SECTION 4

DUST MANAGEMENT

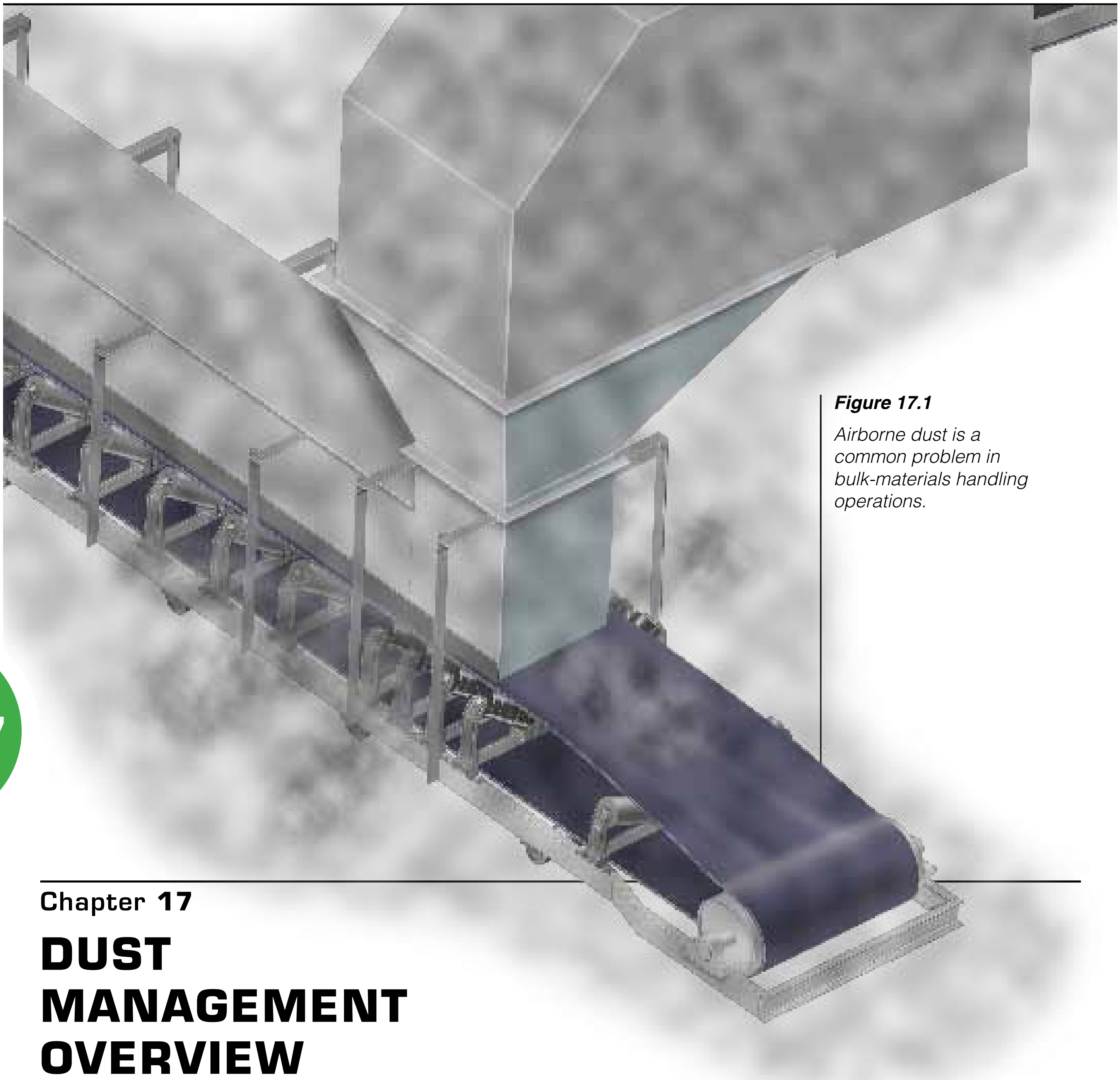

Figure 17.1
Airborne dust is a common problem in bulk-materials handling operations.

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Chapter 17

DUST MANAGEMENT OVERVIEW

In this Chapter…

This chapter defines dust and provides an overview of the topic of dust management. It examines problems associated with dust, including fire and explosions; methods of measuring dust; and methods for minimizing and managing dust. The following three chapters will provide more detail of specific areas of dust control.

Fugitive dust, finely divided materials that have become airborne, is becoming one of the greatest concerns of bulk-materials handling operations. Dust creates problems in the process, in the plant, in employee performance, in employee and community health, and in relations with the neighbors surrounding the plant. This heightened level of concern may be because dust is more visible from outside the plant than spillage. Spillage is more localized; it affects affairs inside the plant. A cloud of airborne dust rising from an operation's conveyors or crushers is visible to outsiders and can create problems in health, safety, neighbor relations, and regulatory compliance (**Figure 17.1**).

To successfully combat the growing nuisance of airborne dust, one must understand how dust is generated, what the consequences of dust are, what agencies are monitoring dust, how dust is measured, and what methods are available to combat dust. When both material spillage and airborne dust are controlled, the operation will be cleaner, safer, and more productive.

DEFINING DUST

Confining this Discussion

This book discusses the control of dust from conveying material or loading and unloading belt conveyors. Other industrial and material handling operations will create dust, including crushing, milling, machining, and truck hauling. Some of the issues and technologies discussed in this and the following chapters may be useful in understanding and controlling dust from these sources.

Solving the problems of dust is complicated by the nature of dust. The creation of dust has a significant number of variables that are regularly altered by changes in environment and materials. The variety of process designs and plant layouts, of production techniques and technologies, of system options and equipment choices, and of differences in conveyors and the materials conveyed will affect conditions and results. These differences might even be detected on a daily basis within a single operation. Thus, the information presented here cannot be considered absolutely applicable in all circumstances. Any application of this information must be carefully reviewed in light of the specific circumstances before options are selected and investments are made. The first step is to understand the nature of the problem before considering the specific options for a given operation.

The Definition of Dust

Dust is defined by the Mine Safety and Health Administration (MSHA) in the United States as "finely divided solids that may become airborne from the original state without any chemical or physical change other than fracture."

This is a complicated way of saying dust is "material that, when disturbed, can take to the air and stay there." While it is nice to say that all disturbances can be eliminated, bulk-material industries are full of disturbances. Examples include, but are not limited to, a solid lump of material broken by impact, crushing, abrasion, or grinding; material transferred from one belt, vessel, process, or container to another; or material agitated by wind, workers, or machinery.

The size of a particle of dust is measured in microns (μm). Micron is a shortened form of micrometer, a unit of measurement that is one-millionth of a meter. The equivalent in Imperial measurements is 1/25400 (or 0.0000394) of an inch. A human hair is typically 80 to 100 microns in diameter.

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Respirable dust is that dust which is small enough to enter the lungs when inhaled. The U.S. Department of Labor's Office of Occupational Safety & Health Administration (OSHA), in their handbook entitled Dust Control Handbook for Minerals Processing, defines respirable dust as follows:

> Respirable dust refers to those dust particles that are small enough to penetrate the nose and upper respiratory system and deep into the lungs. Particles that penetrate deep into the respiratory system are generally beyond the body's natural clearance mechanisms of cilia and mucous and are more likely to be retained.

