Guide to Combustible Dust Explosion Hazards

Combustible dusts are fine particles that may present an explosion hazard when suspended in the air in the existence of certain conditions. Although dust explosions can be catastrophic and cause employee deaths and/or injuries as well as damages up to and including the destruction of entire buildings, employers and employees may be unaware that a hazard exists.

Catastrophic explosions generally make news because of the loss of lives and jobs along with the destruction of property. Newscasters and editorial commentators often ask, "How could this have happened?"

Actually, the hazards of dust explosions and the conditions leading up to them have long been known. Similarly, control measures to prevent them have been extensively researched and published in detail by organizations like the National Fire Protection Agency (NFPA) International.

In 2003, the U.S. Chemical Safety and Hazard Investigation Board (CSB) launched investigations of three major industrial explosions involving combustible powders:

- At West Pharmaceutical Services in Kinston, North Carolina, plastic powder that had accumulated above a suspended ceiling exploded, killing six and gravely injuring many others
- At CTA Acoustics in Corbin, Kentucky, phenolic resin (another plastic powder) exploded, killing seven and injuring many others
- At a Hayes-Lemmerz automobile wheel plant in Indiana, aluminum powder exploded, killing one worker. The plant was subsequently closed.

Following these events, the CSB Board launched a nationwide study to determine the scope of the problem and to recommend new safety measures for facilities handling combustible powders. In their final report, issued in November 2006, the CSB Board identified 281 fires and explosions that occurred over a 25-year period, resulting in the loss of 119 lives and 718 injuries.

The latest government initiative developed to control this problem was implemented on March 11, 2008; the **OSHA Combustible Dust National Emphasis Program** (NEP).

What Happens When Dust Explodes?

When a dust explosion occurs in a building, walls may blow out, floors may heave, and ceilings may collapse. All of this can occur in just a few seconds. Therefore, it is not unusual for local fire protection and electrical systems to fail, in some cases instantly. Fires initiated by the thermal energy of the explosion may follow.

Sometimes, the primary event disperses larger amounts of dust into the air. A very large flammable dust cloud can ignite, which could lead to one or more secondary explosions.

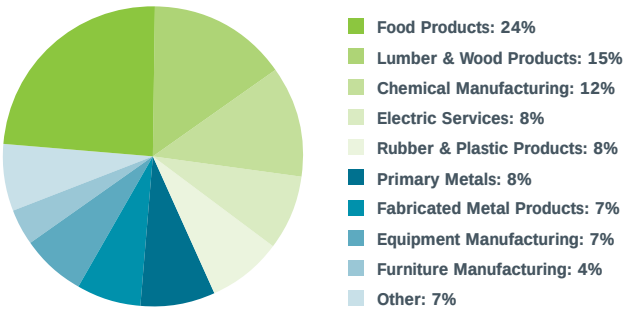
Other times, an initial explosion propagates a blast wave of a rapidly advancing flame front, a fireball that disperses more dust and ignites as it expands.

These subsequent effects can be far more destructive than a primary explosion due to the increased quantity and concentration of dispersed combustible dust.

Industries at Risk

Products such as grain, flour, and sugar can develop a dust cloud during the refining process. When heat and oxygen are also present, the possibility of ignition exists. Ignition sources include static, friction, sparks from machinery or electrical equipment, heat, or fire. Although 24 percent of these types of dust explosions have occurred in the food industry, the problem also affects other industries.

Dust Explosion Incidents by Industry



Most solid organic materials, as well as many metals and some non-metallic, inorganic materials, burn or explode if finely divided and dispersed into the air in sufficient concentrations. For example, polishing, grinding, transporting, and shaping many of these materials can produce very small particles. These particles can easily become airborne and settle on surfaces, crevices, dust collectors, and other equipment. When disturbed, the materials can generate potentially explosive dust clouds.

Combustible dust explosions can occur in any industry handling combustible dusts, including metal fabrication, plastics, furniture and wood products, and chemical manufacturing; however, four industry sectors (food products, lumber and wood products, chemicals, and primary metals) account for more than half of all dust explosions. For a comprehensive list, see *Industries That May Have Combustible Dusts* on pages 4-5.

What Factors Contribute to Dust Explosions?

There are five factors that lead to dust explosions. These five factors are known as the "Dust Explosion Pentagon" and all must be present for an explosion to occur.

1. The presence of combustible dust itself (fuel). This can be almost any organic material, grain flour, plastic, corn starch, pharmaceuticals, and even powdered metals such as aluminum.
2. A source of oxygen (oxidizer). Because air contains appreciable amounts of oxygen, air is all that is necessary to support an explosion.
3. An ignition source (heat, fire, sparks, static electricity, electric arc).
4. Dispersion of dust particles in sufficient quantity and concentration.
5. Confinement of the dust cloud. Since buildings have walls, ceilings, floors, and roofs, they create confinement.

