested protection methods:
Separation of the hazard (isolate with distance);
Segregation of the hazard (isolate with a barrier);
Deflagration venting of a building, room, or area;
Pressure relief venting for equipment;
Provision of spark/ember detection and extinguishing systems;
Explosion protection systems (also refer to NFPA 69, Standard on Explosion Prevention Systems);
Sprinkler systems; and
The use of other specialized suppression systems.
Training

Employees

Workers are the first line of defense in preventing and mitigating fires and explosions. If the people closest to the source of the hazard are trained to recognize and prevent hazards associated with combustible dust in the plant, they can be instrumental in recognizing unsafe conditions, taking preventative action, and/or alerting management. While OSHA standards require training for certain employees, all employees should be trained in safe work practices applicable to their job tasks, as well as on the overall plant programs for dust control and ignition source control. They should be trained before they start work, periodically to refresh their knowledge, when reassigned, and when hazards or processes change.

Employers with hazardous chemicals (including combustible dusts) in their workplaces are required to comply with 29 CFR 1910.1200, the Hazard Communication standard. This includes having labels on containers of hazardous chemicals, using material safety data sheets, and providing employee training.

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Management

A qualified team of managers should be responsible for conducting a facility analysis (or for having one done by qualified outside persons) prior to the introduction of a hazard and for developing a prevention and protection scheme tailored to their operation. Supervisors and managers should be aware of and support the plant dust and ignition control programs. Their training should include identifying how they can encourage the reporting of unsafe practices and facilitate abatement actions.

References

1. Occupational Safety and Health Administration (OSHA), the Massachusetts Office of the State FireMarshall, and the Springfield Arson and Bomb Squad. "Joint Foundry Explosion Investigation Team Report." OSHA, Springfield, MA, (No date).

2. Chemical Safety and Hazard Investigation Board (CSB). "Investigation Report: West Pharmaceutical Services, Inc. Dust Explosion." CSB, Washington, DC, September 2004.

3. Chemical Safety and Hazard Investigation Board (CSB). "Investigation Report: CTAAcoustics, Inc. Combustible Dust Fire and Explosions." CSB, Washington, DC, September 2004.

4. Chemical Safety and Hazard Investigation Board (CSB). "CSB Investigators Find Likely Source of Dust Explosion at Indiana Automotive Plant." CSB News Release, Washington, DC, November 5, 2003.

5. National Fire Protection Association (NFPA). "Industrial Fire Hazards Handbook," 3rd Edition. NFPA, Inc., Quincy, MA, 1990.

6. Cross, J., and Farrer, D., "Dust Explosions," New York: Plenum Press, 1982.

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8. Britton, L.G., Cashdollar, K.L, Fenlon, W., Frurip, D., Going, J., Harrison, B.K., Niemeier, J., and Ural, E.A., "The Role of ASTM E27 Methods in Hazard Assessment Part II: Flammability and Ignitability," Process Safety Progress, v. 24, pp. 12-28, 2005.

General Information

FM Global, "Prevention and Mitigation of Combustible Dust Explosions and Fire", Data Sheet No. 7-76, January 2005.

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Center for Chemical Process Safety (CCPS). "Guidelines for Safe Handling of Powders and Bulk Solids." CCPS, American Institute for Chemical Process Safety, New York, New York, January 2005.

Sources of Additional Information

Note: This SHIB was developed using the latest information and requirements from the references below. Editions are not listed here, since users of this document should refer to the most current editions.

***Code of Federal Regulations (CFR)* [Standards]**

U.S. Government Printing Office
732 N. Capitol Street, NW Washington, DC 20401
Telephone: 1-866-512-1800 (toll-free)

OSHA Standards, Interpretations, and Publications

U.S. Department of Labor/OSHA OSHA Publications Office
200 Constitution Ave., NW, N-3101
Washington, DC 20210
Telephone: (202) 693-1888
or by Fax: (202) 693-2498

Related OSHA standards found in 29 CFR:

1910.22 - General Requirements: Housekeeping·
1910.38 - Emergency Action Plans
1910.94 - Ventilation
1910.107 - Spray Finishing Using Flammable and Combustible Materials
1910.146 - Permit-Required Confined Spaces (references combustible dust)
1910.178 - Powered Industrial Trucks
1910.269 - Electric Power Generation, Transmission and Distribution (coal handling)
1910.272 - Grain Handling Facilities

1910.307 - Hazardous (classified) Locations (for electric equipment)
1910.1200 - Hazard Communication

U.S. Chemical Safety and Hazard Investigation Board

2175 K Street, NW, Suite 400
Washington, DC 20037-1809
Telephone: (202) 261-7600
Fax: (202) 261-7650

ASTM International

100 Barr Harbor Drive
P. O. Box C700
West Conshohocken, PA 19428-2959
Telephone: (610) 832-9585
Fax: (610) 832-955

Related ASTM Standards:
E789-95 Standard Test Method for Dust Explosions in a 1.2-Litre Closed Cylindrical Vessel
E1226-00e1 Standard Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts
E1491-97 Standard Test Method for Minimum Autoignition Temperature of Dust Clouds
E1515-03a Standard Test Method for Minimum Explosible Concentration of Combustible Dusts
E2021-01 Standard Test Method for Hot- Surface Ignition Temperature of Dust Layers
National Materials Advisory Board (NMAB) Publications

National Academies Press
500 Fifth St., NW Washington, DC 20001
Telephone: (202) 334-3313
Fax: (202) 334-2451

Related NMAB Publication:
NMAB 353-4 (1982), Classification of Dusts Relative to Electrical Equipment in Class II Hazardous Locations.
National Fire Protection Association (NFPA)

1 Batterymarch Park
Quincy, MA 02169-7471
Telephone: (800) 344-3555

Related NFPA Standards:
NFPA 61, Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities
NFPA 68, Guide for Venting of Deflagrations
NFPA 69, Standard on Explosion Prevention Systems
NFPA 70, National Electrical Code®

NFPA 91, Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids
NFPA 120, Standard for Fire Prevention and Control in Metal/Nonmetal Mining and Metal Mineral Processing Facilities
NFPA 432, Code for the Storage of Organic Peroxide Formulations
NFPA 480, Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders
NFPA 481, Standard for the Production, Processing, Handling, and Storage of Titanium
NFPA 482, Standard for the Production, Processing, Handling, and Storage of Zirconium
NFPA 484, Standard for Combustible Metals, Metal Powders, and Metal Dusts
NFPA 485, Standard for the Storage, Handling, Processing, and Use of Lithium Metal
NFPA 495, Explosive Materials Code
NFPA 499, Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas
NFPA 505, Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operation
NFPA 560, Standard for the Storage, Handling, and Use of Ethylene Oxide for Sterilization and Fumigat
NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids
NFPA 655, Standard for Prevention of Sulfur Fires and Explosions
NFPA 664, Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities
NFPA 1124, Code for the Manufacture, Transportation, Storage, and Retail Sales of Fireworks and Pyrotechnic Articles
NFPA 1125, Code for the Manufacture of Model Rocket and High Power Rocket Motors

International Code Council (ICC)
5203 Leesburg Pike, Suite 600
Falls Church, VA 22041
Telephone: 1-888-ICC-SAFE (422-7233) Fax: (703) 379-1546
Related ICC Publication:
International Fire Code

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