Most regulating agencies define 10-microns or smaller as the size of respirable dust. According to OSHA, MSHA defines respirable dust as the fraction of airborne dust that passes through a 10-micron (3.28 x 10^{-5} ft) size-selecting device (sieve) (**Table 17.1**).

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CONSEQUENCES OF DUST

Unlike material spillage, which generally stays close to the point on the conveyor where the material is released, airborne dust affects the entire operation. Once dust is released into the air, it will settle wherever the currents of air take it. There are many dangers, expenses, inconveniences, and inefficiencies associated with airborne dust.

It is in an operation's legal and financial best interest to deal properly with dust.

When an operation violates a safety regulation, there are legal ramifications for the parties accountable (including personal culpability and possible financial liability for executives of operations where safety violations occur); therefore, there is a personal incentive to eliminate dust.

Health Risks

The greatest danger of dust is in the exposure of workers, neighboring homes, and businesses to dust. If the material is toxic, carcinogenic, or otherwise hazardous, having it airborne can endanger large numbers of people. In addition to the toxic dangers of materials, there is a respiratory danger presented by airborne dust. Once respirable dust is taken into the lungs, it might not be expelled. Prolonged exposure will lead to buildup of material in the lungs. Most regulating agencies define 10 microns as the size of respirable dust. When airborne particles 10 microns or smaller are inhaled, they will stay in the lungs; therefore, dust particles of 10 microns or smaller have a much lower allowable concentration. With toxic materials, the allowable concentration is even lower. In the United States, silica is normally regulated to the point where maximum allowable concentrations are below 2 milligrams per cubic meter (2.0 x 10^{-6} oz/ft^3) per eight-hour day. Many government and private agencies have deemed that continued exposure to concentrations higher than these will cause silicosis.

OSHA has determined admissible dust levels for the United States (**Table 17.2**). The levels determined by OSHA are representative of levels of regulation seen, and increasingly enforced, around the world.

Explosion Risks

Another danger of dust is its potential for explosion. Materials that obviously have this potential are coal and other fuels. Even materials that are not flammable in their bulk state can combust when airborne as fine dust. For example, aluminum dust is flammable.

Table 17.1 **Percentages of Particle Sizes Passing Through a 10-Micron Size-Selection Device**

Particle Size (μ)	10,0	5,0	3,5	2,5	2,0
% Passing Sieve	0	25	50	75	90

There are five contributing components necessary for a dust explosion to occur. The first three form the "triangle" of components of any fire:

A. Fuel (ignitable dust)

B. Ignition source (heat or electric spark)

C. Oxidizer (oxygen in the air)

The final two components are required to create a dust explosion:

D. Suspension of the dust into a cloud (in sufficient quantity and concentration)

E. Confinement of the dust cloud

If any one of these components is missing, there can be no explosion.

Many businesses offer products and solutions to counter the requirements for explosion, but the control of ignitable dust will decrease the chance for explosion as well as increase the effectiveness of these products.

It is the responsibility of the plant owners and management to be aware of the explosive properties of material in its various states and to actively eliminate the potential for explosion.

Safety Risks

The control of dust and other fugitive material is a key issue in preventing employee accidents. At any operation where dust reduces visibility and accessibility, there is an increased risk of problems in the operation of heavy equipment or the movement of personnel. The presence of dust requires cleaning and placing plant personnel in the vicinity of conveyors and other process equipment, resulting in a higher risk of injury.

Airborne dust generally creates an unpleasant working environment. Workers will have higher morale and increased productivity if conditions where they spend their working days are not seen as dirty, unpleasant, and possibly unhealthy.

In some plants, workers must wear a respirator to work in the vicinity of dust-generating material-handling systems. This increases the safety hazard due to impaired visibility, and it adversely affects morale. In addition to the dust problem, the company is viewed as not concerned with the employees' health and well-being, as they are forced to work in an environment that is possibly hazardous and certainly uncomfortable.

Table 17.2

Admissible Dust Exposure Levels per Eight-Hour Day per the Occupational Safety & Health Administration (OSHA) (USA)

Substance	Type	mg/m^3
Silca: Crystalline *Cristobalite: Use ½ the value calculated from the count or mass formula for quartz.* *Tridymite: Use ½ the value calculated from the formula for quartz.*	Quartz (respirable) Quartz (total dust)	$\frac{10\ mg/m^3}{\%SiO_2+2}$ $\frac{30\ mg/m^3}{\%SiO_2+2}$
Amorphous	Amorphous, including natural diatomaceous earth	$\frac{80\ mg/m^3}{\%SiO_2+2}$
Coal Dust	Respirable fraction < 5% SiO_2 Respirable fraction > 5% SiO_2	2.4 mg/m^3 $\frac{10\ mg/m^3}{\%SiO_2+2}$
Inert or Nuisance Dust	Respirable fraction Total dust	5 mg/m^3 15 mg/m^3

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NIMBY and Neighbor Relations

In the "old days," the accepted excuse for visible signs of a plant's presence, like dust and odors, was that those were signals that the plant was "making money."

That is no longer true. Now, the "Not In My Backyard" syndrome—sometimes shortened to the acronym "NIMBY"—is stronger. Environmental groups are more organized. No one wants their property values impaired by the outputs of an industrial operation. Community groups are more likely to complain to, and seek support from, stockholders, environmental groups, and regulatory bodies. The need to expand an operation, such as an aggregate plant, often brings about lengthy and often contentious permitting hearings.

One solution for the increasingly-cumbersome permitting processes is for the operation to maintain good working relations with the communities in which they operate. Efforts like community donations, open houses, and plant tours work to showcase the operation and demonstrate the value the plant provides and the efforts it is making to be a good neighbor.

Those efforts can go for naught if dust clouds rise from operating equipment on a regular or even periodic basis.

Regulatory Agencies

In addition to the health and explosive dangers of dust, an operation has to be conscious of the visual nature of dust pollution. It is becoming increasingly common for industries that produce dust to be inspected and fined because of the visual pollution to surrounding homes and businesses. It is much easier to spot a dust plume from a distance than spillage. For this reason, a bulk-materials operation must be aware of the enviro-political climate in the area in which they are operating.

Regulatory agencies are empowered to protect the health of workers and others; accordingly, they will monitor and review dust-level results. Agencies will also act in the interest of other parties, including neighbors concerned about protection of their property and groups concerned with the overall environment. In addition, they are susceptible to pressure from interest groups and the media.

As a result, many companies and/or individual operations control the discussion of their regulatory limits and test results. Management does not want this information discussed outside the plant, because the results are "bad," the data is subject to misinterpretation by outsiders, or the discussion points out that dust is an issue for the facility.

Mention must also be made of other regulatory agencies, which, while not formally responsible for regulating airborne dust, are responsible for other aspects of the governmental control of industrial operations, such as land use permits and zoning. These regulatory bodies are subject to, and vulnerable to, outside influences including neighborhood residents, owners (and/or potential developers) of adjacent tracts of land, and environmental interest groups.

