Preventing explosions: How to safely clean up combustible dusts

In this article, a dust hazard expert describes safe ways to clean up accumulated combustible dust before it can cause an explosion in your plant. Sections cover accumulated dust hazards, the basics of safe dust cleanup, and strategies for safely removing accumulated dust in your plant. The information also summarizes National Fire Protection Association guidance on safe cleanup of combustible dusts.

Fugitive dust accumulations in bulk solids plants have fueled some of industry’s most catastrophic dust explosions, including the devastating 2008 Imperial Sugar plant explosion in Georgia. In this incident, an explosion inside a conveyor initiated a pressure wave that lofted adjacent accumulated dust into a dust cloud denser than the sugar dust’s minimum exploisible concentration (MEC). Just milliseconds after the pressure wave, the ruptured conveyor released an explosion flame front that ignited the dust cloud. Six successive deflagrations killed 14 workers, seriously burned more than 30 others, and destroyed the building.

Defining accumulated dust hazards
Routinely cleaning up fugitive dust accumulations — before they exceed the amount considered hazardous for that dust — prevents the dust from becoming an explosion hazard. Examples of dangerous accumulations of fugitive dust in a sugar refinery are shown in Figure 1. National Fire Protection Association (NFPA) Standard 654: Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids explains when to clean up such dust accumulations to prevent them from becoming an explosion hazard.
For instance, the standard states that immediate dust cleanup is required whenever dust with a 75-lb/ft³ bulk density forms a layer ½ inch thick (the allowable thickness) over a surface area of at least 5 percent of the room’s floor area. This 5 percent rule doesn’t apply, however, if the floor area exceeds 20,000 square feet; in this case, a dust layer of the allowable thickness that covers 1,000 square feet requires immediate cleanup. For lower-density dusts, the allowable thickness can be proportionately increased by the densities’ ratios; so, for instance, for a dust with a 15-lb/ft³ bulk density, the allowable dust layer is $rac{3}{32} \times \frac{75}{15} = \frac{5}{32}$. Figure 2 illustrates some of these allowable thicknesses.

Dust accumulations on overhead piping, conduit, steel structures, and other surfaces should be included when determining the dust coverage area. Dust accumulated on these surfaces often exceeds 5 to 10 percent of the room’s floor area and represents a greater explosion risk, because if the overhead cleaning method causes a lot of the dust to fall off all at once, the dust can form a cloud with a concentration greater than the dust’s MEC. If the dust cloud then contacts an ignition source, the dust will explode.

Figure 2
Allowable dust thicknesses

![Allowable dust thicknesses](image)

Figure 3
Hazardous dust cloud

![Hazardous dust cloud](image)

For more guidance on how to assess the extent of accumulated dust hazards in your plant, see Annex D in NFPA 654 and FM Global’s Loss Prevention Data Sheet 7-76: Prevention and Mitigation of Combustible Dust Explosions and Fires.¹

The basics of safe dust cleanup

While removing accumulated dust is important for preventing dust deflagration conditions in your plant, failing to pay attention to safety details during dust cleanup will increase the dust explosion risk.

Safety details. Safe dust cleanup is based on the three elements required for a dust explosion. You must: 1) minimize the fuel required for a deflagration by removing the dust from the area; 2) avoid dispersing the dust into a dense cloud; and 3) neutralize any potential ignition sources.

Translating these details into a safe cleanup plan starts with using cleaning methods and tools in ways that won’t disperse dust into a dense cloud. For instance, using a compressed-air hose to blow dust down off all the equipment in a room, vigorously sweeping dust off the entire floor and overhead surfaces, or bumping overhead structures and dislodging the dust accumulated on them during cleaning can quickly create hazardous dust clouds, as shown in Figure 3.

Safe cleanup also requires planning how to avoid ignition sources that could ignite the dust cloud as you clean. For instance, you’ll need to identify and avoid or eliminate ignition sources such as static electricity, hot surfaces, or a piece of electrical equipment not rated for dust hazards.

