

# UNDERSTANDING AND PREVENTING METAL-DUST HAZARDS

Jayant Khambekar\* and Brian H. Pittenger\*\*

## WHAT IS DUST AND HOW IS IT GENERATED?

There are many definitions of dust in the literature. These definitions vary regarding the particle size and suspension characteristics. As an example, the NFPA (National Fire Protection Association) definition of dust in NFPA 68 is *any finely divided solid, less than 420  $\mu\text{m}$  in dia.* According to the International Organization for Standardization (ISO 4225-ISO, 1994), dust consists of *small solid particles, conventionally taken as those particles below 75  $\mu\text{m}$  in diameter, which settle out under their own weight but which may remain suspended for some time.* According to the “Glossary of Atmospheric Chemistry Terms” (IUPAC, 1990), dust is a collection of *small, dry, solid particles projected into the air by natural forces, such as wind, volcanic eruption, and by mechanical or man-made processes such as crushing, grinding, milling, drilling, demolition, shoveling, conveying, screening, bagging, and sweeping.* While there appear to be different definitions of dust, broadly speaking dust can be described as fine material capable of remaining suspended in air for some time.

Where does dust come from? As far as the industrial environment is considered, dust is generated during manufacturing or handling operations. For example, let us focus on typical manufacturing operations in the PM industry. During powder manufacture by comminution, dust is generated as the metal oxides and reduced metals get crushed. During production of powder metal parts, as different elemental metal powders and additives are mixed, dust is generated. Handling of this mix in various types of equipment provides further opportunities for dust to separate and concentrate. These include operations such as hopper filling, blending/blender discharge, and compaction. Dust may also be produced by PM part-finishing operations.

The mechanisms that generate dust and keep it suspended in air arise from aerodynamic forces. Any dust that is generated can get carried away to another place as a result of air currents. Ventilation air flows or air streams generated during material drops act on fines in the material (the dust), and separate them from the main stream, Figure 1. Thus, even if dust generation may occur at one location, dust problems can be experienced at another location, away from the source.

*During metal powder production, powder handling, and green compaction, as well as powder metallurgy (PM) part-finishing operations, several opportunities exist for the generation of dust. The dust particles can be present originally in the powder being handled or they may form during intentional or unintentional breakage of particles during handling and processing operations. Dust can represent a serious health, environmental, and safety hazard. Unfortunately, unawareness about the consequences of dust generation and lack of measures to control dust have resulted in explosions and fatalities in the PM industry. In light of these events, the purpose of this article is to highlight dust handling by PM industry personnel. Better-informed plant personnel are the first step in preventing health, environmental, and safety hazards from dust generation!*

\*Senior Project Engineer, \*\*Senior Consultant Director, Jenike & Johanson, Inc., 400 Business Park Drive, Tyngsboro, Massachusetts 01879, USA, (978) 649-3300; E-mail: jkambekar12@jenike.com

## UNDERSTANDING AND PREVENTING METAL-DUST HAZARDS

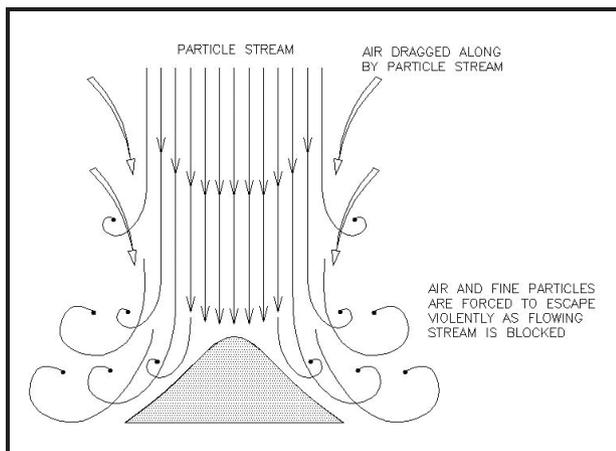


Figure 1. Example of dust generation during powder handling

### WHAT ARE POTENTIAL HAZARDS OF DUST?

Dust can represent a serious health, environmental, and safety hazard. Many times, dust particles may not be readily visible to the naked eye, especially when airborne. Airborne dust may enter the body by ingestion and skin absorption. However, the most vulnerable hazards associated with dust are inhalation and combustion.

