Explosion protection for dust collection systems handling metal dust

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Recent tragic incidents have highlighted the hazards of handling combustible metal dusts. This article briefly reviews general combustible dust hazards and then discusses the special characteristics of metal dusts and how those characteristics affect explosion protection.

We've all heard about catastrophic combustible dust explosions that have occurred over the past 15 years.[1] These incidents have increased awareness of the risks associated with combustible dust, but compliance with OSHA and NFPA standards remains inconsistent, and explosions still happen. [***Editor's note:*** All OSHA and NFPA standards discussed in this article and listed in this article's References section are available at www.osha.gov and www.nfpa.org respectively.] Also, while general knowledge of combustible dust hazards is growing, the special hazards related to metal dusts are less well known. Metal processors may think their plants have a lower explosion risk because they aren't handling highly combustible materials such as flour or sugar, but many metal dusts have characteristics that create a very high explosion risk.

Metal processing conditions have changed over the past 20 years. In the past, metal cutting and drilling processes, for example, used liquid cooling emulsions to reduce the heat generated during machining and maintain the metal's temperature to achieve precision. Multi-spindle drill heads generated relatively large metal chips for waste, which were suspended in toxic cooling emulsions and stored in central storage tanks. Disposing of the material in these storage tanks was costly and caused health and environmental concerns.[2]

Today, high-speed cutting machines are the norm in metalworking processes. The resulting waste particles are much smaller and require less cooling emulsion, if any. Dust collectors collect the particles at workstations through various types of dust hoods or enclosures, depending on the application.

The challenge of handling the waste material still remains, however. A wet dust collector (which uses cooling emulsion) carries a high cost to recycle or dispose of the large volume of suspended metal particles. A dry dust collector (which doesn't use cooling emulsion) eliminates the emulsion-disposal problem but creates a combustible dust hazard.[2]

A number of severe metal-dust explosions have occurred in recent years, causing catastrophic damage and many fatalities.[3-5] In July 2014, a dust explosion in a Chinese automotive parts plant killed 146 workers and injured more than 100.[6] The explosion most likely started in a dust collector and spread through the plant, fueled by accumulated metal dust both inside pipes and on pipes and other surfaces because of poor housekeeping practices. The pressure wave generated by the initial explosion would have propelled the accumulated dust into the air, creating an ideal scenario for a secondary explosion.

Adopting an explosion protection program that includes prevention measures as well as mitigation methods can reduce (but not eliminate) the chances of a dust explosion occurring at your plant. Before discussing metal dusts' properties and how to protect your plant from a metal dust explosion, it's important to know the basics of combustible dust and the explosion pentagon.

Combustible dust and the explosion pentagon

The dust deflagration index (K_{St}) measures a dust's explosivity relative to other dusts. Through testing, each dust is assigned a K_{St} value indicating the severity of explosion the dust is able to generate. According to OSHA and NFPA, any dust with a K_{St} value greater than zero is a "combustible dust." The greater a dust's K_{St} value, the stronger that dust's explosion capabilities. A dust with a K_{St} greater than zero up to 200 will generate a weak explosion, a dust with a K_{St} greater than 200 up to 300 will generate a strong explosion, and a dust with a K_{St} greater than 300 will generate a very strong explosion.[7]

If your operation involves combustible dust, you must perform a risk analysis to determine your risk level. You must also implement a management of change (MOC) program and take reasonable measures to prevent an explosion and minimize the risk of injury and damage if an explosion occurs.[8] An MOC program documents and justifies process changes and accounts for how those changes will affect system operation and safety. This helps to ensure that a system modification doesn't have dangerous unintended consequences or adversely affect operations. [***Editor's note:*** For more information on risk analyses and MOCs, see the "For further reading" section at the end of this article.]

A dust collector or silo is often the starting point in the chain of events leading to a combustible dust explosion. While a dust collector removes hazardous dust from the workspace, it can also present a potential dust explosion risk because the collected dust swirling inside the enclosed collector provides ideal conditions for a dust explosion.

A dust explosion can't occur, however, unless all five elements of the dust explosion pentagon, as shown in Figure 1, are present. As the figure shows, a dust explosion requires combustible dust (1) and oxygen (2) suspended in a cloud (3), confined in an enclosed space (4), and exposed to an ignition source (5). The ignition source might be a mechanically generated spark, an electrostatic discharge, a hot surface or bearing, or an open flame. Any ignition source that finds a perfect concentration of airborne dust will trigger combustion (or a deflagration), but an explosion requires that the dust be confined and that the pressure increase caused by the combustion is great enough to breach the enclosure.

