# Addressing Combustible Dust Hazards

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Facilities that handle or generate dusts are at risk for explosions and flash fires. Follow this approach to understand and mitigate your combustible dust hazards.

Many industries — from chemicals, plastics, and pharmaceuticals to food processing and mineral recovery — face combustible dust hazards in their facilities. Incidents such as the explosions and fires at the Imperial Sugar refinery in Port Wentworth, GA, in February 2008 demonstrate the need to effectively manage these risks.

The U.S. Occupational Safety and Health Administration (OSHA) is currently developing a combustible dust regulation. Until that is finalized, engineers should be guided by National Fire Protection Association (NFPA) standards *(1–5)* and by recognized and generally accepted good engineering practices (RAGAGEPs).

Each company needs to determine the appropriate strategy for controlling its combustible dust hazards and select specific safeguards based on a hazard evaluation and risk assessment. Although the potential consequences of improperly handled dusts can be significant, relatively inexpensive solutions may be sufficient to address the actual risks.

This article outlines a methodology for examining the risks associated with a facility's combustible dusts and identifies ways to ameliorate those risks. As illustrated in Figure 1, this involves reviewing the literature, testing dust samples, performing a preliminary audit, evaluating electrical classifications of processing areas and equipment, implementing interim measures, and performing detailed hazard analyses and risk assessments.

## Gather information

The first step in understanding the risks involved with combustible dusts is to acquire knowledge, and a self-taught approach is often sufficient. Consult the engineering literature and become familiar with RAGAGEPs. Purchase key reference materials, download free reports, and obtain critical RAGAGEP documents, such as those produced by the NFPA or outlined in the Center for Chemical Process Safety's (CCPS) *Guidelines for Safe Handling of Powders and Bulk Solids (6)*. Supplementing this library with quality training is also helpful.

Some dusts, such as metal powders and wood processing dusts, have unique hazards, which are addressed in references specific to those materials. Most combustible dusts, however, fall into the category of "general dusts" and are covered by NFPA's *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids* (NFPA 654) *(1)*. References 1–11 will provide a strong foundation and are a good place to begin.

## Testing

Dust samples from the plant should be analyzed to determine their physical and chemical properties and to evaluate their combustibility. The least expensive way to gauge combustibility is to request information from each raw material supplier. In addition to individual raw materials, any mixtures that are handled also need to be evaluated.

Testing every mixture and intermediate can be very costly. An alternative and often cost-effective approach is to test a worst-case dust or mixture and design safeguards for the worst-case risks. If this proves too conservative — *i.e.,* if it results in expensive safeguards that may not be necessary — basic testing of additional samples may be warranted. The need for additional testing may be identified during a process hazard analysis, which will be discussed later.

Two basic tests are necessary for nearly every solid:

explosion severity ($K_{St}$), which confirms combustibility, provides data necessary for deflagration vent sizing, and to some extent quantifies the hazard; and minimum ignition energy (MIE), which provides evidence of the likelihood of ignition. These two tests provide sufficient information for a basic understanding of the hazard level associated with the majority of solids.

Other tests should be considered only if the results will be used for decision-making in the design of safeguards. For example, some situations may require a minimum auto-ignition temperature (MAIT) test of a dust cloud in air, or a limiting oxygen concentration (LOC) test.

It takes time to collect samples and obtain test data. Qualitative information on combustibility (*i.e.,* yes or no) based on fundamental knowledge of the molecule (*e.g.,* molecular formula, moisture content, and particle size) and publicly available data can help you decide if immediate action is necessary. Testing has been completed on many dusts and the results are reported in various references, such as Ref. 10 and at www.nfpa.org/catalog/services and www.dguv.de/ifa/en/gestis/expl/index.jsp. If there is reason to believe that the dust you are working with is combustible, do not wait for the test results to take action. Assume the dust is combustible, and move on to the next step — the preliminary audit — while waiting for the results. General public data should be used only for a qualitative determination of combustibility — specific decisions regarding prevention and protection methods should be based on test data of actual process samples.

