

Controlling your plant's combustible dust hazards

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Dust explosions are a hazard in many bulk solids industries. Some safety measures outlined by recent regulations may require outside engineering or consulting help to implement, but many do not. This article explains what you can do to minimize your plant's risk for a dust explosion.

Airborne combustible dust in the right concentration and exposed to an ignition source will ignite and create a *deflagration* (or rapidly traveling flame front). If that deflagration occurs within a confined space, such as a manufacturing process vessel, the pressure buildup can cause the vessel to rupture or explode. In some cases, such an explosion can spread well beyond its point of origin. A primary explosion can disturb settled dust from nearby surfaces and disperse the dust into the air. This larger combustible dust cloud can then ignite and create a secondary explosion with potentially devastating consequences for plant workers and property.

In response to a series of fatal dust explosions, in 2007 OSHA issued a National Emphasis Program (NEP)¹ (and reissued it in 2008) to focus on combustible dust safety at manufacturing plants. The NEP is broad and covers most industries, listing multiple NFPA standards, ASTM tests, and Factory Mutual industry guidelines as applicable references in its appendices. These references are regularly updated, so to ensure that your new or existing plant is safe and compliant with regulations, you should use the most current versions rather than the versions that were available when the NEP was issued.

Your insurance carrier has an experienced loss-control staff that can provide technical assistance or advice regarding

dust hazards. Contact your insurance carrier early during a capital project to discuss potential hazards and mitigation methods. This will allow you to include the carrier's safety recommendations in the project's capital cost estimate.

While you may need outside engineering or consulting help to meet *all* current regulations, there are many things you can do yourself to minimize the possibility of a dust explosion at your plant and comply with the instructions, industry standards, tests, and guidelines identified in the NEP.

Know your dust's explosion characteristics

Any organic, food, pharmaceutical, agricultural, or metal dust is likely to be combustible. Don't assume, however, that dust from an inorganic material won't burn or support burning; many inorganic materials are combustible or can act as an oxidizer to support combustion.

If your plant uses or processes combustible dust, it's your responsibility, per NFPA 68,² to know and keep on file the dust's material physical properties, including explosion characteristics. Keeping a file of material safety data sheets (MSDSs) may not be sufficient, since most MSDSs for bulk solids don't include information about combustibility or dust characterization. If you purchase the material, the material supplier should provide this information. If the supplier doesn't provide the information, you must have the material tested.

For venting, extinguishing, or containing dust explosions for most materials, you need to know the following properties:

- *Deflagration index* (K_{st}), which is the maximum rate of pressure rise (measured in bar meters per second) per ASTM E1226³ testing methods.

- *Maximum explosive pressure* (P_{max}), which is the maximum pressure (measured in bars) created by a dust explosion within an enclosed vessel per ASTM E1226.

If you're handling a material with a high K_{st} value (>200 bar meters per second) and a high P_{max} (>7 bar) or if your process has special operating conditions, material storage concerns, or other factors that could ignite the material, you may need to know some or all of the following additional material properties:

- *Minimum explosible concentration* (MEC), which is the lowest concentration of suspended dust required for combustion per ASTM E1515.
- *Limiting oxygen concentration* (LOC), which indicates the lowest percent oxygen concentration that can support combustion of the dust.
- *Minimum ignition temperature* (MIT), which is the lowest temperature that will ignite a suspended dust cloud per ASTM E1491 or dust layers on a hot surface per ASTM E2021. These are two different values, and the material's combustibility and your plant's circumstances will determine whether you need to know both characteristics.
- *Minimum ignition energy* (MIE), which is the lowest-energy electric spark required to ignite a suspended dust cloud per ASTM E2019.
- *Resistivity and conductivity*, which are measures of how strongly the material resists or conducts the flow of electric current per ASTM D257. Resistivity and conductivity indicate how readily the material can build up and retain electrostatic charge during transport and storage.

