WHITE PAPER

Controlling Dangerous Dusts in the Chemical Processing Industry

Effectively controlling toxic and combustible dust generated in chemical processing facilities is essential to protecting employee health, maintaining product quality and preventing devastating explosions. This white paper examines these dangers, applicable regulatory guidelines and how to use a high-efficiency dust collector to keep workers safe and facilities in compliance.

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Dust Hazards in the Chemical Processing Industry

Controlling toxic and combustible dust is a common yet serious challenge in the chemical processing industry. Everyday processes like mixing, conveying and blending create dangerous dusts that become airborne, endanger air quality and can create fire and explosion hazards.

Although each processing facility has unique dust issues based on the raw materials used, they must all comply with worker exposure limits, environmental regulations and combustible dust standards.

Chemical processors must comply with Occupational Safety & Health Administration (OSHA) regulations to protect their employees from exposure to airborne dusts, as well as National Fire Protection Association (NFPA) standards to provide a safe working environment.

Chemical processes create dangerous dusts that become airborne

Occupational Exposure to Toxic Dusts

Regular exposure to certain types of chemical dust particles can be hazardous and irritate the eyes and skin. Such conditions can cause health problems for workers and may require treatment and protective equipment. Other fine chemical dusts can travel deep into the lungs, becoming embedded and causing serious respiratory conditions such as occupational asthma and even lung cancer.

OSHA regulations govern employers whose processes generate dust, and the agency will issue citations and fines for lack of compliance. Under OSHA, companies must control toxic chemical dust emissions into the indoor workplace atmosphere to comply with the established permissible exposure limit (PEL) for workers. If no legal limits are applicable, then the company is required to define in writing, implement and measure its own environmental safety plan to comply with the general duty clause.

Activities That Create Airborne Dust Hazards

- Batching
- Blending
- Coating
- Conveying
- Crushing
- Drying
- Milling
- Mixing
- Packaging
- Screening
- Sack Tipping
- Salting
- Sieving
- Weighing

OSHA Regulations Governing Occupational Exposure

OSHA 1910 is a broad, general standard that covers most industries. It is a comprehensive and complex standard with 20 subsections. OSHA PELs include limits on airborne concentrations of hazardous chemicals in the air for general industry in 1910.1000–Air Contaminants. They are listed by chemical name in Tables Z-1, Z-2 and Z-3. Most OSHA PELs are eight-hour time-weighted averages (TWAs), although there are also ceiling and short-term exposure limits (STELs). Many chemicals include a skin designation to warn against skin contact.

OSHA 1910.22: Walking-Working Surfaces is a housekeeping standard that requires all places of employment, passageways, storerooms, service rooms and walking-working surfaces to be clean, orderly, dry, sanitary and free from hazards. This means that manufacturers must prevent dust from accumulating on these surfaces.

OSHA 1910.134: Personal Protective Equipment (PPE) requirements aim to minimize occupational diseases caused by breathing air contaminated with harmful dusts, fumes, mists, gases, smokes, sprays or vapors and coming into physical contact with these dusts. It recommends accepted engineering control measures to mitigate these risks as a first step before relying on PPE.

OSHA 1910:307: Hazardous (Classified) Locations covers the requirements for electric equipment and wiring in locations where there is a risk of fire or explosion because of the presence of flammable vapors, liquids or gases or combustible dusts or fibers.

The National Electrical Code (NEC) defines hazardous location types, and many chemical processing facilities are Class II, where there is a sufficient amount of combustible dust present in the air to be explosive or ignitable under normal, everyday operating conditions.

Reducing Worker Exposure to Toxic Dust

The best way to reduce workers' exposure to hazardous dusts is to install a dust collection system with high-efficiency primary and secondary cartridge-style filters. It is preferable to capture chemical fumes and dust at their source to prevent them from expanding throughout the plant. This is accomplished by incorporating a hood or extraction arm into the chemical process machinery. Source capture is extremely effective, and it requires the least energy and capital investment.

However, once they are captured, dust should be isolated from the rest of the facility and contained in a specific area. For example, a portioned area can be kept under negative pressure. The extracted air is either drawn directly into a local collector or ducted to a dust collector located remotely. In some cases, the filtered air can be safely returned back into the facility to create a push-pull airflow pattern to improve the contaminant control.