Types of Dusts Involved in Explosions

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 phenolformaldehyde)
- (poly) Methyl acrylate
- (poly) Methyl acrylate, emulsion polymer
- Phenolic resin

Types of Dusts Involved in Explosions (continued)

- (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

What Conditions Indicate a Potential Hazard?

According to the reissued Occupational Safety and Health Administration (OSHA) Combustible Dust NEP, conditions that indicate a potential dust deflagration, other fire, or explosion hazard exists include:

- **Plant History of Fires:** The plant has a history of fires involving combustible dusts.
- **Material Safety Data Sheets (MSDS):** The MSDS may indicate that a particular dust is combustible and can cause explosions, deflagrations, or other fires. However, MSDS should not be used as the only source of information because this information is often excluded from MSDS.
- **Dust Accumulations:** Annex D of NFPA 654 contains guidance on dust layer characterization and precautions. It indicates that immediate cleaning is warranted whenever a dust layer of 1/32-inch thickness accumulates over a surface area of at least five percent of the floor area of the facility or any given room. The five percent factor should not be used if the floor area exceeds 20,000 feet^2, in which case a 1,000 foot^2 layer of dust is the upper limit. Accumulations on overhead beams, joists, ducts, the tops of equipment, and other surfaces should be included when determining the dust coverage area. Even vertical surfaces should be included if the dust adheres to them. Rough calculations show that the available surface area of bar joists is approximately five percent of the floor area and the equivalent surface area for steel beams can be as high as 10 percent. The material in Annex D is an idealized approach based on certain assumptions, including uniformity of the dust layer covering the surfaces, a bulk density of 75 pounds per foot^3, a dust concentration of 0.35 ounces per foot^3, and a dust cloud height of 10 feet. Additionally, FM Data Sheet 7-76 contains a formula to determine the dust thickness that may create an explosion hazard in a room, when some of these variables differ.

Observe areas for accumulations of hazardous dust levels (e.g., greater than 1/32 of an inch, approximately equal to the thickness of a paper clip). Likely areas of dust accumulations are: structural members; conduit and pipe racks; cable trays; floors; above ceiling; and on/around equipment (leaks around dust collectors/ductwork).

Addressing Combustible Dust Risks

Facilities at risk need to comply with national consensus standards such as those by NFPA International (see *References* on page 8). Most have been available for many years but are not well understood or properly observed.

To identify factors that may contribute to an explosion, OSHA recommends a hazard assessment of materials handled, operations (including byproducts), spaces (including hidden ones), and potential ignition sources.

Dust Control Measures

- Implement a hazardous dust inspection, testing, housekeeping, and control program
- Use proper dust collection systems and filters
- Minimize the escape of dust from process equipment or ventilation systems
- Use 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
- If ignition sources are present, use cleaning methods that do not generate dust clouds
- Use only vacuum cleaners approved for dust collection
- Locate relief valves away from dust deposits

Ignition Control Measures

- 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
- Select and use industrial trucks properly
- Use cartridge activated tools properly
- Use an equipment preventive maintenance program

Injury and Damage Control Measures

- Separation of the hazard (isolate with distance)
- Segregation of the hazard (isolate with a barrier)
- Deflagration isolation/venting
- Pressure relief venting for equipment
- Direct vents away from work areas
- Specialized fire suppression systems
- Explosion protection systems
- Spark/ember detection for suppression activation
- Develop an emergency action plan
- Maintain emergency exit routes

Industries That May Have Combustible Dusts

SIC	INDUSTRY	NAICS
0723	Crop Preparation Services for Market, Except Cotton Ginning	115114, 115111
52	Fresh Cookies, Crackers, Pretzels, and Similar "Dry" Bakery Products	311821
2062	Refining Purchased Raw Cane Sugar and Sugar Syrup	311312
2087	Flavoring Extracts, Syrups, Powders, and Related Products, Not Elsewhere Classified	311930
2099	Prepared Foods and Miscellaneous Food Specialties, Not Elsewhere Classified	311212
2221	Broadwoven Fabric Mills, Manmade Fiber and Silk	313210
2262	Finishers of Broadwoven Fabrics of Manmade Fiber and Silk	313311
2299	Textile Goods, Not Elsewhere Classified	313111
2421	Sawmills and Planing Mills, General	321113
2431	Millwork	321911
2434	Wood Kitchen Cabinets	33711
2439	Structural Wood Members, Not Elsewhere Classified	321213, 321214
2452	Prefabricated Wood Buildings and Components	321992
2493	Reconstituted Wood Products	321219
2499	Wood Products, Not Elsewhere Classified	321920, 321219
2511	Wood Household Furniture, Except Upholstered	337122
2591	Drapery Hardware and Window Blinds and Shades	337920
2819	Industrial Inorganic Chemicals, Not Elsewhere Classified	325188, 325998, 331311
2821	Plastic Materials, Synthetic Resins, and Nonvulcanizable Elastomers	325211
2823	Cellulosic Manmade Fibers	325221
2834	Pharmaceutical Preparations	325412
2841	Soap and Other Detergents, Except Specialty Cleaners	325611
2851	Paints, Varnishes, Lacquers, Enamels, and Allied Products	32551
2861	Gum and Wood Chemicals	325191
2899	Chemicals and Chemical Preparations, Not Elsewhere Classified	325510, 325998
3011	Tires And Inner Tubes	326211
3061	Molded, Extruded, and Lathe-Cut Mechanical Rubber Goods	326291