Problems in the Process

In addition to the environmental, safety, and health issues discussed above, there are a number of reasons to control fugitive dust in order to improve the process internally.

Dust affects the quality of an industrial operation and its output. It contaminates the plant and possibly even the finished product. Dust will settle on sensitive instruments and sensors, impairing the instruments' ability to monitor a process and confusing the data supplied to the operators. In some industrial operations, such as iron-ore sinter and pelletizing plants, material dust in the process is a contaminant that adversely affects results.

Another danger of airborne dust falls into the category of property damage. If a material is corrosive, so is the dust. As airborne dust settles on every surface within an operation, there is the potential for massive damage due to operation-wide corrosion. Airborne dust will be pulled into the air intakes on motors and pumps, leading to premature failure of this critical and expensive equipment.

Dust represents a loss of valuable material, a material that has been paid for and, in many cases, has had some level of processing applied to it. Fugitive dust represents a lost opportunity for profit. In some plants, the airborne dust will have higher concentration of the operation's target mineral than the general body of material. Dust at large precious-metal mines was found to have more gold and copper than the raw ore, with concentrations increased from 25 to nearly 100 percent. The recovery of this valuable dust offers a significant payback on the investment in dust-control systems.

Dust also increases the amount of maintenance work required. It consumes labor man-hours of plant personnel, adding expense and distracting workers and managers from other responsibilities. It is important to take into account the extra man-hours needed to clean up areas where dust settles. Spillage falls below a conveyor; in contrast, dust will settle all over a plant, including elevations well above the dust's release point.

Fugitive dust can affect a plant's production capacity by reducing the availability of conveyors and equipment due to accidents, extra required maintenance, and downtime for cleanup.

MEASUREMENT OF DUST

Proper dust studies are needed to evaluate an operation's compliance with regulations as well as the effectiveness of its dust-control measures. The method of dust sampling is specific to the region and the agency doing the survey. More popular sampling methods include personal dust samplers, location-specific dust samplers, visual opacity readings, and handheld electronic dust-measuring devices. Those sampling methods are discussed below.

Personal Dust Sampling

The exposure of a worker to a concentration of dust can best be measured with a personal dust sampler (**Figure 17.2**). This is a small vacuum pump attached to a tube which is connected to the worker's collar or neck. The worker wears the sampler throughout the course of the workday. At the end of the shift, the amount of dust captured by the sampler is weighed. This weight is divided by total airflow the pump has pulled throughout the day and the time in operation to determine a concentration of dust in the air. This repeatable methodology is useful in determining the amount of dust in the air and the size of the dust particles, as well as measuring an individual's exposure to a dust hazard. Real-time particulate monitoring devices are also available.

Basic Location-Specific Dust Sampling

Basic location-specific dust sampling is usually completed by placing many pans or containers in a dusty area and leaving them for a specific period of time (**Figures 17.3** and **17.4**). The amount of dust that settles into the containers is weighed. This sampling is normally done before and after a dust-control solution is implemented.

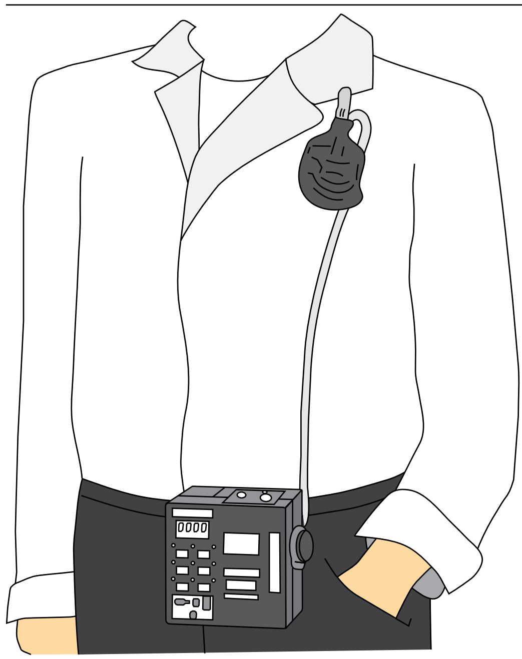

Figure 17.2

Worn by a worker, a personal dust sampler will determine the individual's exposure to airborne dust.

These two values are compared to assess the relative effectiveness of the dust-control measure. While this is a basic and intuitive method to measure the effectiveness of a system, it does not provide any information about the concentration of dust in the air or the size of the dust particles. It should be noted that this type of sampling measures not the content of the dust in the air, but rather the amount of dust that settles in the place where the pans are located. The results can be affected by air currents above the pans.

Figure 17.3

The pans on the floor around this conveyor tail have been placed to collect samples of the dust in this location.

Advanced Location-Specific Dust Sampling

Advanced location-specific dust sampling is a combination of the personal dust sampler and the basic location-specific dust sampler in that it uses a vacuum to capture air (**Figure 17.5**). The sampling device is placed in a fixed location for a given amount of time. The method used to analyze the concentrations is similar to basic location-specific sampling, but these systems can be much more accurate and controlled. The results can be output to a computer or some other monitoring device, allowing readings to be taken remotely.

Another version of the location-specific dust sampler is the microwave opacity tester. This device operates by releasing light or microwaves into an air stream. The light or radiation is deflected or absorbed by dust in the air. The energy is measured across the air stream, and the amount of dust can be calculated from this value by measuring the difference in the strength of the signal sent and the signal received (**Figure 17.6**). More elaborate equipment can be utilized to measure the size of the particles. While this equipment is very accurate, it tends to be expensive and not