### Effects on Health Due to Dust Exposure

If dust is released in the atmosphere, people may get exposed to it and inhale it. If the dust is harmful, there is a chance that someone will suffer from an adverse health effect, which may range from some minor impairment to irreversible disease and even life-threatening conditions. The health risks associated with a dusty environment depend on the type of dust (physical, chemical and mineralogical characteristics), and exposure. Exposure depends on the dust concentration, particle diameter of the dust, and exposure time (duration). It is further influenced by conditions that affect the uptake, for example, breathing rate and volume. Health effects resulting from exposure to harmful dust may become obvious only after long-term exposure; this is often the case with pneumoconiosis, a lung disease. It may happen that effects appear even after exposure has ceased, thus being more easily overlooked or mistakenly attributed to non-occupational conditions. However, many types of dusts have effects that result from shorter exposures to higher concentrations.

Health effects, which may result from exposure to different types of dust, include pneumoconiosis, cancer, systemic poisoning, hardmetal disease, irritation and inflammatory lung injuries, allergic responses (including asthma and extrinsic allergic alveolitis), infection, and effects on the skin. Many dusts are confirmed carcinogens, for example, hexavalent chromium

and certain chromates, arsenic (elemental and inorganic compounds), and certain nickel-bearing dusts. Deposited radioactive particles expose the lungs to significant doses of ionizing radiation, which may cause carcinoma of the lung tissue, or they may be transported from the lungs and damage other parts of the body.

Some dusts can pass to the bloodstream, thus being carried through the organism and exerting toxic action on one or more organs or systems, e.g., kidneys, liver, and blood. Such type of systemic intoxication can be acute (i.e., of rapid onset and short duration), or chronic (of long duration and usually slow onset), depending on the type of dust and degree of exposure. Toxic metal dusts—such as lead, cadmium, beryllium, nickel, and manganese—may cause systemic intoxications, affecting blood, kidneys, or the central nervous system.

Overexposure to certain hardmetal dusts (e.g., cobalt and tungsten carbide) or hardmetal-containing dusts may lead to diffuse pulmonary fibrosis, with increasing dyspnoea. Severe cases may progress even after cessation of exposure. This disease is often complicated with occupational asthma.

The National Institute for Occupational Safety and Health (NIOSH) indicates that deaths from work-related respiratory disease and malignancies account for about 70 percent of all occupational disease mortality. In the year 2000, there were an estimated 386,000 deaths from asthma, chronic obstructive pulmonary disease, and pneumoconiosis.

For more information on occupational diseases and impairments resulting from exposure to dusts, readers can refer to a publication by the World Health Organization (WHO).<sup>1</sup>

### Dust Combustion/Explosions

Dust also represents an explosion hazard when it is combustible, Figure 2. The hazards of combustible dust encompass a wide range of materials, industries,

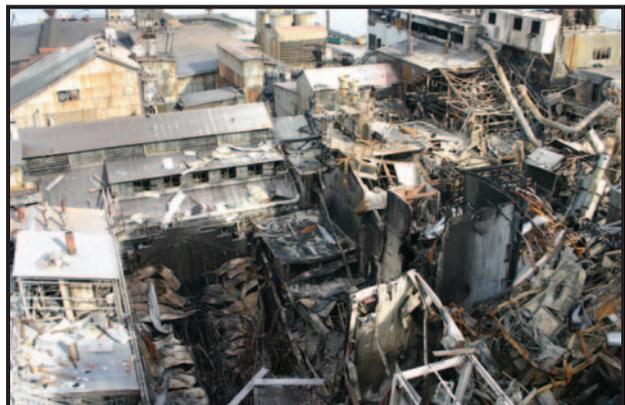


Figure 2. Example of a dust explosion (U.S. Chemical Safety Board)

and processes—including metal powders. Any combustible material can burn rapidly when in a finely divided form. Many materials that are commonly known to oxidize (for example, magnesium) can generate a dust explosion. However, many otherwise mundane powder metals (such as iron, aluminum, and titanium) can form suspensions in air that may lead to an explosion. Generally speaking, the focus of industrial dust-explosion discussions has remained on organic materials such as sugar and wood. However, dust explosions have occurred in the PM industry as well. Following are some examples where metal dust concentrations led to explosions.

In 2003, a fatal explosion occurred at Hayes Lemmerz International, Inc., an aluminum-wheel manufacturing plant in Indiana.<sup>2</sup> It was caused by ignition of aluminum dust. The manufacturing process in the plant involved machining of wheel castings. The machining operation creates aluminum chips and scraps. These were dried prior to being sent to a furnace for re-melting. The dust from the scraps was collected and conveyed to a dust collector outside the building.

The U.S. Chemical Safety and Hazard Investigation Board (CSB) determined that an explosion in the dust collector sent a pressure wave through the system ductwork and back into the building. A fireball then erupted inside the building, which lofted and ignited further aluminum dust that had accumulated on rafters and equipment.