Consult a corporate safety manager and your insurance carrier to determine which properties you need to know for your material and application. You can find the explosion characteristics of many commonly used bulk solid materials online or in standards such as NFPA 61 and 68. Only use this published information to get an approximation of a material's explosion characteristics; however, never use the information for equipment or venting design. The published values may not accurately represent your specific material's properties.

Be sure to also determine the explosion characteristics of materials that result from intermediate process steps in your operation. This includes materials that are blended with other ingredients, crushed, agglomerated, or treated. If you purchase any preblended or custom-made batches of minor or micro ingredients, you should test those materials as well.

If your plant changes ingredient suppliers, be sure to request the ingredient's physical properties from the new supplier. The new ingredient may be chemically the same

as the previous ingredient but may have different physical and explosion characteristics. For example, spray-dried milk powder from one supplier may have a significantly different bulk density, flowability, P_{max} , or K_{st} than milk powder from another supplier depending on the method of spray atomization, the liquid feed conditions at the dryer inlet, the drying temperature, and the flow patterns inside the dryer. Also, if you expand your product line by changing an existing product's formula, be sure to know the explosion characteristics of any new ingredients.

Practice good housekeeping

Poor housekeeping is probably the largest contributor to dust explosion or fire risk, and dirty, dusty conditions in your plant will likely be cited during an inspection as an OSHA violation of the General Duty Clause. Housekeeping is also the area over which you have the greatest amount of control when attempting to minimize your dust hazard exposure. There is, however, a human tendency to neglect housecleaning or cleanup work unless clear rules or expectations are in place. (Just ask the parent of any teenager.)

Workers will typically attend to their manufacturing duties but may not completely perform cleanup activities unless specifically directed or unless a problem occurs that's too big to ignore, such as a major spill. Workers may overlook minor spills or dust displacement and leave the cleanup for the following shift.

Never use compressed air to clean up a bulk solids spill or remove accumulated dust. Compressed air just redistributes the material to other areas, and the resulting dust cloud could be sufficiently dense to create a combustible dust hazard or a respiratory hazard to workers in the area. Only use an intrinsically safe vacuum cleaning system rated for Class II, Group G, Division 1 environments to remove combustible dust. You can also use water to hose down an area and remove any loose or accumulated dust if doing so is safe for the equipment and facility.

The following areas are common sources of combustible dust accumulation in bulk solids manufacturing plants:

Spills. When a bulk solid material spill occurs, protocol should be to clean it up as soon as possible. Spills or accumulated material will normally be around bag dumps and bulk bag unloading stations or near transfer points between equipment, including:

- Inlets and outlets of bins, silos, tanks, and rail and truck hoppers
- Spouts between equipment
- Diverters
- Conveyor inlets and discharges

High surfaces. Transferring material from one location to another causes a corresponding displacement of air. Usually, the material moves downward by gravity, while the displaced air moves upward. The upward-moving air can entrain dust, which, unless the air is contained or removed by a dust collection system, will settle in the surrounding area. Since the air movement is vertical, the dust can be carried high and settle on high surfaces in the area. Also, air currents and drafts may cause the dust to disperse over a larger area, so the dust may settle on elevated surfaces in an extended zone around the spill or transfer point.

A dust layer that's *opaque* (that makes seeing the underlying surface difficult), is significant and should be removed as soon as possible. Disturbing a dust layer just a few millimeters thick can easily create a dust cloud that could ignite and cause a deflagration. Conduct regularly scheduled inspections and clean off high surfaces in rooms or areas that contain bulk solids handling equipment.

Be sure to observe the area from a high vantage point to determine where dust has accumulated. This may sound obvious, but I've often seen areas that looked clean when viewed from the ground but that had dust buildup on top of pipes and horizontal surfaces. If there are no high vantage points, such as walkways or platforms, use a scissors lift, portable steps, or a ladder. Typical high surfaces include:

- Tops of equipment
- Ledges
- Building structural members
- Tops of storage cabinets
- Tops of pipes
- Tops of HVAC or process ductwork
- Conduits
- Electrical panels and cabinets
- Lighting fixtures
- Sprinkler heads



Fugitive dust settled on high surfaces and pipes can be disturbed by an initial dust explosion in a vessel and create a combustible atmosphere for subsequent, larger explosions.