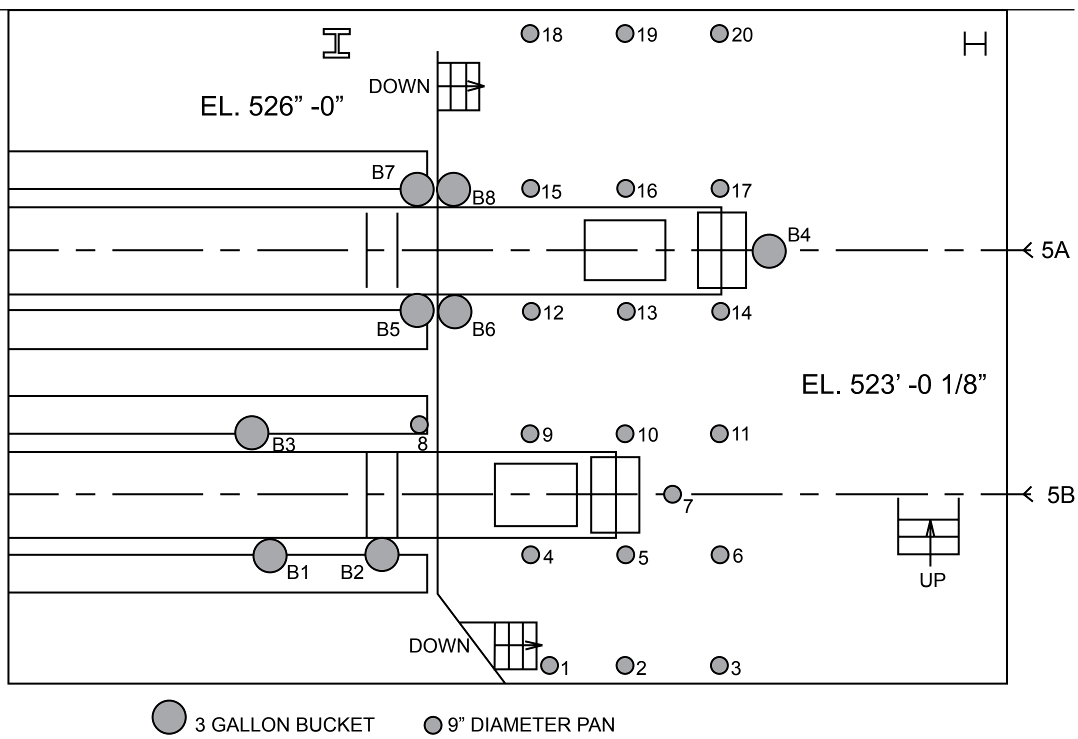

Figure 17.4

This drawing shows the plan for collecting the dust and spillage around the tail pulleys of two conveyors.

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portable. This type of sensor would be employed by an operation to monitor a particular piece of equipment.

Visual Opacity Readings

A visual opacity reading is performed by a trained licensed inspector who observes the area for a set amount of time and documents the amount of visible dust in the air. While this method has been accused of being subjective, it is thoroughly regulated and generally accepted among environmental protection agencies in the United States.

Handheld Electronic Dust-Measuring Devices

Technology is always striving to make the "higher technology" (more scientific) methods of dust measurement more portable. Handheld devices can measure concentration, dust size, and many other properties of dust. As technology advances, these devices will become less expensive and more commonly seen in the field (**Figure 17.7**).

Standard Testing Methodologies

As the dust-measurement methodologies vary from region to region and application to application, it is in an operation's best interest to know who will be measuring their dust and what method they will be using. A number of national and international organizations have supplied standardized procedures for measuring dust. Some examples are listed below:

A. ASTM International (ASTM)

ASTM D4532-97 (2003) *Standard Test Method for Respirable Dust in the Workplace Atmospheres*

ASTM D6552-06 *Standard Practice for Controlling and Characterizing Errors in Weighing Collected Aerosols*

B. Deutsches Instit für Normnug (DIN-European Union)

DIN/EN 481 *Workplace Atmospheres: Size Fraction Definitions for Measurement of Airborne Particles*

C. International Organization for Standardization (ISO)

ISO 20988 *Air Quality—Guidelines for Estimating Measurement Uncertainty*

ISO 7708 *Air Quality—Particle Size Fraction Definitions for Health-Related Sampling*

ISO 12141 *Stationary Source Emissions—Determination of Mass Concentration of Particulate Matter (Dust) At Low Concentrations*

Consultation with standard organizations such as ISO, ASTM, and regulatory agencies for specific regions is advised to determine the current regulations and accepted testing methods.

Figure 17.5

This advanced location-specific dust-sampling system uses a vacuum to pull in dust-laden air.

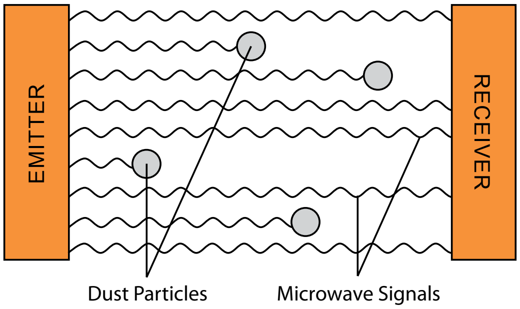

Figure 17.6

The microwave opacity tester uses the difference in the strength of the signal sent and the signal received to determine the amount of dust in the air.

Figure 17.7

Handheld devices can now measure the concentration and size of dust.

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METHODS OF DUST MANAGEMENT

Minimizing the Creation of Dust

Airborne dust is created whenever a dry material is moved, manipulated, and subjected to air currents strong enough to raise or redirect the small particles within the body of material. One of the most common circumstances in which this occurs is conveyor transfer points where loading, unloading, or transit of the material creates air currents that carry the dust away from the material-handling system.

Dust emissions in conveying can be significantly reduced with an engineered transfer system, an effective sealing system, the addition of a dust-suppression system, and/or the use of an effective dust-collection system.

The first consideration in dust control should always be the minimization of the amount of dust actually created. While it is unlikely dust can be completely eliminated, any change in system design or production technique that will reduce the amount of dust produced should be considered. For example, if the energy released by the falling stream of material at the impact area can be reduced, then less energy will be imparted to the material, and fewer dust particles will be created or driven off. Consequently, it is best to design conveyor systems with minimal material-drop distances.

This type of improved engineering can be undertaken as a retrofit, or it can be considered at the initial plant-design stage. Methods to reduce the dust created through better engineering include, but are not limited to:

A. Shortening drops between conveyors

B. Loading material in the same direction as the receiving belt is moving

C. Avoiding drastic changes in material trajectory

D. Maintaining a cohesive material stream while controlling the flow of air into and out of the transfer point

These methods can be achieved through a combination of proper conveyor layout and creative design of conveyor transfers. For example, an engineered chute incorporating a "hood and spoon" can be of great assistance in achieving these methods. Other engineering improvements are available to make dramatic reductions in the creation and release of airborne dust. The success of these improvements can eliminate the need for, or greatly reduce the size and costs of, dust-collection and dust-suppression systems. *(See Chapter 7: Air Control and Chapter 22: Engineered Flow Chutes.)*

Three Ways to Control Dust

If an operation cannot prevent dust from becoming airborne, it must find ways to control it. Control can be accomplished by containing, suppressing, or collecting airborne particles. Before a dust-control system is selected, it is necessary to understand the contributing factors that create airborne dust.

The conditions that determine whether fine materials become airborne are air velocity, particle size, and cohesion of the bulk material. These characteristics contribute to the amount of dust generated by the following intuitive, relative relationship: The amount of dust generated is proportional to air velocity as divided by the factors of particle size and material cohesiveness (**Figure 17.8**).

This relationship emphasizes three important principles that can be utilized to control dust:

A. Dust creation can be minimized by lowering the air velocity around the bulk material.

$$\text{Dust Generated} \propto \frac{\text{Air Velocity}}{\text{Particle Size} \bullet \text{Cohesiveness}}$$

Figure 17.8

Relationship in Creating Airborne Dust.

B. Dust creation can be minimized by increasing the particle size of the bulk material.

C. Dust creation can be minimized by increasing the cohesiveness of the bulk material.

Where one or more of these characteristics is a given, the ability to control dust depends on altering one or both of the other characteristics. For example, where the size of coal particles being transported cannot be changed, the air velocity or cohesive force of the particles must be altered to minimize dust emissions. Many dust-control systems combine several of these principles.