Industries That May Have Combustible Dusts (continued)

SIC	INDUSTRY	NAICS
3069	Fabricated Rubber Products, Not Elsewhere Classified	326299
3081	Unsupported Plastics Film and Sheet	326113
3082	Unsupported Plastics Profile Shapes	326121
3086	Plastics Foam Products	326140, 326150
3087	Custom Compounding of Purchased Plastics Resins	325991
3089	Plastics Products, Not Elsewhere Classified	326199
3291	Abrasive Products	327910
3313	Alumina and Aluminum Production and Processing	331312
3334	Primary Production of Aluminum	331312
3341	Secondary Smelting and Refining of Nonferrous Metals	331314
3354	Aluminum Extruded Products	331316
3363	Aluminum Die-Castings	331521
3365	Aluminum Foundries	331524
3369	Nonferrous Foundries, Except Aluminum and Copper	331528
3398	Metal Heat Treating	332811
3441	Metal Cans	332431
3469	Metal Stampings, Not Elsewhere Classified	332116
3471	Electroplating, Plating, Polishing, Anodizing, and Coloring	332813
3479	Coating, Engraving, and Allied Services, Not Elsewhere Classified	332812
3496	Miscellaneous Fabricated Wire Products	332618
3499	Fabricated Metal Products, Not Elsewhere Classified	332999
3548	Lighting Equipment, Not Elsewhere Classified	335129
3644	Noncurrent-Carrying Wiring Devices	335932
3714	Motor Vehicle Parts and Accessories	336322
3761	Guided Missiles and Space Vehicles	336414
3799	Transportation Equipment, Not Elsewhere Classified	333924
3995	Burial Caskets	339995
3999	Manufacturing Industries, Not Elsewhere Classified	321999, 325998, 326199
4221	Farm Product Warehousing and Storage	493130
4911	Electric Services Establishments Engaged in the Generation, Transmission, and/or Distribution of Electric Energy for Sale	221112
4952	Sanitary Treatment Facilities	221320
4953	Refuse Systems	562920
5093	Scrap and Waste Materials	423930
5162	Plastics Materials and Basic Forms and Shapes	424610

Preliminary Dust Explosion Hazard and Control Assessment

	Yes	No	N/A
Is combustible dust present? If yes, what types of combustible dust are present?	☐	☐	☐
Has there been a Risk Assessment or audit of facilities against NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids or a Process Safety Management Audit? (Obtain a Copy with findings)	☐	☐	☐
Does the facility have 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 in operating areas?	☐	☐	☐
Under the housekeeping program, is the dust on floors, structural members, and other surfaces removed concurrently with operations?	☐	☐	☐
Is there dust accumulation of 1/32 inch thick, or greater?	☐	☐	☐
For housekeeping violations, what are the dimensions of the room and the dimensions of the area covered with the dust?	☐	☐	☐
Are the dust-containing systems (ducts and dust collectors) designed so that fugitive dusts do not accumulate in the work area?	☐	☐	☐
Are dust collectors greater than eight cubic feet in volume located inside buildings?	☐	☐	☐
If dust explosion hazards exist in rooms, buildings, or other enclosures, do such areas have explosion relief venting distributed over the exterior walls of buildings and enclosures?	☐	☐	☐
Is such venting directed to a safe location away from employees?	☐	☐	☐
Does the facility have isolation devices to prevent deflagration propagation between pieces of equipment connected by ductwork?	☐	☐	☐
Does the facility have 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?	☐	☐	☐
Does the facility have separator devices to remove foreign materials capable of igniting combustible dusts?	☐	☐	☐
Are electrically-powered cleaning devices, such as sweepers or vacuum cleaners, used in dusty areas, approved for the hazard classification, as required under 1910.307(b)?	☐	☐	☐
Is smoking permitted only in safe, designated areas?	☐	☐	☐
Are areas where smoking is prohibited posted with “No Smoking” signs?	☐	☐	☐
Is exhaust from the dust collectors recycled?	☐	☐	☐
Does the dust collector system have spark detection and explosion/deflagration suppression systems or other alternative measures?	☐	☐	☐