Hidden locations. Over time, dust can accumulate in hidden or seemingly enclosed locations. Periodically check hidden areas such as interstitial spaces above ceilings or below floors. Electrical panels may not be properly sealed in areas near bulk solids handling equipment, and dust may enter and accumulate inside the panels over time. Have qualified personnel regularly open and inspect electrical or control panels near such equipment in accordance with approved electrical safety guidelines. Accumulated combustible dust in electrical cabinets or panels should be removed since ignition sources such as electrical sparks or hot surfaces may be present. Replace door gaskets and seal conduit connections as necessary. In severely dusty environments, you may need to pressurize the panel or replace it with an enclosure that's properly rated for the conditions.

HVAC systems. Since light airborne dust will often follow the air currents in the area, always inspect HVAC return-air intakes for accumulated dust. A noticeable dust buildup on a return's louvers or grillwork may be an indication that dust is entering the HVAC return-air system. Excessive dust in the HVAC system could create nuisance fire alarms, since smoke detectors may not be able to distinguish between airborne dust and smoke particles. Also, if airborne dust is causing nuisance fire alarms in the HVAC system, dust is likely accumulating inside the ductwork as well. This can become a fire hazard over time, particularly in ductwork that contains heating elements, which could ignite the accumulated dust. Inspect return-air ducts periodically and clean them out as necessary. To prevent dust from entering return-air ducts, install inlet filters on the return-air intakes.

Applications handling moisture-sensitive materials often use a desiccant wheel system to dehumidify the process airstream. Such systems have a steam- or electrically heated hot-air regeneration section. If the regeneration air intake is in an area where combustible dust is present, the system could accumulate dust on the heating surfaces and that dust could possibly ignite. Regularly check to ensure that inlet air filters are present, properly positioned, and clean.

Packaging operations. If your facility has a packaging operation, you'll have dust from handling, cutting, and forming the cardboard cartons or cases. Over time, cardboard dust can accumulate in the immediate area if housekeeping isn't thorough. Cardboard dust is combustible, light, and can easily become airborne around powered conveyors and other equipment with moving parts. Packaging equipment will often use compressed air for pistons, actuators, vacuum generators for suction cups, and blow-offs, and the air released from these could distribute cardboard dust over a wider area. Packaging equipment handling cardboard usually has electrical wiring or components that may not be rated for dusty environments and should be cleaned frequently to prevent dust accumulation.

Prevent ignition sources

A dust explosion can't occur unless an ignition source, such as a spark, heat, or an open flame is present, so preventing such ignition sources is critical to reduce your dust explosion risk.

Static electricity. Plastic or rubber belt conveyors or plastic surfaces in contact with flowing bulk solids will build up an electrostatic charge. Electrostatic discharges may occur without being visibly apparent because of high ambient humidity. You can easily check for electrostatic charge using an inexpensive, hand-held meter. If your conveyor is developing high electrostatic charge, you may need to install a grounded static-control brush near the moving belt to passively neutralize the charge using induction. In some cases, you may need to install an air ionizer to actively neutralize the charge.

Pneumatic conveying and dust collection piping or ductwork can also build up electrostatic charge, which can be enhanced by dry conveying air and degradation of the material being conveyed. Piping runs must be properly grounded and have electrical continuity between pipe sections to prevent electrostatic buildup.

Pipe sections are typically joined using either a clamp coupling, flange, compression fitting, or other clamp type, such as a Tri-clamp or Victaulic clamp. The external clamp coupling, as shown in Figure 1, is one of the simplest and most popular methods for connecting pipe sections. The clamp coupling wraps around two butt-end sections of pipe or tubing like a splint. Bolts along the clamp's longitudinal flange tighten the clamp and secure the two pipe sections. A rubber gasket along the clamp's entire inner surface makes an airtight seal.