Minimizing Air Velocity

The easiest and most effective method to control dust is to minimize air velocity. Dust particles are heavier than air, and they will settle out if given still conditions and enough time. By reducing air velocity, particles have a chance to fall back into the material stream. Dust travels in the air stream, so it stands to reason that if air is controlled, dust can be managed.

Perhaps the earliest (and easiest) dust-control technology is simply to enclose the airborne dust (or the dust-generating location/operation) so the dust particles have the opportunity to settle before being carried outside the area. This is a method of minimizing air velocity, and thus preventing the pickup of fine particles from a body of material. As the enclosure volume increases, the velocity decreases, allowing the airborne particles to drop from the air.

An effectively-designed transfer chute reduces the air velocity by minimizing air drawn into the transfer point, sealing the leaks that allow dust-bearing air to escape, and allowing the dust time to settle out of the air. The traditional transfer-point enclosure is the most common method used to combat dust. The advantage of the traditional steel chutework is that it is rigid, permanent, and can completely enclose the transfer point. This makes it the ideal candidate for an upgrade to any transfer point. Even a basic technique, such as the installation of dust curtains at the exit end of the chute, is one method to slow air movement.

An effective enclosure can theoretically be put on any transfer point. However, in some operations rigid, permanent, completely enclosed transfer points cannot be used, so the equipment cannot be enclosed. For example, many sand and gravel operations require equipment to be mobile, so a fixed transfer chute is undesirable. Other operations may need to visually monitor a transfer point, so a completely enclosed chute would not be suitable.

Increasing Particle Size

If enclosing the transfer point is not an option, then increasing the size of the particles of dust to make them heavier and more prone to dropping from the airflow may be the solution. Increasing the size of the particles of dust will make the dust particles heavier. A heavier particle will not be so easily picked up by air movement, and it will fall out of the air more readily when air velocity slows. A heavier particle also will have more momentum, so it will not be as affected by shifts in airflow.

Dust-suppression systems are generally based upon the principle of increasing dust particle weight to improve dust control and return the particles to the main material stream. These systems increase the weight of airborne dust particles by combining the particles with drops of water (or with a water-and-chemical solution). The wet, and now heavier, dust particles fall back into the material stream before they can escape into the atmosphere.

It is relatively difficult to capture dust particles once they have become airborne. Fog dust-suppression systems specifically target dust in this difficult state. *(See Chapter 19: Dust Suppression.)* A fog system needs time and relatively undisturbed space to bond with airborne dust particles. This necessitates an enclosed transfer point and relatively slow moving air. Fog systems are

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more successful when the dust particles and water droplets are of similar size. To achieve the small water-droplet size necessary to match the small particles of airborne dust, the water must be pumped at high pressure through atomizing nozzles or atomized with air. Both methods for making small water droplets to match small particles are expensive and complicated.

Dust collection is also used to increase material size. This method uses a vacuum to pull the air (and the dust it carries) out of the material-handling system. The dust agglomerates to itself or on the surface of the filter system and is then collected at a central location or deposited back onto the belt with the use of local collectors. *(See Chapter 20: Dust Collection.)*

Dust-collection systems require the enclosure of the transfer point(s) and a substantial amount of overhead space. Such systems do nothing to reduce the material's potential to create dust: When the material is agitated at the next transfer point, dust must be dealt with again.

Increasing Material Cohesiveness

The final common method used to minimize dust is to increase the cohesiveness of the material; that is, the material's "desire" (or ability) to stick together. The properties of the material must be altered in order to increase its ability to stick to itself. A real-life example of improved cohesiveness would be beach sand versus desert sand. Both types of sand have approximately the same size particles in solid form. Desert sand does not stick to itself; the particles can easily fracture off and become airborne as dust. The added moisture content of beach sand increases cohesion; the particles will stick together and not become airborne when the material is dropped.

A simple way to increase cohesiveness is to introduce water or another binding agent to the material. Care must be taken when applying moisture to a bulk material. If water is applied to the top of material lying on a pile or a conveyor belt, it will wet only the outside of the material. When this material is disturbed, by being reclaimed from a stockpile or by traveling through a transfer point, the particles are rearranged and dry surfaces are exposed to the air. Dust can then be released from these dry surfaces. The ideal application point for moisture addition is when the material is in free fall. This allows the water to penetrate the material and contact more of the material's surface.

The advantages of the application of water include the residual effect of the dust suppression. A wet material will retain its elevated cohesion level (and hence, the inability to generate dust) for as long as the material remains wet.

A disadvantage of the application of water is the large amount of water required to thoroughly wet most materials. The drawback is that, because wet material sticks to itself and system components, the moisture can create problems, including the blinding of screens, the plugging of chutes, and the carryback of material on the belt. Even the efficiency of a crusher is reduced with wet material. When designing a material-handling system or considering suppression as a solution for dust problems, the effect of added moisture must be considered.

Another concern of applying water is the added performance penalty that comes from wetting down a product that must be heated or burned. Individual operations must decide if the cost of fugitive dust is greater than the thermal penalty of suppression. An additional issue is that some materials, such as cement, cannot be exposed to water. A thorough understanding of an operation's material and process is required before a suppression system is selected.

One method to minimize the amount of water required for dust suppression is to improve the water's ability to wet the material with the addition of a surfactant to the water supply. The solution of water and chemical is then applied as a spray or foam. The addition of a surfactant will minimize the amount of water necessary to do the job, but it increases operating costs. *(See Chapter 19: Dust Suppression.)*

REDUCING THE RISK OF FIRE AND EXPLOSION

Risks of Fire and Explosion

As evidenced by silo explosions in the grain-handling industry, dust explosions are very powerful and a very real risk. Consequently, extreme care must be taken to minimize this risk. For many dusts, a settled layer as thin as the thickness of a paper clip—only 1 millimeter (1/32 in.)—is enough to create an explosion hazard. A 6-millimeter (1/4-in.) layer is a bigger problem—big enough to destroy a plant.

For there to be a dust explosion, these factors need to be present: a confined combustible dust at the right concentration, a gas that supports ignition, and an ignition source. Many fine dusts, including chemicals, food products, fertilizers, plastics, carbon materials, and certain metals, are highly combustible, the first requirement for a dust explosion. By nature, any dust-collection device contains clouds of these fine particles suspended in air, which itself is a gas that supports ignition, the second requirement.

In any mechanical material-handling operation, there are a number of possible ignition sources, the third requirement for a dust explosion:

A. Mechanical failures that cause metal-to-metal sparks or friction
B. Fan blades that spark when they are struck by a foreign object
C. Overheating from a worn bearing or slipping belt
D. Open flames from direct-fired heaters, incinerators, furnaces, or other sources
E. Welding or cutting causing a point-source ignition or a hot-particle dropping (perhaps several floors) to a flammable atmosphere
F. Static electricity discharge
G. Migration of flammable dust into the hot region of a compressor or catalytic reactor

Categorizing Dust Explosions

There are several ways to look at dust-related conflagrations:

A. Flash fire

A flash dust fire is the sudden ignition of unconfined dust. A flash fire is usually localized and can cause significant damage or injury. A flash fire can create the conditions for a secondary explosion, which can cause catastrophic damage and fatal injuries.