Preliminary Dust Explosion Hazard and Control Assessment (continued)

	Yes	No	N/A
Are all components of the dust collection system of non-combustible construction?	☐	☐	☐
Are ducts designed to maintain sufficient velocity to ensure the transport of both coarse and fine particles?	☐	☐	☐
Are duct systems, dust collectors, and dust-producing machinery bonded and grounded to minimize accumulation of static electrical charge?	☐	☐	☐
Is metal ductwork used?	☐	☐	☐
In areas where a hazardous quantity of dust accumulates or is present in suspension in the air, does electrical wiring and equipment comply with 1910.307(b) requirements?	☐	☐	☐
Does the facility allow hot work only in safe, designated areas?	☐	☐	☐
Are bulk storage containers constructed of non-combustible materials?	☐	☐	☐
Does the company use methods to dissipate static electricity, such as by bonding and grounding?	☐	☐	☐
Are employees involved in operating, maintaining, and supervising facilities that handle combustible dust trained in the hazards of the combustible dust?	☐	☐	☐
Are MSDSs for the chemicals which could become combustible dust under normal operations available to employees?	☐	☐	☐

Dust Control System NFPA 654 Requirements

The following checklist can serve as a quick audit of your dust control system. If the answer is "no" to any of these questions, further investigation is recommended as well as correction to meet the intent of NFPA 654 or NFPA 91 and related NFPA standards to reduce the risk of dust deflagration.

1. Do you have a completed process hazard analysis (or a similar process safety study) and associated equipment explosion prevention and protection strategies as described in NFPA 654 for site processes that handle combustible dust?
2. Have you updated the process hazard analysis within the last five years – or more recently if there has been a process modification?
3. Are key points of the process hazard analysis incorporated into site standard operating procedures?
4. Are dust accumulations on floors, equipment, and overhead items (ducts, conduit, and structure) less than 1/32 to 1/16 inch (0.8-1.6 mm) due to routine housekeeping or process equipment and dust control system design or both?
5. Do cleanup methods avoid the generation of large clouds of dust?
6. Are fugitive dust sources adequately contained by dust control system hoods and enclosures?
7. Does test data for each dust control system show that adequate conveying velocity exists in each branch of the system ductwork to prevent internal dust accumulation?
8. Were dust control duct branches added after system redesigns?
9. Do duct branches that are no longer needed have an air inlet at the old connection on the duct main to maintain airflow required to meet downstream conveying velocity requirements?
10. Are there trained personnel who inspect, maintain, and troubleshoot the dust control systems to keep them within design duct conveying velocity range?
11. Does the site "management of change" review process include dust control systems and use trained personnel to make changes?

Many solids processing companies have a serious potential for a dust explosion and may not even recognize the risks. If the dusts in your dust control system are combustible, you may be risking injury or damage from a dust explosion if those systems are not designed or operated in accordance with NFPA recommendations.

References

OSHA Combustible Dust National Emphasis Program
CPL 03-00-08 (03/11/08)
http://www.osha.gov/dsg/combustibledust/index.html

CSB Complete Dust Explosion Data covered at:
http://www.csb.gov/index.cfm?folder=completed_investigations&page=info&INV_ID=53
http://www.csb.gov/index.cfm?folder=recommendations&page=index

NFPA International Standards
(NFPA standards can be viewed online at no charge: http://www.nfpa.org/aboutthecodes/list_of_codes_and_standards.asp)

- *NFPA 61* Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities, 2008
- *NFPA 68* Guide for Venting of Deflagrations, 2007
- *NFPA 69* Explosion Prevention Systems, 2008
- *NFPA 70* National Electrical Code®, 2008
- *NFPA 77* Recommended Practice on Static Electricity, 2007
- *NFPA 91* Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids, 2004
- *NFPA 484* Combustible Metals, 2006
- *NFPA 499* Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas, 2008
- *NFPA 654* Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids, 2006
- *NFPA 655* Prevention of Sulfur Fires and Explosions, 2007
- *NFPA 664* Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities, 2007

ASTM Standard Test Methods

- *E789* Dust Explosions in a 1.2-Litre Closed Cylindrical Vessel
- *E1226* Pressure and Rate of Pressure Rise for Combustible Dusts
- *E1491* Minimum Autoignition Temperature of Dust Clouds
- *E1515* Minimum Explosible Concentration of Combustible Dusts
- *E2021* Hot- Surface Ignition Temperature of Dust Layers

Related General Industry OSHA Standards

- *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

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