A chemical manufacturing facility may also require special options or accessories to improve the safety and reliability of the system. Bag-in/bag-out filters and hopper discharge options can be used to limit exposure and cross-contamination of collected material when performing filter and dust removal maintenance. Additional features such as duct and equipment clean-out doors, stainless steel construction, safety after-filters (HEPA) and FDA-compliant paint are also commonly used with the air filtration unit based on contaminant properties.

Examples of OSHA PELs for chemical dusts in general industry:

- Cadmium: 5 µg/m^3
- Zinc oxide: 15 mg/m^3
- Chromium: 5 µg/m^3
- Iron oxide: 15 mg/m^3
- Cobalt: 0.1 mg/m^3

Regular exposure to chemical dust particles can irritate the eyes, skin and lungs.

Extracted air can be ducted to a dust collector located outside of the processing plant.

Wide-pleat style cartridge filter media

TYPES OF FILTERS AND FILTRATION MEDIA

Primary filter media should be selected for each application based on the dust particle size, flow characteristics, quantity and distribution. If the dust being collected is toxic and the primary filtration system does not use a HEPA filter, it is recommended that a secondary HEPA filter be used downstream. Secondary filters prevent hazardous dusts from discharging to the atmosphere and can be configured to prevent return air ducting contamination and the associated costs of cleaning hazardous dust leakage.

A wide, uniformly pleated filter allows the collected dust to release from the filter, keeping the resistance lower through the filter for a longer period of time. When the pleats of the filter media are tightly packed, the reverse pulse cleaning system of the dust collector will not eject the dust that has settled in between the pleats. Tightly packed pleats increase the resistance of the air through the filters and diminishes airflow, thus shortening filter life.

There are two basic categories of media commonly used in pleated cartridge filters. The choice is usually driven by dust type, operating temperatures and the level of moisture in the process:

- Nonwoven cellulosic blend media is the most economical choice for dry dust collection applications at operating temperatures up to 160 °F (71 °C).
- Synthetic polyester media or polyester-silicon blend is a lightweight, washable media that can handle dry applications with maximum operating temperatures ranging from 180 °F (82 °C) up to 265 °F (129 °C). These filters are washable and can recover from a moisture excursion, but they are not intended for wet applications.

HemiPleat® Gold Cone™ cartridge filter

Standard and nanotechnology filter media treated with a flame retardant are recommended for applications considered a fire risk. Conductive or anti-static filters may be used where conveyed dusts generate static charges that require dissipation. Cartridge filters with anti-static media can also be used in explosive dust applications, making it possible to conform to NFPA requirements and lessen the risk of ignition sources due to static electricity charges.

High-efficiency dust collection systems also use self-cleaning mechanisms that regularly pulse dust off the filters, allowing units to run longer between filter change-outs. When a layer of nanofibers is applied on top of the base filter media, it promotes surface loading of fine dust and prevents the dust from penetrating deeply into the filter's base media. This translates into better dust release during cleaning cycles and lower pressure drop readings through the life of the filter.

Combustible Dust Explosions

A dust explosion occurs when a confined and concentrated combustible dust cloud comes into contact with an ignition source. Many chemical dusts qualify as combustible dusts. These chemical dusts can accumulate on surfaces, where a spark or flame can ignite them, causing a fire or explosion. Common ignition sources are kilns or a welding flame, but they also can be a lit match or cigarette.

Good housekeeping and installing a well-designed dust collection system can prevent airborne dust from building up in the work environment, on electrical equipment and other areas where dust can accumulate, such as false ceilings.

These measures help to negate the risk of a primary and/or secondary explosion. The primary explosion is the first point where an explosion occurs and is usually an isolated incident. A secondary explosion occurs when the primary explosion pressure disturbs the dust collected in the areas mentioned above, creating a far more extensive and potentially deadly explosion.

Dust collectors minimize the amount of combustible dust that can collect on floors and other surfaces, and they contain chemical dust in one area. But the dust collectors themselves can be a fire or explosion hazard if they are designed incorrectly or not equipped with the proper explosion protection controls.