## The preliminary audit

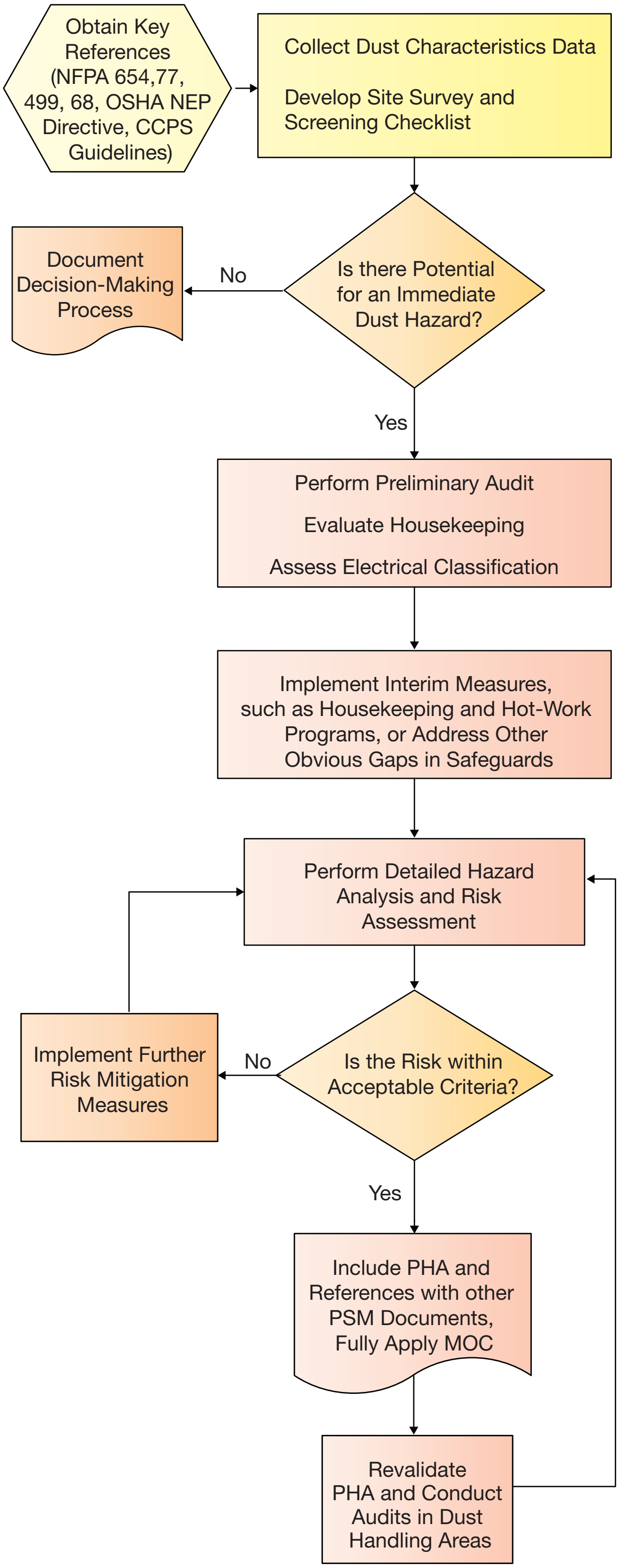
A plant walkthrough is essential to identify potential dust explosion hazards and current methods of control.