Your dust’s combustible properties. For safe dust cleanup, it’s critical to know what it takes to ignite your dust. Al-
though knowing all of your dust’s combustible properties is important, be sure to know your dust’s minimum ignition temperature (MIT) for a dust cloud or layer and the dust’s minimum ignition energy (MIE) in particular.

**Strategies for safe dust cleanup**

You can use various methods to safely clean up combustible dust accumulations in your plant, as long as you apply them appropriately. These methods include compressed-air blowdown, sweeping, water washdown, and vacuum cleaning. They can be used by your plant’s cleaning crew or an outside cleaning contractor and are suitable for initial cleanup of major dust accumulations as well as for later routine cleanup.

The following information describes each cleanup method and sums up strategies for safely using the method. Some information here is from NFPA 654, which covers all of the methods except water washdown; be aware that this standard also emphasizes that vacuum cleaning is the safest cleanup method for combustible dust.

**Compressed-air blowdown.** Using compressed air to blow dust off equipment and surfaces can create dust clouds with a concentration exceeding the dust’s MEC. Key NFPA 654 safety strategies for compressed-air blowdown are to limit ignition sources in the area and minimize dust cloud size by limiting how extensively the method is used. This standard limits the use of compressed-air blowdown to areas that can’t be reached with vacuum cleaning. For instance, the standard allows using compressed air only for blowing dust off the inaccessible sections of a machine into an adjoining aisle. Then sweeping or vacuum cleaning, not compressed air, can be used to consolidate the dust into piles and clean the aisle.

Section 8.2.2.2 in NFPA 654 permits compressed-air blowdown for dust cleanup only when the cleanup worker follows these steps, in this order, for de-energizing and cooling down any ignition sources in the area:

- Vacuum all accessible dust.
- De-energize any nearby electrical equipment that isn’t rated for combustible dust.
- Allow any hot equipment or other surfaces to cool below the dust’s MIT.
- Use 15-psig compressed air or steam to move dust out of inaccessible areas.
- Vacuum all accessible dust.

**Sweeping.** Vigorously sweeping dust from floors and other surfaces with a broom can also generate dust clouds. The same key NFPA 654 safety strategies apply: limit area ignition sources and minimize dust cloud size by limiting sweeping’s use.

If your dust is easily ignited by static electricity, the cleanup worker should use a broom with soft, natural bristles to avoid generating static during sweeping and use a conductive, nonsparking dust pan, such as one made of aluminum or conductive plastic, to collect the dust. Sweeping a floor creates a dust cloud that’s close to the ground, so the cloud generally won’t be denser than the dust’s MEC unless the sweeping is extremely vigorous. But sweeping dust from overhead piping, conduit, steel structures, and other surfaces can create a dust cloud denser than your dust’s MEC.

Before sweeping, the cleanup worker must meet the same Section 8.2.2.2 requirements as for compressed-air blowdown, in the same order, to de-energize and cool down any ignition sources in the area.

**Water washdown.** Water washdown is used by some bulk solids plants to clean up combustible dust. Such plants already use water to wash floors, so the floors are equipped with drains to direct the wastewater to an appropriate treatment system, and the plant’s electrical equipment is watertight.

For nonmetal combustible dusts, the safety strategy for water washdown is to wet the dust, thus increasing its conductivity and reducing the potential for static electricity to ignite the dust. However, water washdown must be done correctly to avoid creating a combustible dust cloud. When washing down a dusty area, the cleanup worker should wet the accumulated dust by first applying a water mist to it, then increase the flow to a high-velocity water stream to remove the wet dust from the area. If the worker uses a high-pressure stream of water at the start, not much dust will be wetted, because the air induced alongside the high-velocity water stream will fan the dust cloud away from the area where the water is applied.

**One caution:** If your dust doesn’t dissolve in water, it’s best to push the wet dust to an area where it can easily be cleaned up rather than have it run into a floor drain; the drain piping can plug if there isn’t enough water to convey the dust to the wastewater treatment system.

Using a water mist is also a good way to reduce the airborne dust around a dust pile fire; the mist will wet the dust without creating a dust cloud that can move into the fire area and cause a dust explosion.