To prevent electrostatic buildup between joined pipe sections, an external clamp coupling includes an internal grounding strap that runs through the coupling and contacts both pipe sections. If you need to open a pipe connection to clear a clog or correct a leak, ensure that the grounding strap is properly reinstalled, or the gasket could electrically isolate the two pipe sections from each other, creating the potential for static buildup. Also, if the pipe sections are subject to axial or lengthwise movement, some of the conveyed material could become trapped between the internal conductive strap and the pipe and act as an insulator.

Flanges, compression fittings, Tri-clamps, and Victaulic clamps also work well in pneumatic conveying systems, but these methods all require a mating gasket or ring between two flanged pipe faces. Flange bolts or flange clamps made of conductive metal can provide electrical continuity between pipe sections.

For all coupling types, I'd advise using a conservative "belt and suspenders" approach to ensure continuity between

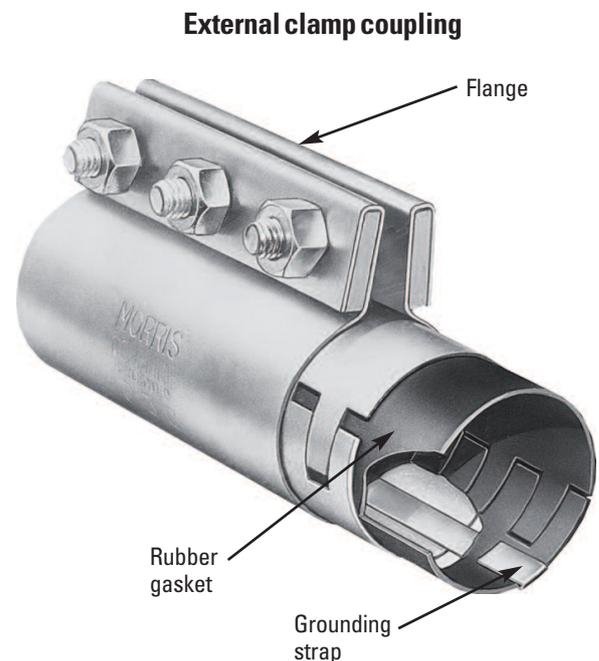
pipe sections. The belt and suspenders approach uses a jumper cable permanently connected to the piping on either side of the coupling as described in NFPA 77. The cable should be securely attached to either a flange bolt or a lug that's welded to the pipe. Avoid attaching the jumper cable using clamp-style connectors, which can loosen or have inadequate metal contact over time. The jumper cable should be 10-AWG stranded wire or larger and should be long enough to connect across the coupling but not long enough to create a trip or snag hazard. An uninsulated grounding strap or cable wrapped around the coupling and pipe sections and held in place by springs is inadequate. Dirt and buildup on the pipe and cable can insulate the cable from the pipe and result in poor continuity.

Plastic or rubber hoses used to pneumatically convey bulk solids or for dust removal should contain conductive helical internal wiring, which should be attached to the pipe connections at both ends of the hose. The internal wiring reinforces the hose and provides electrical continuity along the conveying pathway.

Periodically check pneumatic conveying and dust collection piping and ductwork for proper grounding and to ensure that there's very little or no electrical resistance across joints and couplings.

Filling a large bin or silo with a bulk solid material can cause static electric or brush discharges, which may have enough energy to ignite the dust in the headspace above the material pile even if the silo is grounded. These discharges may create crackling noises and flashes during filling (per NFPA 77, Section 5.3.8). If this is a concern for your operation, contact your corporate safety manager.

Figure 1



Tramp metal. Bulk solids handling processes should include magnets or metal detectors to prevent metal contamination or damage to the equipment. *Tramp metal*, (or metal fragments) contacting fast moving metal equipment surfaces such as in a mill, grinder, mixer, fan, or blower could create sparks that could ignite airborne combustible dust. Regularly check magnets and metal detectors for collected material and regularly check metal detectors for proper operation and sensitivity. For each detector, keep an inspection log showing the inspection date and the inspector's name.