A facility has a combustible dust explosion hazard if the five elements represented by the corners of the dust explosion pentagon — fuel, oxygen, ignition, dispersion, and confinement, as depicted in Figure 2 — are present in any of its dust-handling unit operations (*e.g.,* dust collectors, mills, silos). The presence of these five elements in the vicinity of

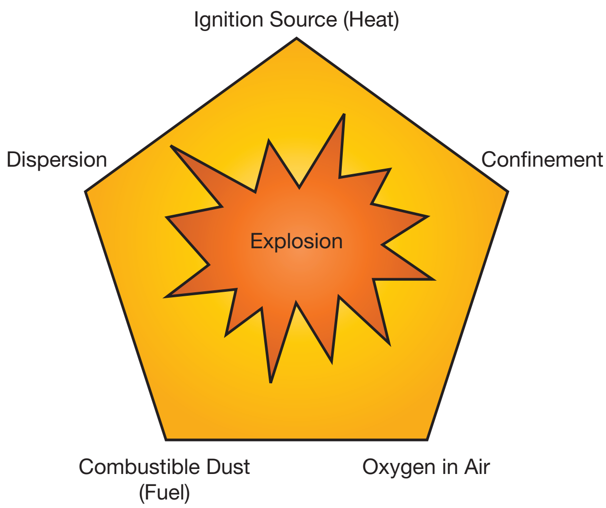
### If my dust's $K_{ST}$ is very low, must I treat it the same as a high-$K_{ST}$ dust?

This question comes up often. The short answer is yes. If a dust is combustible, it will have a $K_{St}$ value greater than zero, and all operations must be treated with the same rigor.

However, if characterization testing in a 20-L sphere determines $K_{St}$ < 45 bar-m/s, the dust should be retested in a 1-$m^3$ chamber. It has been demonstrated that false positives can occur on marginally explosive dusts in a 20-L sphere.




▲ **Figure 1.** Follow this process to evaluate the risks associated with combustible dusts and to identify ways of mitigating risks.




▲ **Figure 2.** The dust pentagon depicts the five elements that contribute to combustible dust hazards.

a combustible dust indicates the risk of a primary explosion. Accumulations of dust in high enough quantities within a room or facility can lead to a secondary dust explosion. It is possible to have a combustible dust explosion hazard present within process equipment but not have a secondary dust explosion hazard across the facility.

A third hazard, a flash fire that could expose personnel, may also be present, and require that appropriate precautions be taken to protect employees. A facility has a combustible dust flash fire hazard if the four elements other than confinement (*i.e.,* fuel, oxygen, ignition, and dispersion) are present.

An ideal approach to the preliminary audit is to first develop a checklist of key reminders for use while touring the facility. Such a checklist can be based on the elements of an OSHA National Emphasis Program (NEP) inspection *(12, 13)* and general requirements (*e.g.,* electrical classification or poorly maintained electrical junction boxes, posted signs, dust leaks) outlined in NFPA standards *(1–5, 14)* or other references.

In a safety and health bulletin (SHIB 07-31-2005), OSHA states that facilities should assess their potential for dust explosions based on identification of the following:

- materials that may be combustible when finely divided
- processes that use, consume, or produce 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
- potential ignition sources.

Table 1 provides a few line items from a typical checklist for a dust assessment audit.

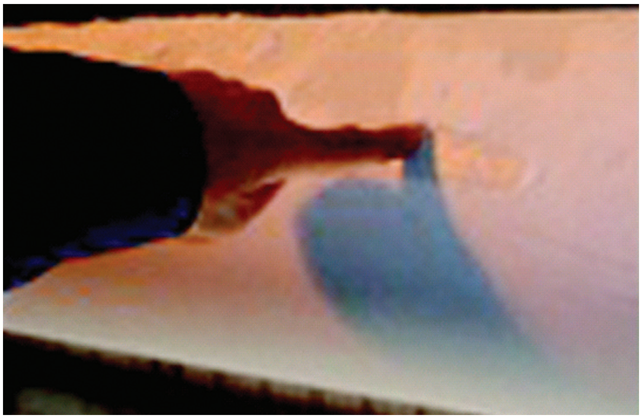
To gauge the three key hazards — primary explosion, secondary explosion, and flash fire — walk around each area that handles a combustible dust. Note the amount of dust that has accumulated around the equipment, as well as on horizontal ledges, such as I-beams, the tops of tanks, or any other horizontal surface or process equipment structure.