B. Explosion

When dust is confined and ignited, an explosion is created. This rapid explosion of gases will generate significant and destructive over-pressures that can even demolish the building, leading to greater damage and injury.

C. Primary or secondary

An initial or primary explosion can cause secondary explosions by disrupting, dispersing, and igniting new sources of dust removed some distance from the original blast. Secondary explosions can be more destructive than the primary explosion, and every explosion can lead to additional secondary explosions.

D. Magnitude

The speed and force of an explosion are direct functions of a measurable characteristic called the deflagration index. Dust explosions can be more hazardous than explosions caused by flammable gases.

Control Mechanisms

Where the ingredients—confined combustible dust at the right concentration, ignition-supporting gas, and an ignition source—are present, precautions must be taken to avoid an explosion.

These precautions include:

A. Inerting

The addition of an inert gas (typically nitrogen or carbon dioxide, rather than air) into the collector

B. Suppressing

Adding a suppressant material as explosive pressure starts to rise

C. Venting

Adding an explosion relief-panel or bursting membrane, which releases the explosion energy out of the enclosure

Proper grounding of the dust-control systems will help reduce the risk by increasing conductivity through the system, allowing static charges to leak into the ground.

It is advisable to consult with equipment suppliers to design dust-collection systems for handling potentially explosive dusts.

Venting

The theory behind explosion vents is simple. The vent is a deliberately weakened wall that will release early in the pressure rise created by a rapidly rising temperature. Once this weakened area is opened, the burned and unburned dust and flame can escape the confined area, so the vessel itself does not experience the full rise in pressure. If the release is early and large enough, the pressure will remain low inside the vessel to protect it from damage. However, the fire or explosion can develop outside the vessel, and if dust is present, other equipment

SAFETY CONCERNS

As noted above, airborne dust is a safety issue in and of itself, but an operation must also be aware of the safety concerns associated with its dust-control equipment. In addition to the standard latent-energy risks associated with any piece of industrial equipment, a bulk-materials operation must be aware of the potentially explosive nature of its dust-control solutions.

If an operation is attempting to control dust to prevent an explosion, care must be taken to ensure the dust-control equipment has the proper hazardous-duty rating for the expected conditions. Any electrical enclosure or motor must be spark-resistant or rated for hazardous duty.

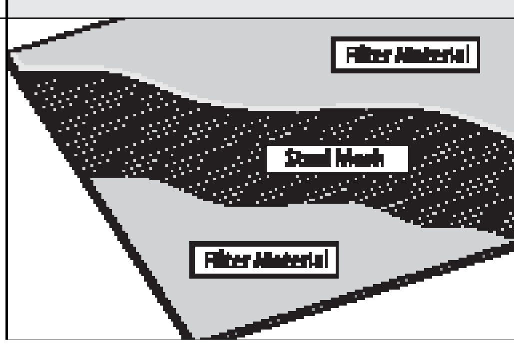

Figure 17.9

Dust collector filters should include a conductive thread woven into the filter fabric to carry any static buildup safely to ground.

When air moves through a filter media, the media develops a static charge. If the media is close to a grounded structural member, the static charge could discharge as a spark, possibly igniting any flammable dust in the air. Filter manufacturers have created media that dissipate a static charge through stainless steel mesh embedded in the filter material or through conductive carbon fibers woven into the material (**Figure 17.9**). These additions allow any charge generated by the airflow to move to the ground before it can spark. If a filter is used in an explosive environment, care must be taken to select static-discharging filter media.

The established safety procedures for entry into any confined spaces, including transfer-point enclosures and dust collectors, should be closely followed. Proper lockout / tagout / blockout / testout procedures must be completed and water, chemical, and electrical sources must be de-energized prior to performing maintenance on dust-collection or dust-suppression systems.

can be damaged, so venting systems do not eliminate the need for dust-control systems and high standards of housekeeping.

There are two types of explosion-venting devices. Rupture disks are thin panels that will open faster than other designs. They must be sized to withstand normal negative operating pressure—typically 2 to 3 kilopascals (0.29 to 0.44 lb_f /in.^{2})—yet rupture at a positive explosive pressure. A more widely used design is the spring-set door. This door—available in either hinged or unhinged designs—will vent (pop open) during a conflagration.

DUST-CONTROL SYSTEM MAINTENANCE

Adequate room for access and maintenance must be provided during installation of dust-control systems. The serviceability of a dust-control system must be considered when comparing systems prior to purchase. One dust collector may be less expensive than another, but the less expensive option may require a man lift and the removal of a wall to change a fuse, whereas the more expensive unit may have the fuses in an enclosure at ground level. It is in an operation's best interest to purchase a dust-management system that is maintenance-friendly. If a component causes a shutdown, every extra minute taken to repair that component affects the overall profitability of the facility.

Dust-control solutions are usually multiple-component systems that require multiple inputs. A dust collector typically requires electricity and compressed air; a foam-suppression system may need electricity, compressed air, water, and chemicals. With these elaborate systems, there are more parts that can wear out or break down. Particular attention should be paid