Key findings of the CSB included inadequate house-keeping in the foundry area and insufficient maintenance of the chip-processing equipment, leading to the dust accumulation that fueled the secondary explosion. In particular the findings noted the dust-collector filters were infrequently cleaned, some ducts leaked dust because they were eroded, maintenance workers were not wearing flame-retarding clothing at the time of the accident, and the company did not have formal written maintenance procedures or employee training in place for the dust-collector system.

The CSB also determined that Hayes Lemmerz did not ensure the dust-collector system it ordered was designed in accordance with guidance in a prominent fire code published by the National Fire Protection Association. Aluminum dust is among the most explosive metal dusts and the conditions in dust collectors that are not properly designed, installed, or maintained present risk for an explosion and fire.

Similar to aluminum dust, iron dust is also combustible in nature. In 2011, fatalities occurred at the Hoeganaes Corporation's iron powder producing facility in Gallatin, Tennessee.<sup>3</sup> Iron powder dust was not identified as the primary source of the explosions.

However, accumulations of combustible iron dust were dispersed from the primary blast and contributed to the injuries.

Recently, an explosion occurred at ATI Rowley Operations of Allegheny Technologies that involved titanium dust.<sup>4</sup> Two maintenance workers were involved in the blast. A particulate filter that separated titanium dust from the air might have been a factor in the explosion—the investigation is still going on in this case. ATI has its own emergency response team that decontaminated the men.

These examples clearly demonstrate the explosion dangers associated with metal dusts. Let us look at the details of a dust explosion and the various elements necessary for a dust explosion to occur.

### Fire Triangle and Dust Explosion Pentagon

For a fire to start, three elements must be present: a fuel, an oxidizer, and an ignition source. Together these are described as a *fire triangle*. When these three elements are present, a fire results. For a combustible dust to explode, two additional elements are required. These are a dispersion of dust particles in sufficient concentration and confinement of the dust cloud. Together these five elements, referred to as a *dust explosion pentagon*, can cause a dust explosion, Figure 3. If a dust cloud (diffused fuel) is ignited within a confined or semi-confined bin, area, or building, it burns very rapidly and may explode. The safety of employees is threatened by the ensuing fires, additional explosions, flying debris, and collapsing building components.

An initial (primary) explosion in processing equipment or in an area where fugitive dust has accumulated may shake loose more accumulated dust, or damage a containment system (such as a duct, bin, vessel, or collector). As a result, if ignited, the additional dust dispersed into the air may cause one or more secondary explosions. These can be far more destructive than the

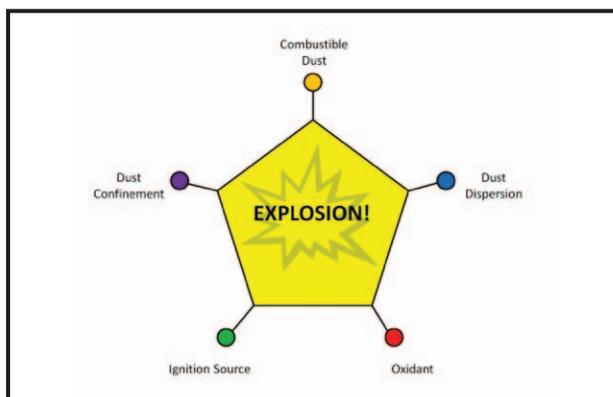


Figure 3. Dust explosion pentagon

## UNDERSTANDING AND PREVENTING METAL-DUST HAZARDS

primary explosion due to the increased quantity and concentration of dispersed combustible dust.

### ASSESSMENT OF DUST EXPLOSION POTENTIAL

Given the risks associated with metal dusts, it is prudent to perform an assessment of powder handling/storage operations at the plant to evaluate dust explosion potential. Any shortcomings identified during such an exercise should be immediately rectified. Some of the key areas to be evaluated during such assessment are as follows:<sup>5</sup>