If the accumulations are less than 1/32 in. *(12)* covering less than 5% of the floor area, there is potential only for a primary explosion or flash fire. If you can write your name in the dust accumulation (Figure 3) or if the underlying paint color is obscured, then the dust accumulations are too high.

If dust has built up on more than 5% of the horizontal surface area, there may be a secondary explosion and flash fire hazard. There are cases in which much more dust has accumulated without an explosion hazard, depending on the dust density; Ref. 15 provides details on the calculations to quantify threshold values. In addition, if a large pile of dust (1–2 in. by 3 ft diameter) has accumulated at a discharge

**Table 1. Identify recommendations for mitigating hazards based on observations related to regulatory issues.**

| Regulatory Issue | Notes from Field Audit | Recommendation |
|---|---|---|
| Ductwork-related problems (*e.g.,* not grounded or not constructed of metal) | All ductwork was constructed of metallic components, including flexible metal hoses. The ductwork was grounded using metal U-bolt supports attached to the building steel. Most flanges had bonding jumpers attached. | Ensure that all flanges in the conveying systems are equipped with bonding jumpers. |
| Improperly designed deflagration venting (venting to areas where employees are likely to be exposed to explosion or deflagration hazards) | Deflagration vents all appeared to be directed to normally unoccupied areas. | N/A |
| Equipment must have one or more of the following:<br>• Oxygen concentration reduction<br>• Deflagration venting<br>• Deflagration containment<br>• Deflagration suppression<br>• Dilution with noncombustibles | It appeared that most equipment was protected using deflagration venting. However, the design basis for the relief devices should be verified. | Confirm that all dust-handling equipment has some means of explosion protection provided. Confirm design basis for all deflagration vents. |



▲ **Figure 3.** If you can write your name in the accumulated dust, a combustible dust hazard is likely present.

point that represents only a very small portion of the surface area of the room, it is most likely not sufficient to constitute an explosion hazard for the facility. It may, however, be a flash fire hazard.

The key protection for a secondary dust explosion or flash fire is to confine the dust inside the equipment. If that is not possible, the flash fire hazard must be addressed to ensure that personnel are not exposed to a fire. If a flash fire hazard is present and it is not feasible to prevent the escape of dust from the equipment, employees need to wear flame-retardant clothing.

Improved housekeeping to eliminate sources of dust generation is an acceptable approach to mitigating or eliminating many consequences associated with a dust hazard. As long as the housekeeping does not require the hiring of additional employees, it is also a very low-cost solution.

## Electrical classification

Electrical classification is an important engineering safeguard. With regard to dusts, an area's electrical classification is based on the thickness of the dust layer. If combustible dust is present, the area is designated as Class II. Within Class II, a thickness of more than 1/8 in. is classified as Division 1, while a thickness of less than 1/8 in. obscuring the surface color is classified as Division 2. If the surface color is discernible under the dust layer, it is unclassified (Table 2). Consult NFPA 70 *(14)*, and NFPA 499 *(2)* to determine the proper electrical classification for dust-handling operations.

The thickness of dust on surfaces and the concentration of airborne dusts are the key variables that determine whether electrically classified equipment is required. It is more cost-effective to ensure good containment than to install electrically classified equipment. Keeping dust inside equipment is the key to eliminating the need for classified equipment.

The dust layer thicknesses observed during a walk-through can provide a good indication of the type of equipment that should be considered for electrical classification upgrading. For instance, in some situations, it may be sufficient to modify the housekeeping schedule to ensure that dust is not able to accumulate in quantities that create an ignition source. If an enclosure has infrequent leaks that do not accumulate to hazardous levels (up to 3/32 in.), and if leaks are cleaned up promptly, the area may be unclassified *(6)*.

If the audit walkthrough indicates a need to classify some parts of the facility as hazardous, there are ways to save money on the installation of classified equipment. Some electrical components that were previously installed without consideration of combustible dust hazards may be sufficient. For example, totally enclosed fan-cooled (TEFC) motors (and many other types of totally enclosed equipment) are acceptable for Class II, Division 2 locations, as long as the maximum external temperature is less than the ignition temperature of the dust that could be present.