OSHA: Combustible Chemical Dusts

- Adipic acid
- Anthraquinone
- Ascorbic acid
- Calcium acetate
- Calcium stearate
- Carboxymethylcellulose
- Dextrin
- Lactose
- Lead stearate
- Methylcellulose
  Paraformaldehyde
- Sodium ascorbate
- Sodium stearate
- Sulfur

Regulations Governing Combustible Dust

In the United States, there are three key entities involved in combustible dust issues, each with its own particular area of responsibility:

- **NFPA** sets safety standards regarding combustible dust, amending and updating them on a regular basis. NPFA's standards aim to prevent an explosion, vent it safely and ensure that it will not travel back inside a building. Most insurance agencies and local fire codes state that NFPA standards shall be followed as code. Exceptions would be where the authority having jurisdiction (AHJ), such as Factory Mutual or local fire marshals, specifies an alternative safety approach, which might be even more stringent.

- **OSHA**, together with local authorities, enforces NFPA standards. OSHA's Combustible Dust National Emphasis Program (NEP) outlines policies and procedures for inspecting workplaces that create or handle combustible dusts. OSHA began rulemaking in October 2009 for a general industry standard for combustible dust; however, the agency has yet to issue a proposed rule.

- **U.S. Chemical Safety Board (CSB)** is an independent federal agency responsible for investigating industrial chemical accidents. Staff members include chemical and mechanical engineers, safety experts and other specialists with chemical industry and/or investigative experience. The CSB investigates combustible dust explosions, sifting through evidence to determine root causes and then publishing findings and recommendations. A CSB study identified 281 combustible dust incidents between 1980 and 2005 that killed 119 workers, injured 718 and extensively damaged industrial facilities. Since that time, the CSB continues to identify serious dust-related incidents on a regular basis.

"NFPA 652 sets requirements for managing combustible dust fires and explosions across industries, processes and dust types."

Relevant NFPA Standards

In trying to sort through the list of combustible dust standards, a good starting point for every chemical processing facility engineer or manager is NFPA 652, the Standard on the Fundamentals of Combustible Dust. This covers the requirements for managing combustible dust fires and explosions across industries, processes and dust types. This standard applies to all facilities and operations that deal with combustible dust, not just hazardous or classified locations. For chemical processors, this means they are required to perform a dust hazard analysis (DHA). The owner or operator of any facility where combustible dust exists is responsible for conducting a DHA to identify the hazards, create a plan for managing the hazards and providing training for anyone affected by the hazards.

NFPA 654, the Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing and Handling of Combustible Particulate Solids, is an all-encompassing standard on how to design a safe dust collection system. It is the most general on the topic, and it will lead you to other relevant documents. Depending on the nature and severity of the hazard, NFPA 654 will guide you to the appropriate standard(s) for explosion venting and/or explosion prevention.

NFPA 68 – Standard on Explosion Protection by Deflagration Venting: This document focuses on explosion venting on devices and systems that vent combustion gases and pressures resulting from a deflagration within an enclosure, for the purpose of minimizing structural and mechanical damage.

NFPA 69 – Standard on Explosion Prevention Systems: This standard covers explosion protection of dust collectors when venting is not possible. It includes the following methods for prevention of deflagration explosions: control of oxidant concentration, control of combustible concentration, explosion suppression, deflagration pressure containment and spark extinguishing systems.

NFPA 70® – National Electrical Code: The NEC covers everything related to the installation of electrical equipment across all industries and all types of buildings. This code is enforced in all 50 states. Chemical processors need to be aware of two main sections of NFPA 70 because they apply to housekeeping: Combustible dust definition and hazardous locations. NFPA 70 defines combustible dust as "dust particles that are 500 microns or smaller and present a fire or explosion hazard when dispersed and ignited in air." The NEC defines different classes of hazardous (classified) and non-hazardous locations. These classes determine the wiring of buildings and also the equipment and housekeeping procedures that can be used in different areas of facilities.

Combustible Dust

Particles that are 500 microns or smaller and present a fire or explosion hazard when dispersed and ignited in air.

Mitigating Combustible Dust

DUST HAZARD ANALYSIS

In chemical processing it is critical to know the explosive potential of the dusts, gases and dust/gas mixtures emitted during operations. NFPA states that a dust hazard analysis is needed to assess risk and determine the required level of fire and explosion protection from combustible dust. The analysis can be conducted internally or by an independent consultant, but either way the authority having jurisdiction will ultimately review and approve the findings.