- Identify combustibility of the dust that you are handling. Some dusts are more combustible than others. The higher the combustibility, the greater the potential for a dust explosion. For example, magnesium and aluminum dusts are highly combustible.
  - The Kst Test (ASTM E1226), which determines the combustibility and deflagration index (explosion severity), provides useful information in this regard. Understand though that many severe accidents have occurred with dusts classified in the lowest Kst hazard class, ST1.
  - In addition, measurement of Minimum Ignition Temperature (MIT), Minimum Ignition Energy (MIE), and Minimum Explosible Concentration (MEC) can provide further information on dust combustibility and many experts consider these vital to establishing suitable engineering controls.
- Identify open areas where combustible dusts may build up. For example, oftentimes air currents carry the generated dust away from the source and it may eventually accumulate on the shop floor.
- Identify confined and/or hidden areas where combustible dusts may accumulate. Examples of such places include tops of equipment, rafters, structural I-beams, flat or even round ducts, drop ceilings, process piping, or inside control and electrical panels and poorly sealed processing equipment. Dust accumulated in such areas may be hard to see. It can build up over time unnoticed, and may reach dangerous concentrations, from a dust-explosion perspective.
- Evaluate the amount of dust accumulation necessary to cause an explosive concentration. This amount can vary as there are many variables that influence the explosive concentration value. For example, the particle size of the dust, the method of dispersion, ventilation system modes, air currents, physical barriers, and the volume of the area in which the dust cloud exists or may exist can affect the amount of dust accumulation necessary for forming an explosive concentration.
- Evaluate all modes by which dust may be dis-

persed in the air.

- Consider possible sources of ignition. Examples include hot surfaces, overheated bearings, embers, burners, poor grounding (electrostatic buildup), electrical shorts, rotating/moving equipment with metal-to-metal contact points.
- Assess the current state of maintenance in the facility. Many accidents reflect insufficient equipment maintenance.
- A thorough analysis will consider all possible scenarios in which dust can be dispersed, both in the normal process and during possible failure modes.

### PREVENTION OF METAL DUST HAZARDS—GOOD OPERATIONS PRACTICES

NFPA 654 contains comprehensive guidance on good operational practices from a dust-explosion perspective.<sup>6</sup> Key points include:

- Clean and recover dust at regular intervals. Use cleaning methods that do not generate dust clouds.
- Control static electricity, including bonding of equipment to ground.
- Control smoking, open flames, mechanical sparks, and friction. Separate heated surfaces from dusts.
- Provide spark/ember detection and extinguishing systems.
- Separate areas having potential for dust explosion from other areas by distance or using barriers.
- Appropriate personal protection equipment (PPE) must be used when in a dusty environment or where dust exposure can occur.
- Provide access to all hidden areas to permit inspection.
- Operators and maintenance personnel are the first line of defense in preventing and mitigating fires and explosions; provide training to recognize and prevent dust hazards.
- Conduct a hazard analysis prior to the introduction of any new material, process, and/or equipment.

### PREVENTION OF METAL DUST HAZARDS—GOOD HANDLING SYSTEM DESIGN

Plants that handle materials in powder form must design the handling system appropriately so that dust generation is minimized to begin with. Also, any dust that is still generated must be captured and handled safely. This section briefly reviews the fundamentals of powder flow and design principles for powder storage and handling equipment from a reliable flow and dust-minimization perspective. This is followed by design principles for dust collection systems.

#### *Dust Generation During Transfers*

Common powder handling equipment in the PM

industry includes super sack and Gaylord box unloading systems, portable containers, blenders, fill hoppers, chutes, feeders, conveyors, and elevators. Within a handling system, it is common for powders to be transferred several times between process equipment. Unfortunately, the transfer points often get designed last, requiring them to fit within a fixed designed layout. This can result in improper designs leading to an uncontrolled material trajectory and hence dust generation.

A primary mechanism of dust generation is the dispersion of fine particles into a turbulent air stream that develops with the falling powder stream. Some of the kinetic energy of the falling stream is transferred from the powder to the air in the stream and, to a lesser degree, to the surrounding air that enters the stream at the boundaries. It is common to see significant dusting at the end of a transfer chute where the air is being forcefully expelled. At the boundary between the powder stream and surrounding air, some of the fine particles are also stripped from the stream due to frictional drag and are then carried away.

Additional turbulence is generated when an air-entrained particle stream strikes a deflection plate or equipment internal surfaces (walls) positioned at abrupt angles to the flow. In an improperly designed chute, the material stream is rarely controlled or concentrated and frequently impacts and bounces off the chute walls. As the material impacts against the chute wall, the velocity of the stream is reduced. This typically results in fines in the powder being carried away by air. Thus, in order to reduce the amount of dust generated during handling, proper design of powder transfers is essential.

#### **Powder-Flow Patterns and Dust Generation**

If powder flows smoothly through the storage and handling equipment, it will generate less dust. If powder flows in an erratic manner, more dust will be generated. Whether powder will flow smoothly or in an erratic manner inside a bin or a hopper depends on the flow pattern inside that equipment. The flow pattern of a powder in a storage container or system is dependent on the powder itself as well as the container design. For example, as a powder discharges by gravity from a storage container, primarily two types of flow patterns can develop: funnel flow and mass flow. Figure 4 shows a schematic of these two flow patterns.