Figure 1

Dust explosion pentagon

Metal dust characteristics

While many metal dusts don't have high K_{St} values compared to organic materials (except aluminum and magnesium oxide compounds, whose K_{St} values can exceed 500), metal dusts have some unique characteristics that place them at a high risk for deflagrations and explosions.

High ignition risk. In metalworking and recycling operations, processing machines such as cutting tools or metal shredders constantly generate heat and often sparks, which can cause ignition. Even in the absence of sparks, the dust can spontaneously ignite if the temperature of the dust or a surface reaches the dust's minimum ignition temperature. While this is true for all combustible materials, the risk of fire and explosions is higher with metal dusts because the processes that generate metal dusts are more likely to create conditions leading to self-ignition.[9] Even with a wet dust collection system, a water-based cooling emulsion could react with the metal dust and generate hydrogen, which has a very low ignition energy and could lead to self-ignition.

High energy content. Metals and metal dusts have a much higher energy content than organic materials. This leads to a very long burning time and a higher burning temperature. After an explosion, an organic material will typically reach a burning temperature of 3,000° to 4,000°F. A metal can easily exceed 5,000°F.[6, 8] Also, a regular extinguishing agent such as water or sodium bicarbonate can't be used for a metal dust fire because it could generate chemical reactions with the metal and actually accelerate combustion. Only a Class D extinguishing agent is effective. However, even a Class D extinguishing agent can only keep a metal fire under control; it can't completely extinguish the flame because the heat is too great.[9]

Smoldering. In a recycling plant, in which a mix of metal and plastic material is ground down and handled for reuse, some grinding and handling processes — computer shredding, for example — can generate very fine dust particles. These fine dust particles can be prone to *smoldering* (slow, low-temperature combustion), which is sustained by the heat created when oxygen directly reacts with the particle surfaces. A smoldering material is prone to self-ignition. Smoldering can provide a pathway to self-ignition where the heat source would otherwise be much too weak to produce an actual flame.[10]

An explosion protection program is critical for any manufacturing process that generates dust, and this is particularly true for an operation that generates combustible metal dust. A metal dust explosion protection program has two main components: prevention and mitigation.

Metal dust explosion prevention

Explosion prevention includes any measure that eliminates one of the required elements of the dust explosion pentagon described earlier. NFPA and OSHA have developed a number of standards and procedures for preventing dust explosions.[11, 12] These standards focus on preventing a combustible atmosphere from developing and emphasize good housekeeping practices and avoiding dust accumulation.

Housekeeping. In some manufacturing processes, maintaining a dust-free environment can be difficult, but good housekeeping practices can minimize the chances that airborne dust will reach its minimum explosible concentration (the dust concentration required to support an explosion) and reduce the amount of dust available to fuel a dust explosion should one occur. Remove accumulated dust using an explosion-proof vacuum system because the dust accumulating inside the vacuum can create another "combustible atmosphere." Never use compressed air to blow accumulated dust from surfaces, because this can also create a combustible atmosphere.

Preventing ignition sources. Preventing ignition sources can be difficult and costly, and you'll never be able to eliminate ignition sources with 100 percent certainty because of the uncontrollable "human factor." You can reduce your explosion risk by establishing procedures to avoid common ignition sources, such as mechanically generated sparks, open flames, hot surfaces, and static electricity. Also be sure to ground all process equipment (which is mandatory) and use intrinsically safe electrical equipment.

Conditioning. Conditioning is modifying a combustible material to make it noncombustible. Spraying water on coal dust, for example, is a method used frequently in coal-mining operations.

Substitution. Substitution is suspending a highly combustible material, such as aluminum dust, in oil to avoid any possible reaction with oxygen. This is the wet dust collection method discussed near the beginning of this article.

Inerting. Inerting is substituting the oxygen in the system with an inert gas, such as nitrogen, to prevent ignition. To ensure that the oxygen level remains low, the system controls the inert gas pressure and constantly monitors the oxygen concentration. The system shuts down if the oxygen concentration reaches a critical level and floods the enclosure with inert gas. Although frequently used in batch operations, such as pharmaceutical production, inerting can be prohibitively difficult and expensive in continuous operations.