However, water washdown has some disadvantages: The mess from water washdown can trickle over a large area, requiring widespread cleanup; the residue must be collected somewhere that can be cleaned; and your electrical system must be watertight to prevent shorting out the equipment.
Water washdown isn’t covered in NFPA 654, and because metal combustible dusts can cause water to break down and release hydrogen gas, NFPA specifically recommends against using this method in plants handling combustible metals.

**Vacuum cleaning.** Vacuum cleaning is NFPA 654’s preferred dust cleanup method because it provides some dust containment as the dust-laden air enters the vacuum cleaner’s pickup point (the vacuum tool attached to the hose), just like dust-laden air entering a capture hood in a dust collection system.

Cleanup workers can vacuum dust with a portable vacuum cleaner or a central vacuum cleaning system. Determining which is right for your plant requires looking at the pros and cons for each, as listed in Table I, in light of your needs.

**Portable vacuum cleaner:** A portable vacuum cleaner includes a tank on wheels, a vacuum producer (mounted on the tank), filters (inside the tank), one vacuum hose connected to the tank, and several vacuum tools for the hose. The vacuum producer can be an electric blower with an explosion-rated motor or a nonelectric compressed-air venturi eductor, as shown in Figure 4. A disposable plastic bag is often used inside the tank to collect dust. Different vacuum tools, as shown in Figure 5, can be chosen to suit your application.

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**Table I**

<table>
<thead>
<tr>
<th>Pros</th>
<th>Central system</th>
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<tr>
<td>Has lower capital cost</td>
<td>Has readily available hose inlets to provide cleanup at logical sites</td>
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<tr>
<td>Is easy to operate</td>
<td>Allows multiple users</td>
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<tr>
<td>Has clear ownership by one worker</td>
<td>Provides faster response to dust spills because only hose and tool must be transported</td>
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<tr>
<td>Allows relocation to other cleanup sites</td>
<td>Provides low-dusting, ergonomic, permanent central waste disposal outside of operating areas</td>
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<tr>
<td>Malfunction affects only one unit</td>
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<table>
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<tr>
<th>Cons</th>
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</thead>
<tbody>
<tr>
<td>Is heavy and cumbersome to transport to cleanup site</td>
<td>Has higher capital cost</td>
</tr>
<tr>
<td>Allows only one user per unit</td>
<td>Ownership may be unclear because system has multiple users</td>
</tr>
<tr>
<td>Requires “fleet” management when multiple units are used</td>
<td>Malfunction affects cleanup capability of entire system</td>
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<tr>
<td>Is dusty and poses ergonomic problems during waste emptying</td>
<td>Occupies dedicated floor space</td>
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<tr>
<td>Requires significant maintenance when multiple units are used</td>
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process for each area to be cleaned. When the tank is filled with dust, the worker removes the tank’s top lid and removes the plastic bag filled with dust or lifts and empties the tank into a waste disposal container.

NFPA 654 outlines two safety strategies for portable vacuum cleaning: limiting ignition sources and keeping the contained dust volume small.

• **Limiting ignition sources:** This strategy requires choosing an appropriate vacuum producer — an electric blower with an explosion-rated motor or a nonelectric venturi eductor — and using conductive components to dissipate static electricity. The electric blower motor and controls must be rated for Electrical Hazard Class II material Groups E (metal dusts), F (carbonaceous dusts), or G (general combustible dusts). The portable vacuum cleaner must be carefully grounded by running a bonding cable between the tank and its connected components to a nearby ground. The unit must also have a conductive vacuum hose (a hose with a resistance of <1 million ohms meets NFPA’s minimum resistance requirement for dissipating static electricity). If the unit uses a venturi eductor, the compressed-air hose leading to the venturi eductor should also be conductive.

• **Keeping dust volume small.** The portable vacuum cleaner’s tank is typically no larger than a 55-gallon drum, which will limit the contained dust’s volume.

A variation of the conventional portable vacuum cleaner, known as a submerged- or liquid-recovery unit, is suitable for certain highly combustible dusts. This unit, as shown in Figure 6, safely removes metal combustible dusts or other easily ignitable dusts such as gunpowder, toner, rocket propellant, and sodium azide (used as automobile airbag propellant) by submerging the collected dust in an appropriate liquid in the vacuum tank. The solids can then be drained as a sludge from the tank for disposal.