In *funnel flow*, only a portion of the powder is in motion during discharge, which flows towards the outlet through a channel that forms within the stagnant material. Funnel flow occurs when a hopper is not sufficiently steep and smooth to ensure flow along the hopper walls or when the outlet is not fully effective.

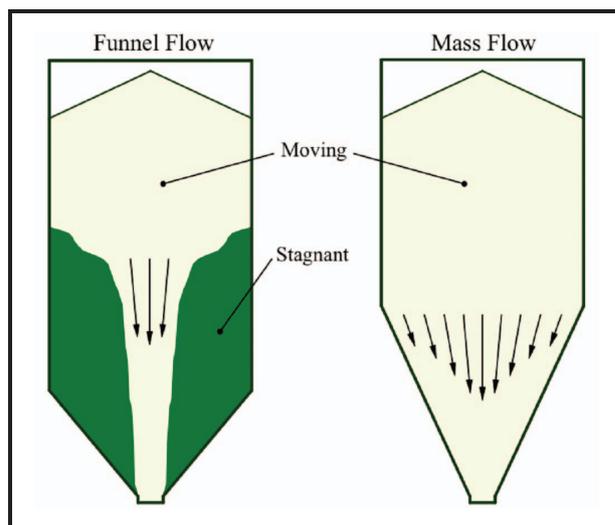


Figure 4. Funnel flow and mass flow patterns

In *mass flow*, all of the material is in motion whenever any is discharged; there is no stagnant material. Mass flow occurs when the hopper is sufficiently steep and smooth to ensure flow along the hopper walls. Shallow valleys are not permitted and the outlet must be fully effective.

The flow problems that can occur in a powder storage system are associated with the flow pattern in which the storage system discharges. Funnel-flow systems are most susceptible to flow problems. A discussion follows of the common flow problems that can lead to sudden stop/start of discharge and hence present potential for dust generation. We use the word “bin” to represent all kinds of powder storage systems, such as a hopper, silo, or portable container.

Most common of the flow problems is the case where powder does not come out from the bin. A *no-flow* condition can result either from arching (also known as bridging) or ratholing. *Arching* occurs when an obstruction in the shape of an arch or bridge forms over the hopper outlet, leading to a no-flow condition. Arching can occur due to the cohesive strength of the powder, or due to mechanical interlocking of large particles (less likely in the powder metal industry). Arching can occur in both mass-flow and funnel-flow bins. However, funnel flow is more prone to cohesive arching than mass flow. Figure 5 shows an example of an arching problem.

*Ratholing* only occurs in a funnel-flow bin. In funnel flow, material moves towards the outlet through a steep, funnel shaped flow channel surrounded by stagnant material. As the level of material in the flow channel drops, layers of material from the top surface of the stagnant region slide off into the flow channel. If this fails to occur, the flow channel empties and a rathole

## UNDERSTANDING AND PREVENTING METAL-DUST HAZARDS



Figure 5. Example of powder arching over hopper outlet



Figure 6. Example of powder ratholing in a hopper

forms. This results in a no-flow condition, as illustrated in Figure 6. The occurrence of problems like arching and ratholing results in a non-smooth/erratic flow that can lead to dust generation.

Metal powders, which are typically fine and dry, can also exhibit unique flow characteristics due to two-phase flow of interstitial gas and solid particles as the powder compresses and expands during flow in a bin. Flooding, which is defined as a high uncontrolled discharge, can occur when the desired flow rate is too high to allow the entrained gas to escape or due to a collapsing rathole. This results in an aerated powder, which behaves like a fluid and flows uncontrollably through the bin outlet. This uncontrolled discharge can result in substantial dust generation and a fluid-like ability to leak through any inadequately sealed system.

These flow problems have the potential to generate dust, and in addition can result in a loss of valuable

production time, and excessive maintenance and housekeeping costs. A detail discussion of flow problems and their effects has been presented in the literature.<sup>7</sup>

### **Powder Segregation and Effect on Dust Generation**

When handling a blend or mix of metal powders, or when a metal powder itself has a significant particle-size distribution, the particles can separate by size during handling. This can lead to the formation of zones with a high concentration of fine or coarse particles. This is known as powder segregation, which causes fines to accumulate and discharge from the handling equipment in a slug. This dust may become airborne due to the various reasons cited, resulting in greater dust generation.