Friction. Inspect rotating equipment regularly for proper bearing lubrication and heat discoloration. In some cases, bearing temperature monitoring may be necessary. If rotating or moving equipment becomes unbalanced or misaligned, parts can rub against each other causing a hot spot. V-belt slippage on sheaves can also generate high temperatures in some cases.

Equipment and piping surfaces. Ensure that all exposed surfaces on hot equipment, piping, and ductwork are insulated to prevent accumulated dust from overheating and igniting. Also, don't allow dust to accumulate on motors that aren't Class II, Division 1 or 2, Group G rated, as the dust could overheat and ignite.

Open flames and sparks. Keep combustible dust away from any burners and electrical equipment not rated for a combustible dust environment. Unrated electrical equipment may cause an electrical discharge. This includes open motors, exposed electrical devices, instruments, and fixtures such as lighting, paging systems, and telephones. Also, your plant should have and enforce a hot-work policy to control contractor and maintenance activities that involve welding, cutting, brazing, soldering, grinding, and any other activity that requires an open flame or may generate sparks.

Maintain pneumatic conveying lines and associated equipment

Pneumatic conveying and dust collection systems can have significant and complicated pipe routing throughout a plant. Manufacturers typically ignore conveying lines after installation, since the pipes are "stationary," with no moving parts, but pipe connections can fail and leak combustible dust into the workspace.

Sufficient pipe movement from inadequate pipe supports or loosened clamp bolts can cause a clamp coupling to fail and release dust over time. In a positive-pressure pneumatic conveying system, the system's internal pressure may also cause leakage at couplings over time. Visually check pneumatic conveying and dust collection lines occasionally for signs of leaks and to ensure that all pipe joints are secure.

If your operation receives bulk deliveries by rail car or truck, check the condition of the rail car or truck piping and monitor the piping regularly for leaks while discharging material into your site's storage systems. Rail car or truck piping can be exposed to vandalism, damage during transit, and theft of metal components for the metal's salvage value.

Ensure that bin vents are securely attached to hoppers and periodically check connections and openings to hoppers, vessels, and equipment containing combustible dust. Ensure that any bolted access hatches have all bolts in place and replace any gaskets that appear damaged or brittle or that show signs of dust leakage.

Ensure that dust collection systems are compliant and properly maintained

Existing dust collection systems handling combustible dusts should comply with the NFPA 68 explosion venting standards. A dust collection system installed before NFPA 68 became effective as a standard (in March 2008) is exempt from the explosion venting requirements under Section 1.5 (Retroactivity). However, an authority having jurisdiction (AHJ), such as the fire marshal or state inspector, could still require dust explosion venting or prevention if the AHJ determines that the existing system presents an unacceptable degree of risk. Also, if you're making significant changes to the original design or process, you must bring the existing dust collection system into compliance with NFPA 68. Some examples of significant changes are:

- Major replacement or renovation of existing upstream or downstream equipment
- Filter element design changes, such as replacing bag filters with cartridge filters
- Control changes
- Material feedrate changes
- Ingredient or composition changes to the material being conveyed



When receiving material deliveries by rail car, ensure that all components of the rail car's pneumatic piping are present and in working order.

NFPA 68 requires that manufacturers with systems handling combustible dust and dust explosion venting systems keep and maintain documentation and records for these systems. This means that all drawings, calculations, specifications, maintenance records, and material physical properties need to be available for review by an inspector or AHJ.

Perform a walk-around inspection of baghouses and filters every day, checking the systems for any abnormal visual or audible conditions or signs of leakage. Make sure that all hoses, clamps, and grounding straps are secure. Check reverse pulse-jet filter-cleaning systems for adequate compressed airflow and ensure that the cleaning cycles are sufficient to maintain a low differential pressure across the filters.

Perform the following periodic preventative maintenance steps monthly, quarterly, or annually, depending on plant experience and internal maintenance procedures.