**Central vacuum cleaning system:** A central vacuum cleaning system, as shown in Figure 7, includes a dust collector (typically a pulse-jet baghouse) containing multiple filters; a high-vacuum exhauster; a metal tubing network with multiple spring-closed hose inlets; and vacuum hoses and tools. The hose inlets are installed at points around the plant where powder is often spilled, such as near equipment access doors or material transfer points. Any of the same tools shown in Figure 5 can be used with the vacuum hoses.

In operation, the cleanup worker inserts a vacuum hose fitted with the required tool into a hose inlet in the area to be cleaned. Multiple workers can use the system to clean several areas at once. Because the collected dust is discharged from the system’s dust collector hopper, workers don’t have to manually dispose of the dust.
The central system’s exhauster must be a blower to achieve the high vacuum this system requires. Compared with a dust collection system, which typically requires vacuum of 0.44 to 0.88 inches mercury (6 to 12 inches water column), the central system needs much more — about 6 to 12 inches mercury (82 to 164 inches water column). The greater vacuum is required to provide enough suction to overcome the flow resistance of the vacuum hoses, tools, and tubing between each hose inlet and the dust collector; overcoming the hoses’ and tools’ flow resistance alone consumes about 25 to 50 percent of the system’s total suction, depending on the system’s layout.

The blower can be a multistage, positive displacement, or regenerative type. Which is best for your application depends on the number of workers using the system at one time and the cost of operating the blower. One way to limit the blower’s size and power consumption, and thus keep operating costs low, is to try to keep the system’s tubing network no longer than necessary to handle the distance the dust will be conveyed and to size the blower no larger than necessary to handle the maximum number of workers who will use the system at one time.

The safety strategy for the central vacuum cleaning system is the same as for a dust collection system: The system components must meet combustible dust standards. This means that the system’s tubing, vacuum hoses, and tools must be conductive and grounded. The dust collector must be equipped with an explosion protection system or devices, such as those shown in Figure 8, and the tubing network must have an isolation device to prevent a flame front from traveling outward to workers using the system.

Planning ahead for safe dust cleanup

Regardless of which cleaning method (or methods) you choose and whether an in-house crew or a cleaning contractor will do the job, you need to plan carefully to ensure that your combustible dust is safely removed. Not only must you know your dust’s hazards, you also need to identify the explosion hazards in your plant. This will require conducting job safety analyses or similar reviews to identify operations that can produce dust clouds and any potential ignition sources in your plant. During this process, rely on experienced plant operators to help you pinpoint trouble spots. As part of your cleanup planning, make sure to describe your routine cleanup methods and expectations in a housekeeping procedure for use by in-house or contractor cleaning crews.

If you do hire a cleaning contractor, ensure that the company has experience with cleaning up combustible dust. The contractor should ask detailed questions about your dust and cleanup needs at your initial contact, and you should share all of your combustible dust’s hazard data with the contractor. After all, you both have a vested interest in a safe dust cleanup operation.
References

1. The lowest dust concentration that will propagate a combustible dust deflagration or explosion, as determined by a test described in ASTM E1515; for more information, go to www.astm.org.


4. The minimum ignition temperature (MIT) for a dust cloud or layer is the minimum temperature at which a suspended dust or dust layer can be ignited, as determined by tests described in ASTM E1491 (for a dust cloud) and ASTM E2021 (for a dust layer). The dust’s minimum ignition energy (MIE) is the smallest amount of energy required to ignite the suspended dust, as determined by a test described in ASTM E2019. For more information, go to www.astm.org.

For further reading

Find more information on combustible dust and dust cleaning methods in articles listed under “Dust collection and dust control” and “Vacuum cleaning” in Powder and Bulk Engineering’s comprehensive article index (in the December 2009 issue and at PBE’s Web site, www.powderbulk.com) and in books available on the Web site at the PBE Bookstore. You can also purchase copies of past PBE articles at www.powderbulk.com.

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