A number of different mechanisms can impact a powder blend or mix and result in segregation. However, three of these mechanisms are most common: sifting, fluidization, and dusting segregation, Figure 7. *Sifting segregation*, which is a process by which smaller particles move through a matrix of larger particles, is a common method of segregation. When a powder blend or mix is filled in a hopper, the fines in the blend or mix tend to concentrate below the fill point whereas the coarse roll to the periphery creating a horizontal separation of the coarse and fine particles. If such a blend or mix discharges in funnel flow, a concentration of fines will come out first and can result in dust generation. Segregation may also significantly impact product quality and handleability. For sifting segregation to occur, all of the following conditions must exist: (a) there must be a difference in particle size between the individual components of blend or

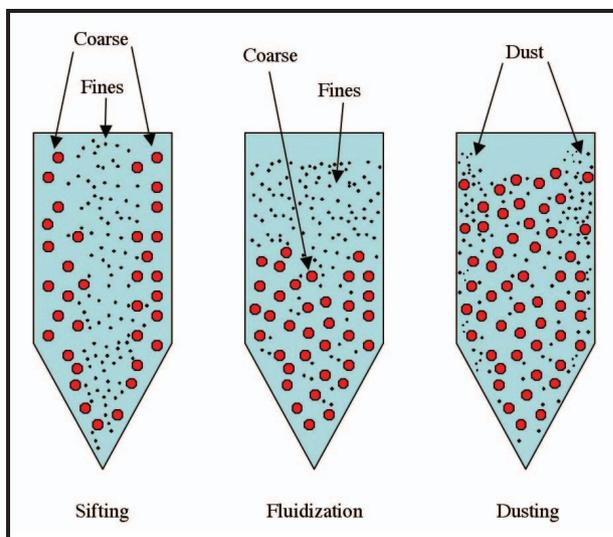


Figure 7. Common segregation mechanisms

mix, (b) mean particle size should be sufficiently large (typically,  $>50\ \mu\text{m}$ ), (c) the powder must be free flowing, and (d) inter-particle motion must be present.

*Fluidization segregation* can cause vertical separation, i.e., horizontal layers of fines and coarse material. Fine powders generally have a lower permeability than coarse materials and therefore tend to retain air longer. Thus, when a bin is being filled the coarse particles are driven into the bed while the fine particles remain fluidized near the surface. Fluidization segregation is also likely to occur when filled/discharged at high rates or if gas counter-flow is present. Fluidization often develops in materials that contain a significant percentage of particles  $<100\ \mu\text{m}$  in size.

*Dusting segregation* involves airborne particles, differences in settling velocities between particles, and air currents to cause movement of suspended particles. This mechanism can occur when powder is dropped and impacts onto a pile surface, causing the release of finer particles into the air.

All these segregation mechanisms increase the potential for dust generation by concentrating fines (dust) in the powder. Even though the original powder may not be expected to contain significant dust, segregation causes separation of dust/fines. This dust can accumulate in stagnant regions in a funnel flow bin and can come out towards the end in a large concentration, creating a greater possibility of a dust cloud. For further information on segregation, readers are referred to other publications.<sup>8</sup>

### **Good Handling-System Design Principles**

For reliable powder storage and handling, the geometry and material of construction of the system's components must be designed to suit the flowability of the powder. The flowability of a powder is influenced by relative humidity/moisture content, storage time at rest, temperature, and fines content, among other things. Hence, to design for reliable flow, the flowability of the given powder must be determined under representative handling conditions by conducting flow-properties tests.<sup>9</sup>

The information obtained from flow tests can be used to design a new powder storage/handling system to achieve reliable flow and smooth discharge or to modify an existing storage/handling system that is experiencing flow issues and resulting in dust generation. Selecting the appropriate flow pattern is critical for a reliable storage system. Mass flow is important to obtain a smooth, non-pulsating discharge without flow problems. Use of mass flow also results in mixing of powder in the center with that in the periphery, thus remixing horizontally separated fines and coarse particles, and reducing segregation. The design parameters

for mass flow are obtained from flow-test results.

In addition to bin design, feeder design is also critical for ensuring reliable and smooth flow. The feeder below the bin must be designed to activate the entire bin outlet. If the feeder fails to do so, stagnant material occurs in partial outlet areas. This stagnant material at the outlet causes a much larger region of material to remain stagnant above it. Even if the bin is designed to achieve mass flow discharge by itself, an improper feeder design will cause the bin to discharge in funnel flow. Hence, a properly designed feeder that provides an increasing capacity in the direction of feed is necessary to withdraw material uniformly from the entire outlet area. The type of feeder most suited for a given application depends upon the flow characteristics of the powder, and site-specific requirements such as powder-handling conditions, available space, and flow-rate control. More information on feeder design and selection has been presented elsewhere.<sup>10</sup>