The first step in a hazard analysis is determining whether your dust is explosive.

The first step in a hazard analysis is determining whether your dust is explosive. NFPA classifies dusts according to their explosibility, that is, their Kst value. Kst is the normalized maximum rate of explosion pressure rise, measured in bar m/s. A bar is a metric unit of pressure, which is slightly less than the average atmospheric pressure on earth at sea level.

NFPA Class ST1 dusts are rated below 200 Kst, Class ST2 dusts range from 200 to 300 Kst, and Class ST3 dusts are rated above 300 Kst. As a rule of thumb, when dusts approach 600 Kst, they are so explosive that wet collection methods are recommended. However, any dust above 0 Kst is considered to be explosive, and the majority of dusts fall into this category. If OSHA determines that even a very low Kst dust is present in a facility with no explosion protection in place, a citation will result, per OSHA's NEP policy.

In addition to Kst, it is important to know other combustible dust properties such as Pmax (the maximum explosion pressure of a dust cloud, measured in bar) and Pred (the maximum pressure developed in a vented enclosure during a vented deflagration). These can be determined using ASTM E 1226-10, Standard Test Method for Explosibility of Dust Clouds.

Any dust above 0 Kst is considered to be explosive, and the majority of dusts fall into this category.

Your dust collection equipment supplier will need the Kst and Pmax values in order to correctly size explosion venting or suppression systems. Failure to provide this information may increase your costs, since the supplier will have to use worst-case estimates of the Kst and Pmax values or may even refuse to provide the equipment.

In addition to conducting explosibility testing to determine whether a dust is combustible, it is important to analyze other dust characteristics to determine the best dust collection system and filters for your chemical processing operation. Other key dust properties to know include particle size, dust shape, gravity, moisture level and abrasiveness. Understanding these components lend to the optimal design of dust-control equipment. Quality equipment suppliers can conduct this type of dust testing and work with you to specify the best system for your application.

Combustible Dust Properties

- **Kst** – Deflagration index (bar m/s)
- **Pred** – Reduced pressure after venting (bar)
- **Pstat** – Vent static burst pressure (psi)
- **Pmax** – Max pressure for an unvented dust explosion (bar)
- **(dp/dt)** Rate of pressure rise (bar/s or psi/s)
- **Pes** – Enclosure strength = 2/3 of yield strength of weakest part or 2/3 of ultimate strength if deformation is allowed

Dust Collectors and Explosion Protection

Combustible dust explosions are a risk in many areas of a chemical processing plant, but a critical location is the dust collection system itself. There are many types of explosion protection devices and systems used to help dust collection systems comply with NFPA standards. They fall into two general categories: passive and active.

Passive systems react to the event, while active systems detect and react prior to or during the event. The goal of a passive system is to control an explosion so as to keep employees safe and minimize equipment damage in the plant. An active system, by contrast, can prevent an explosion from occurring. An active system involves more expensive technology and typically requires recertification on a regular basis.

PASSIVE DEVICES

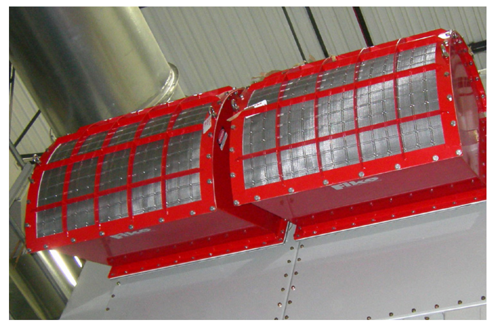
- **Explosion venting:** Designed to be the "weak" link of the dust collector vessel, an explosion vent opens when predetermined pressures are reached inside the collector, allowing the excess pressure and flame front to exit to a safe area. It is designed to minimize damage to the collector and prevent it from fracturing in the event of a deflagration, thereby reducing the safety hazard.

  Understanding the pressure capabilities of your collector is important in the specification and calculations of vent sizing. Comparing vessel enclosure strength (Pes) to the maximum pressure for the vented enclosure (Pred) and vent burst pressure are key to effective deflagration protection.