Another common example of over-investment in electrical classification is the broad-brush approach of classifying entire rooms as hazardous locations, which may not be warranted in many situations. As outlined in NFPA 499 *(2)*, the boundaries of the dust hazard dictate how large an area (in all directions) around dust-generating equipment needs to be classified as a hazardous location. Equipment in an area that handles combustible dust does not need to be electrically classified if dust removal prevents the formation of visible dust clouds and the accumulation of dust layers that obscure surfaces.

## Employee knowledge

Once the audit, sample testing, and data analysis are complete — which typically takes three to four weeks — the results need to be shared with the employees. This should be in the form of a list of areas or equipment that have been identified as potential combustible dust hazards.

Education is the first step in helping personnel to understand the consequences of a dust explosion or flash fire, as well as the importance of good housekeeping and the need to address leaks immediately. Employees must also understand the dust pentagon and the role of each element. For example,

**Table 2. An area's electrical classification is determined based on dust layer thickness (A.5.2.2(a) of NFPA 499).**

| Thickness of Dust Layer | Classification |
|---|---|
| Greater than 1/8 in. (3.0 mm) | Division 1 |
| Less than 1/8 in. (3.0 mm), but surface color not discernible | Division 2 |
| Surface color discernible under the dust layer | Unclassified |
| Source: *(2)*. | |

a belief that residual fugitive dust in the area is an immediate explosion hazard can cause undue anxiety. On the other hand, employees who lack sufficient knowledge to understand how common materials (*e.g.,* sugar, flour, plastics) can generate catastrophic results may become complacent toward a very serious hazard. A balanced approach to the facts is essential for good hazard communication.

## Hazard evaluation

The next step in determining risk levels and the need for additional safeguards is conducting a process hazard analysis (PHA). A recent *CEP* article *(16)* dedicated to this topic outlined how to conduct a hazard evaluation and risk assessment. Conducting the PHA and including the risk assessment in the analysis drives an understanding of the true risk and the required safeguards for the specific operations, as well as facility-wide measures that can help to prevent secondary dust explosions.

Assessing risk and determining safeguards based on the risk assessment delineate intolerable risks from lower risks. These hazard evaluations serve three key functions:

- assess organizational risk and identify gaps in design where additional safeguards may be required
- aid in prioritizing future capital investments for addressing combustible dust hazards based on the risk level
- address a regulatory compliance requirement — the need to complete a PHA as mandated by NFPA 654 *(1)* and OSHA's NEP on combustible dust *(12, 13)*.

From a practical standpoint, the risk assessment may ultimately save money by highlighting which prescriptive safeguards among the RAGAGEPs are important for risk reduction and which are not required because the overall risk is acceptable without them.

## Sustainability

Once the audit and hazard evaluation are complete, develop a plan to address each gap in a reasonable time frame. Implementing all of the recommendations of the PHA should be sufficient to reduce the risks to acceptable levels.

Another key to sustainability is management systems designed to control the hazards. Housekeeping standards should include periodic audits to confirm that cleaning protocols are being executed properly. Management of change (MOC) procedures should be followed to ensure that safeguards are not modified or new hazards introduced as a result of equipment modifications, new recipes, or different solids being handled. Employees should receive periodic refresher training to reinforce their knowledge of the hazards of combustible dust. NFPA 654 *(1)* requires revalidation of the PHA every five years to ensure that changes and modifications are incorporated and that the risk assessment accurately reflects existing operations.

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## Further Reading


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## Closing remarks

In a variety of industries, the task of addressing combustible dust issues has become so large that it seems virtually impossible to manage. Excessive testing, costly investment in equipment modifications, and uncertainty of the hazard all contribute to anxiety. This article's practical approach to evaluating a combustible dust hazard is not only manageable, but also cost-effective. CEP

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