For proper design of powder-transfer points, it is imperative to analyze the velocity of the flowing stream at various points along the transfer-chute surface. The velocity must be controlled to produce a stable, concentrated powder stream. In addition, momentum must be conserved in order to provide a smooth transfer of powder throughout the chute. The key to a proper chute design is to avoid an abrupt unintended loss of energy from the stream by reducing impact, minimizing changes in its direction, and gently capturing and guiding the powder stream. Zones of free fall should be minimized to avoid entraining dust into the surrounding air. A further discussion on chute design is published elsewhere.<sup>11</sup>

### **PREVENTION OF METAL DUST HAZARDS—GOOD DUST COLLECTION SYSTEM DESIGN**

Dust collection systems must be provided in the plant wherever the potential for dust generation exists. The dust-laden air collected by such systems must be handled to safely separate the dust from the air/gas stream. It can be accomplished in a number of ways ranging from inertial separation, where the dust settles by gravity, to pulse-jet cleaned fabric filters. In many dust-collection systems, separation actually occurs by a combination of inertial separation and filtration. Since many of the powders conveyed consist of a range of particle sizes, the larger particles separate as the air stream enters the receiver and the smaller particles are separated at the filter surface.

The selection of a gas-solids separator should be based on the material characteristics (particle size, temperature, abrasiveness, friability, cohesiveness, etc.), degree of separation required, environmental regulations, the concentration of dust and cost.

## UNDERSTANDING AND PREVENTING METAL-DUST HAZARDS

Separation efficiency strongly depends upon the type of separator utilized. Reverse pulse-jet fabric filters are known to be the most efficient at collecting fine particles, while cyclones and inertial collectors are the least efficient.

In powder-filling applications using pneumatic conveying, where material is delivered to several bins, it is not uncommon to use an inertial or cyclone separator at each delivery point and direct the conveying air to a single fabric filter (often called a baghouse). This is more economical than providing a fabric filter at each delivery point. However, it does allow for cross contamination between the receiving bins, as well as the need for an additional step of handling the very fine particles from the filter.

A baghouse typically contains a collection of long, narrow filter bags that are suspended in a large enclosure. A filter bag is fabricated from woven or felted synthetic fabric, typically formed as a tube. As dust-laden gas enters the baghouse and passes through the filter bags, particulates collect on the fabric surface of the bags. Beneath the filter bags is a hopper, which gathers the dust particles separated from the air stream. Over time, accumulation of dust causes the pressure drop across the fabric to rise, and the filter media must therefore be cleaned periodically either by shaking or utilizing a reverse gas-flow high-pressure pulse.

Dust particles dislodged from the filter fall into a hopper located beneath the filter bags. Collectors of this type generally operate as chutes, i.e., they are not designed to fill up with powder. Proper chute-design principles should be used to design such hoppers. If, on the other hand, the dust collector has potential for

dust accumulation, it must be designed using proper bin-design principles described earlier in this article. A properly designed feeder must be provided beneath the hopper to ensure that the entire outlet is active and material discharge occurs smoothly without any stagnant material formation.

Further information about dust-collection system design can be found elsewhere.<sup>12</sup> In addition to ensuring that dust collectors are designed to achieve reliable, smooth discharge, they must be designed in accordance with guidance included in a fire code published by the National Fire Protection Association.

### USEFUL RESOURCES

Table I provides a list of additional resources for readers interested in more information on this topic.

### CONCLUSIONS

The hazards posed by metal dusts are real. Recent incidents have shown that improper handling of metal dusts can cost lives. Apart from this, inappropriate metal-dust handling poses health risks, property damage possibilities, and housekeeping/maintenance costs. The key to reducing metal-dust hazards is to first minimize dust generation whenever possible. For the dust that is generated, safe and proper containment and capture follows. The proper design of powder storage and handling systems is quintessential in this regard. For the dust that still manages to find egress from the main process and accumulate, effective housekeeping and maintenance becomes the next line of protection. Also, it is important to perform site assessments for dust-hazard potentials and implement strategies to minimize the risks.

Training employees as well as management in this area is a crucial first step. All of these prevention measures then need reasonable response measures for protection in the unlikely event of a release which would then include explosion and fire suppression systems, oxygen reduction or inerting, ignition source(s) elimination, and PPE. The purpose of this article is to provide information and education on understanding and preventing metal dust hazards.