  Burst pressure of the vent is designed to be lower than enclosure strength, which will relieve the pressure of the deflagration before it can build to levels that would destroy the collector enclosure.

Industrial dust collector with explosion venting

- **Flameless venting:** Designed to install over a standard explosion vent, a flameless vent extinguishes the flame front exiting the vented area, not allowing it to exit the device. This allows conventional venting to be accomplished indoors where it could otherwise endanger personnel and/or ignite secondary explosions. A safe area around the flameless vent still needs to be established due to the release of pressure and dust/gases.



Flameless venting device

- **Passive float valve:** Designed to be installed in the outlet ducting of a dust collection system, this valve utilizes a mechanical barrier to isolate pressure and flame fronts caused by the explosion from propagating further through the ducting. The mechanical barrier reacts within milliseconds and is closed by the pressure of the explosion.
- **Backdraft damper:** A mechanical backdraft damper is positioned in the inlet ducting. It utilizes a mechanical barrier that is held open by the process air and is slammed shut by the pressure forces of the explosion. When closed, this barrier isolates pressure and flame fronts from being able to propagate further up the process stream.
- **Flame front diverters:** These devices divert the flame front to the atmosphere and away from the downstream piping. Typically, these devices are used between two different vessels equipped with their own explosion protection systems. The flame front diverter is used to eliminate "flame jet ignition" between the two vessels that could overpower the protection systems installed.

ACTIVE DEVICES

- **Chemical isolation:** Designed to react within milliseconds of detecting an explosion, a chemical isolation system can be installed in either inlet and/or outlet ducting. Typical components include the isolation canister, explosion pressure detector(s) and a control panel. This system creates a chemical barrier that suppresses the explosion within the ducting and eliminates the propagation of flame through the ducting and minimizes pressure increase within connected process equipment.

- **Chemical suppression:** Whereas chemical isolation is used to detect and suppress explosions within the ducting, chemical suppression protects the dust collector itself. It is often used, together with isolation, when it is not possible to safely vent an explosion or where the dust is harmful or toxic. The system detects an explosion hazard within milliseconds and releases a chemical agent to extinguish the flame before an explosion can occur.

- **Fast acting valve:** Designed to close within milliseconds of detecting an explosion, the valve installs in either inlet and/or outlet ducting. It creates a physical barrier within the ducting that effectively isolates pressure and flame fronts from either direction, preventing them from propagating further through the process.

- **High-speed abort gate:** The gate is installed in the inlet and/or outlet ducting of a dust collection system and is used to divert possible ignition hazards from entering the collector, preventing a possible explosion from occurring and preventing flame and burning debris from entering the facility through the return air system. A mechanical barrier diverts air to a safe location. Abort gates are activated by a spark detection system located far enough upstream to allow time for the gate to activate.

ADDITIONAL PRECAUTIONS

When planning and designing explosion protection, don't overlook additional devices and materials that can help reduce fire risk within the dust collection system. For spark-generating applications, a range of features and technologies are available, from flame-retardant and carbon anti-conductive filter media to spark arrestors in the form of drop-out boxes, perforated screens or cyclone devices installed at the collector inlet. Fire sprinklers and active fire extinguishing systems may also be required with some installations.

In high dust loading applications, a dust collector that uses vertically-mounted filter cartridges can also reduce fire and explosion risks. This type of arrangement uses gravity along with the pulse cleaning system to effectively and efficiently remove dust from the filters and the collector housing. With some horizontally mounted cartridges, high loading dust becomes trapped in the pleats in the upper third of the filters. This trapped dust can burn even if the filter media is fire retardant.

Summary

Effectively controlling the dusts generated in chemical processing facilities is an essential life-saving and legal obligation. Dust can cause serious harm to employee health, reduce product quality and cause devastating explosions that can hurt or kill workers and bring irreparable damage to your operation.

A high-efficiency dust collector designed specifically for your operation is an accepted and proven engineering control that will filter hazardous contaminants and combustible dusts to make indoor environments safer. With the help of engineering consultants and reputable and experienced equipment suppliers, chemical processing facilities can minimize risk factors and maximize combustible dust safety.

Controlling dust generated in chemical processing plants keeps workers safe and facilities in regulatory compliance.

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