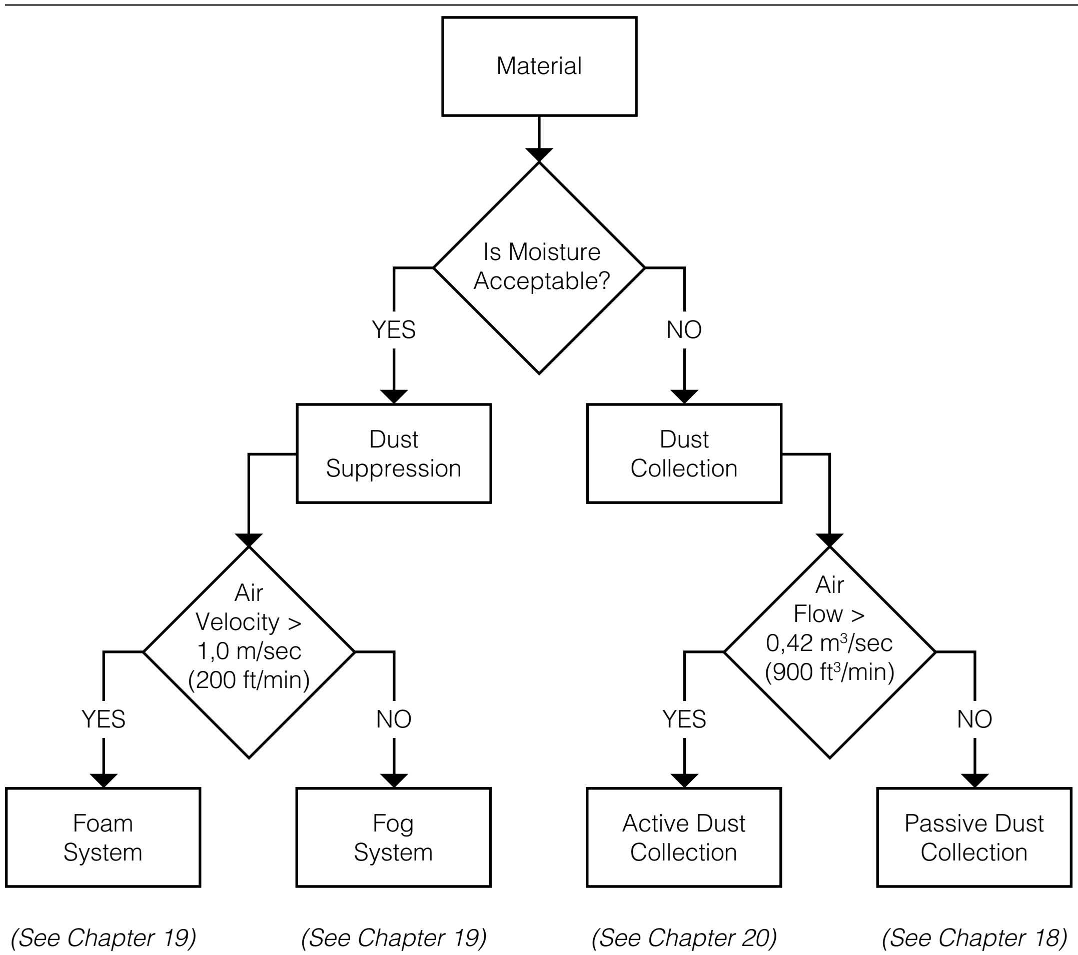

Figure 17.10

Dust-Management Selection Process Flow Chart

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to dust-control system(s) in the operation's scheduled maintenance cycles. The operation has to take ownership of the service requirement or delegate it to a contract maintenance service company.

DUST-MANAGEMENT SELECTION PROCESS

The selection of the best dust-management technology to match the requirements of a given operation begins with an understanding of the material and the dimensions of the conveyor transfer point. There is a simplified approach to making the determination of what systems would be appropriate (**Figure 17.10**).

APPLICATION-SPECIFIC DUST MANAGEMENT

In Closing...

Every industry has preferred dust-control methods that are determined by application preference and regulations in the industry or geographic location.

The systems to control dust include containment, suppression, and collection. These systems can be used individually or in combination. There are a variety of techniques and technologies available to accomplish any one of these methods of dust control.

To successfully combat dust, any bulk-materials handling operation must understand all aspects of its problem. These aspects include the consequences, the sources, the methods of measurement, and the methods of control. An operation must select the most appropriate solution based upon the needs of the operation and the limitations of the application. Whatever solution is selected, the operation must be conscious of the safety and maintenance requirements to keep its dust-control system operating efficiently.

Looking Ahead...

This chapter introduced the section Dust Management and provided an overview of the topic while explaining the importance of controlling dust. The following three chapters continue the discussion of dust management, looking at various aspects more in-depth: Passive Dust Control, Dust Suppression, and Dust Collection. If all of the pieces of the dust-management system fit together correctly, the operation will become cleaner, safer, and more productive.

REFERENCES

17.1 Conveyor Equipment Manufacturers Association (CEMA). (2005). *BELT CONVEYORS for BULK MATERIALS, Sixth Edition*. Naples, Florida.

17.2 Any manufacturer and most distributors of conveyor products can provide a variety of materials on the construction and use of their specific products.

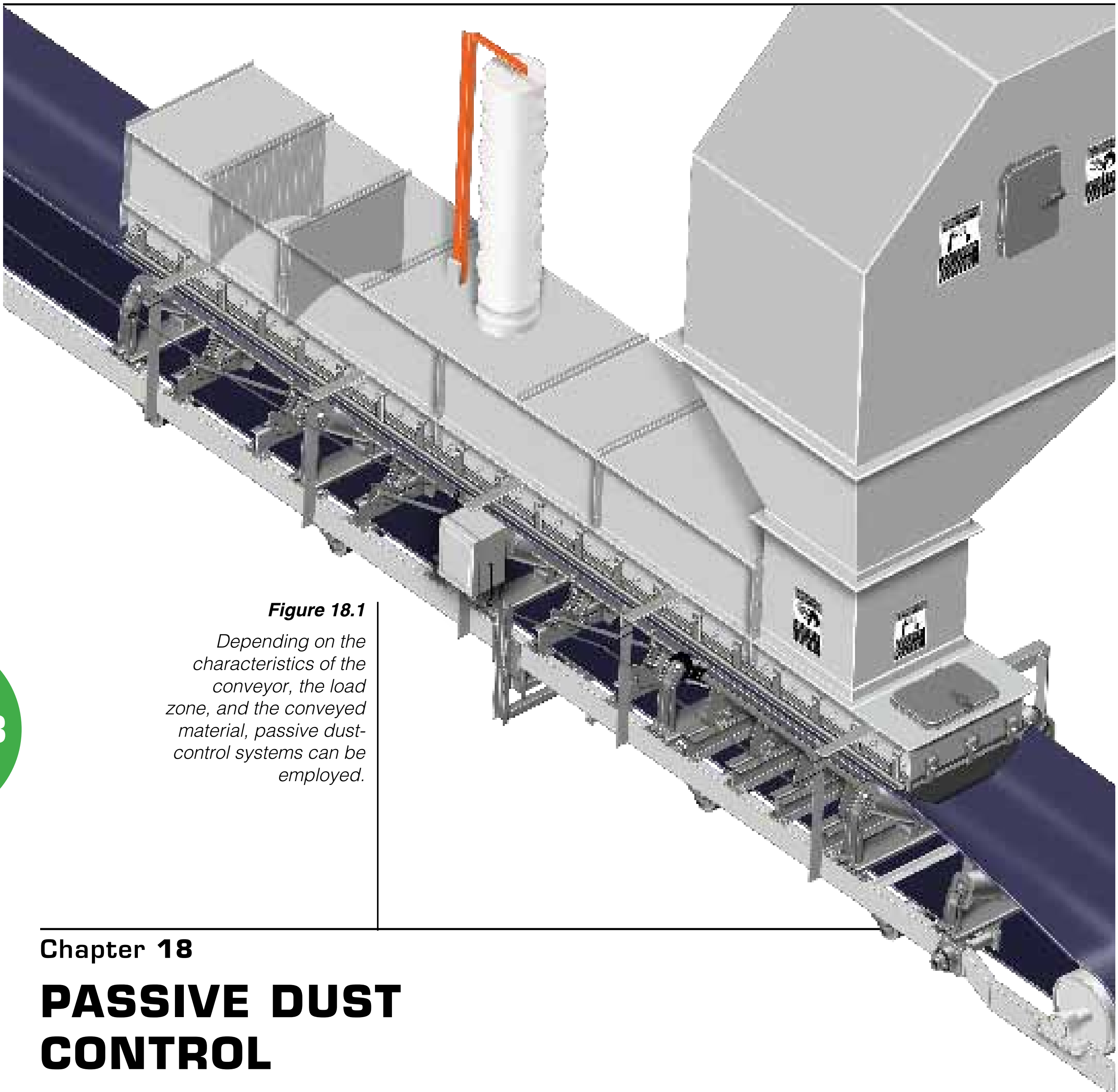

Figure 18.1

Depending on the characteristics of the conveyor, the load zone, and the conveyed material, passive dust-control systems can be employed.