- Check motors, gear reducers, and chain and belt drives for wear, tensioning, and alignment.
- Lubricate all moving parts.
- Check instrumentation for proper operation.
- Open impulse tubes for pressure and differential-pressure gauges and check for material buildup.
- Ensure that all filter elements or bag filter cages are properly seated to their tubesheets and properly grounded to prevent electrostatic buildup per the filter manufacturer's recommendation.
- Check external and internal equipment surfaces for corrosion and erosion. Internal surfaces, such as baffles or near tangential inlets in contact with fast-moving material streams may be subject to wear.
- Check solenoid valves for reverse pulse-jet filter-cleaning systems. Replace the valves if they're sticking in a closed or open position and affecting the cleaning cycles.
- Check the condition of gaskets.
- If possible, inspect the condition of the filter elements or bags.
- Inspect the clean-air space above the tubesheet and the discharge ductwork for signs of any dust leakage or buildup.

Ensure that explosion vents are properly installed and unobstructed.

An explosion vent is a cover panel or door designed to rupture or open during an explosion to relieve pressure buildup inside a vessel or structure. If your dust collector is installed indoors, ensure that all explosion vent panels have properly installed ducts (with no bends, obstructions,

or interferences) to immediately direct a pressure buildup outside the building through an adjacent wall or roof.

Rooftop vents may have a hinged cover that opens or releases during an explosion. Check the cover hinges to be sure they'll open when needed. Tie loose-fitting covers to lanyard or chain anchored to the roof to prevent them from becoming projectiles during an explosion. The vent exterior may have a thin plastic membrane or weather barrier to keep moisture, dust, insects and other contaminants from entering the duct and interfering with the explosion panel's operation. This membrane should be sufficiently thin to break apart easily without creating significant backpressure when a dust explosion occurs.

The vent cover should be lightweight and designed to rupture or open during a deflagration. The vent cover shouldn't be snug fitting and should be wider than the vent duct. The cover's fasteners should be strong enough to secure the cover but fragile enough to release the cover in the event of an explosion. Light gauge nylon fasteners work well, for example, but you should never use metal bolts.

Despite efforts to protect the duct from weather or outside conditions, a vent cover or membrane can still fail or be breached. Water or snow can get inside a vertical vent and rest on the rupture panel or build up in the duct, for example. This can affect the vent's burst pressure and effectiveness. Insect activity around a vent connected to a sugar or sweetener operation may be an indication that the vent's explosion disc has been compromised. Regularly check the exterior area around explosion vents on rooftops or exterior walls to ensure that there are no obstructions, that the area is safe for venting, and that the vent hasn't been compromised in any way.

If your indoor dust collector isn't located near a wall or roof for direct venting outside, you can install an indoor (or flameless) explosion vent. Indoor explosion vents use a



This dust-collector tubesheet is leaking, allowing dust to pass from the dirty side below the tubesheet to the clean side above.

vent panel in conjunction with metal flame arrestors, which absorb a dust explosion's heat, extinguish the explosion's flames, and release only the combustion gases into the building. Indoor explosion vents are heavy and may require special structural supports. Keep the vent's external mesh surface clean of debris or accumulated dust, and ensure that the vent is accessible to replace the vent panel if an explosion occurs. The vent should be positioned away from work areas or shielded to protect workers in the area.

Train workers

NFPA 68 requires that workers at plants handling combustible dust receive periodic training about combustible dust hazards. Manufacturers are already required to conduct annual training for lockout-tagout, confined space entry, personal protective equipment, and emergency response; these annual training exercises should also include a segment reviewing combustible dust hazards. **PBE**

References

1. OSHA's combustible dust NEP is available at www.osha.gov.
2. The NFPA standards discussed in this article are available at www.nfpa.org.
3. The ASTM testing methods discussed in this article are available at www.astm.org.

For further reading

Find more information on this topic in articles listed under "Explosion/fire protection," "Dust collection and dust control," and "Safety" in *Powder and Bulk Engineering's* article index in the December 2015 issue or the Article Archive on *PBE's* website, www.powderbulk.com. (All articles listed in the archive are available for free download to registered users.)

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