### REFERENCES

1. "Hazard Prevention and Control in the Work Environment: Airborne Dust", World Health Organization, WHO/SDE/OEH/99.14, Geneva, August 1999.
2. Information from the website of U.S. Chemical Safety and Hazard Investigation Board (CSB), <http://www.csb.gov/csb-determines-fatal-2003-incident-at-hayes-lemmerz-plant-in-indiana-most-likely-caused-by-explosion-in-dust-collection-system-company-did-not-identify-or-control-hazards-of-aluminum-dust/>
3. Information from the website of U.S. Chemical Safety and Hazard Investigation Board (CSB), <http://www.csb.gov/csb->

**TABLE I. RESOURCE INFORMATION ON DUST HAZARDS**

Resource	Information
Hazard communication guidance for combustible dusts, OSHA 3371-08 2009	Information about identifying and controlling the potential for dust explosions
NFPA standard 484	Information on metal dust hazards
NFPA standard 480	Information on magnesium dust hazards
NFPA standard 481	Information on titanium dust hazards
NFPA standard 482	Information on zirconium dust hazards
NFPA standard 485	Information on lithium dust hazards
NFPA standard 70	National electric code
NFPA standard 499	Information about classification of combustible dusts
NFPA standard 68	Information about deflagration venting systems
NFPA standard 69	Information about explosion prevention systems
NFPA standard 91	Information about exhaust systems

[releases-final-investigation-report-on-three-accidents-at-the-hoeganaes-iron-powder-facility-in-gallatin-tennessee/](#)

- Information from the website of ABC 4 news, <http://www.abc4.com/content/news/state/story/Tooele-County-burn-victims-improving-at-hospital/c65lgXA6B0m85xPDMPZ6hw.csp>
- "Combustible Dust in Industry: Preventing and Mitigating the Effects of Fire and Explosions", OSHA Safety and Health Information Bulletin, SHIB 07-31-2005
- "Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids", NFPA Standard 654, 2013.
- J.K. Prescott and R.A. Barnum, "On Powder Flowability", *Pharmaceutical Technology*, 2000, vol. 24, no. 10, pp. 60-84.
- J.W. Carson, T.A. Royal and D.J. Goodwill, "Understanding and Eliminating Particle Segregation Problems", *Bulk Solids Handling*, 1986, vol. 6, no. 1, pp. 139-144.
- A.W. Jenike, "Storage and Flow of Solids", *Bulletin 123*, Utah Engineering Experimental Station, November 1964.
- J.W. Carson, "Troubleshooting Problems with Three Common Feeders", *Powder and Bulk Engineering*, 2005, vol. 19, no. 12, pp. 19-26.
- G.J. Petro, T.J. Baxter and F. Cabrejos, "Chutes: The Ultimate Dust Control", *Powder and Bulk Engineering*, 2004, vol. 18, no.7, pp. 36-46.
- G.J. Mehos, "Designing Dust Collectors", *Chemical Engineering Progress*, 2011, vol. 107, no. 9, pp. 32-38. 

# It's A Matter Of Choice



CM Furnaces, long recognized as an industrial leader in performance-proven, high temperature fully continuous sintering furnaces for MIM, CIM and traditional press and sinter now **OFFERS YOU A CHOICE**, for maximum productivity and elimination of costly down time.

Choose one of our exclusive BATCH hydrogen atmosphere Rapid Temp furnaces. Designed for both debinding and sintering, these new furnaces assure economical, simple and efficient operation.

**OR...** choose our continuous high temperature sintering furnaces with complete automation and low hydrogen consumption.

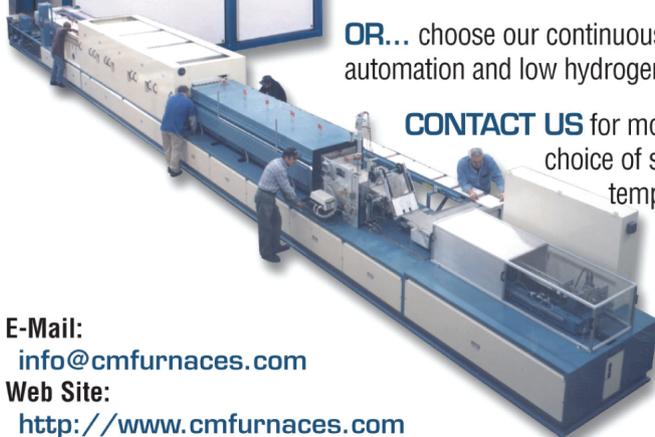
**CONTACT US** for more information on our full line of furnaces with your choice of size, automation, atmosphere capabilities and temperature ranges up to 3100°F / 1700°C.

E-Mail:

[info@cmfurnaces.com](mailto:info@cmfurnaces.com)

Web Site:

<http://www.cmfurnaces.com>



**CM**  
**FURNACES INC.**

103 Dewey Street Bloomfield, NJ 07003-4237  
Tel: 973-338-6500 Fax: 973-338-1625