Metal dust explosion mitigation

Preventive measures are important, but it's not possible to guarantee explosion prevention when handling combustible dust. You should always assume that all five dust explosion elements could be present in your dust collection system and take steps to mitigate the effects of a dust explosion if one occurs.

The most basic mitigation step you can take is to install your dust collector outside. NFPA 484 extensively covers the use of wet and dry dust collectors and states that dry dust collectors should be located outside of buildings in a safe location.[13] In practice, however, many dry dust collectors are installed indoors to avoid lengthy ductwork, which could cause dust to settle inside the ducts and create a dust accumulation hazard.

NFPA 484, Chapter 9.4.13.15 includes exemptions to the mandatory outdoor installation requirement. For both new and existing dust collection systems, a dry dust collector is permitted indoors if a process hazard analysis ensures that the risk for workers and equipment is properly minimized. Also, the dust's minimum ignition energy (MIE) must be greater than 100 millijoules, the P_{max} (maximum explosion pressure) must be less than 8 bar gauge, the K_{St} value must be less than 150, and the material mustn't be spontaneously combustible under UN Class 4.2.[13] Many metal compounds fall within these conditions, unless the compound contains magnesium oxide or very fine aluminum particles.

Aside from locating the dust collector outdoors, explosion venting, isolation, and suppression are the primary explosion mitigation methods for metal dust applications.

Explosion venting. An enclosure (such as a dust collector) should be fitted with properly sized explosion vent panels if the enclosure is located outside the building or close to an exterior wall. An explosion vent panel is designed to burst during an explosion, allowing the pressure and flame to escape and preventing damage to the enclosure.

You can use an explosion vent panel to vent an outdoor dust collector handling metal dust, but you must direct the vent away from people, buildings, parking lots, or other areas that could create a hazard. Refer to NFPA 68 for help calculating the required vent area for your application.

For applications where a dry dust collector must be installed indoors, either chemical suppression or an indoor venting system is required. Indoor venting systems have been used on dust collectors for more than 25 years. An indoor venting system, as shown in Figure 2, is designed to prevent the pressure buildup inside the dust collector from surpassing the dust collector's P_{red} (or design strength), which was used to calculate the dust collector's vent area. The venting system dissipates the explosion's heat, as shown in Figure 3, so no dangerous heat or flames escape, which could injure workers or trigger a secondary explosion.

An indoor venting system is typically only approved for organic materials with limited K_{St}, explosion pressure, and MIE values.[13] However, in 2014, one indoor venting system, the REMBE Q-Rohr-3, became the first to receive ATEX[14] approval for use in metal dust applications and also conforms to NFPA 484, Chapter 9.4.13.15 requirements for indoor venting systems.

You can also use an indoor venting system on an outdoor dust collector to prevent the possibility of flames and heat

Figure 2

Indoor venting system

Figure 3

Aluminum dust explosion with an indoor venting system installed

extending out of the dust collector. A dust explosion with a high aluminum content, for example, can create a very hot and long fireball that extends far outside the dust collector, as shown in Figure 4.

Explosion isolation. In addition to venting, interconnected enclosures must be equipped with devices designed to isolate an explosion so it doesn't propagate from one enclosure to another. Passive isolation flap valves and active quench valves suit this purpose. You can also use a chemical suppressant to isolate the explosion and prevent it from spreading and causing secondary explosions.[15]

Finally, recirculating the dust collection system airstream back into the building is permitted for many dust types, however, this practice is strictly prohibited in metal dust applications.[13, 15]

Metal dust's unique characteristics do present a potential combustible dust explosion risk, whether your dust collector is located indoors or outdoors. However, an explosion protection program that includes the prevention and mitigation measures outlined here can help you ensure both your workers' safety and your plant's compliance with OSHA and NFPA standards. **PBE**

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Figure 4

Flame length of an aluminum dust explosion without an indoor venting system installed

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14. ATEX is the common name for the European directives for controlling explosive atmospheres.
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For further reading

Find more information on combustible dust hazards and dust explosion prevention in articles listed under "Safety" and "Dust collection and dust control" in *Powder and Bulk Engineering*'s article index in the December 2014 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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