Chapter **18**

PASSIVE DUST CONTROL

In this Chapter…

In this chapter, we discuss a variety of methods used for passive dust control that can be incorporated into initial conveyor design or added later as the need arises: methods to suppress dust and to capture it. Information about installation and ways in which those methods would be used in different applications is included.

Conveyor loading zones and discharge points are prime sources for the creation and release of airborne dust. There are a variety of systems to control airborne dust that can be installed at conveyor loading and unloading zones. Choice of the right system will depend on a number of factors, including the nature of the material carried, the height of drop onto the belt, and the speeds and angles of unloading and loading belts.

Depending on the characteristics of the conveyor, the load zone, and the conveyed material, passive dust-control systems—systems that do not require external supplies such as electricity or water—can be employed (**Figure 18.1**).

MINIMIZING DUST AT TRANSFER POINTS

While it is unlikely dust can be completely eliminated, the first consideration in dust control should always be the minimization of the amount of airborne dust created. Therefore, any change in system design or production technique that will reduce the amount of dust produced should be considered.

For example, minimizing the drop height reduces the amount of energy imparted to the fines and cuts the amount of dust driven off into the air. Consequently, it is best to design conveyor systems with minimum practical material-drop distances.

Since it is generally not possible to totally prevent the creation of dust, other systems to suppress and capture it must be employed. In their simplest form, these dust-control systems involve nothing more than attention during the engineering of the transfer point to the need to reduce airflow.

Airflow through the system can be managed by minimizing the amount of air entering the transfer point, building the enclosure large enough to slow or minimize airflow, and utilizing additional control measures to slow air movement. As air velocity is reduced, airborne particles are too heavy to be supported by the reduced air speed and begin dropping from the air stream.

CHUTES AND SETTLING ZONES

Enlarging the Settling Zone

As an example of Bernoulli's Principle, the Ventui effect is that a current of air speeds up as it passes through a constriction. This is due to the rise in pressure on the upwind side of the constriction and the pressure drop on the downwind side, as air leaves the constriction. In keeping with this basic physics principle, to slow airflow through the transfer point, the enclosed area should be made larger.

On conveyor transfer points, this enclosed area is called a settling zone (**Figure 18.2**). A settling zone is the area past the loading zone's impact area. The length of the settling zone is designed to slow the airflow and allow airborne dust to return to the main material cargo. *(See Chapter 11: Skirtboards, especially Equation 11.1.)* The

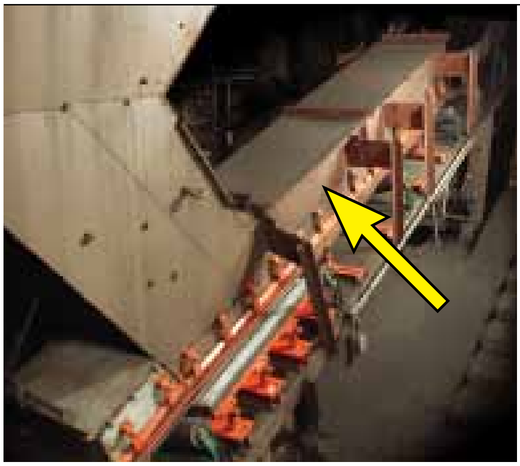

Figure 18.2

A settling zone is the area past the loading zone's impact area, where the airflow is slowed and airborne dust is allowed to return to the main material cargo.

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height of the settling zone should be such that the calculated airflow through the transfer shall be slowed to less than 1,0 meters per second (200 ft/min). *(See Chapter 11: Skirtboards, especially Equation 11.2.)*

Modular Chutewall Systems

Skirtboard areas can be built or enlarged to serve as effective settling zones through the use of modular chutewall systems (**Figure 18.3**). These systems use formed wall panels with a bolt-together assembly method to combine the economy of prefabrication with the ease of on-site assembly. They come in standard sizes and can be combined to fit most settling-zone requirements.

Figure 18.3

Modular chutewall systems use formed wall panels with a bolt-together assembly method to combine the economy of prefabrication with the ease of on-site assembly.

Figure 18.4

The modular system can be used for design and construction of the settling zones on a new transfer point or the modification of existing transfer points.

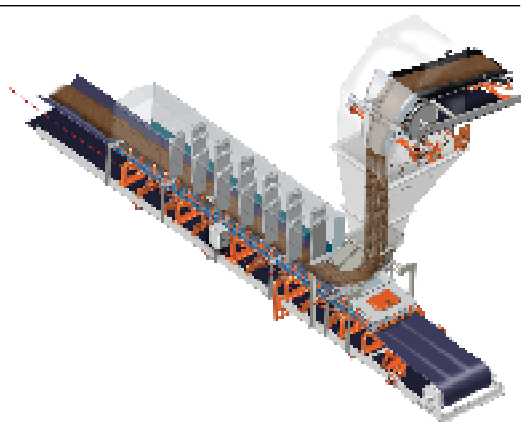

Figure 18.5

Engineered flow chutes typically incorporate a "hood and spoon" design that directs and confines the stream of moving material.

Existing settling zones can be readily enlarged using these modular chutewall or skirtboard systems (**Figure 18.4**). The modular system can also be used for the design and construction of the settling zones on new transfer-point construction to take advantage of its simplicity and off-site fabrication. Modular systems make it easier to update systems if transfer-point alterations are required by changes in material or conveyor specifications.

Engineered Flow Chutes

An advanced approach to passive dust control is the use of engineered flow chutes. These chutes usually incorporate a "hood and spoon" design that directs and confines the stream of moving material (**Figure 18.5**).

The hood minimizes the expansion of the material body, deflecting the stream downward. The spoon provides a curved loading chute that provides a smooth line of descent, so the material slides down to the receptacle, whether that is a vessel or the loading zone of another conveyor. The spoon "feeds" the material evenly and consistently, controlling the speed, direction, and impact level of the material in the load zone.

Basically, these "hood and spoon" chutes keep the material stream in a tight profile and minimize the disruption of the natural flow of material through the transfer. Keeping the material in a consolidated body reduces the amount of air that is induced into the transfer point; controlling the path of the material reduces impact and, therefore, dust generation.

By reducing the velocity and force of material impact in the load zone to approximate the belt speed and direction, this system mitigates splash when material hits the receiving conveyor. Therefore, there is less dust and high velocity air escaping. As the material is deposited more-or-less gently on the belt, there is minimal tumbling or turbulence of the material on the belt. There is less impact, which will reduce damage to the belt, and less side forces that push material out to the sides of the belt.

In some cases, either the hood or spoon is used, but not both. Sometimes there is not enough space to include both in the design. For very adhesive materials, the hood can be used to direct the stream downward for center loading. This variation is often seen on overland conveyors handling highly variable materials or when handling sticky materials, like nickel concentrate or bauxite. Gravity and the flow of material will tend to keep the hood from building up and plugging the chute. In other cases, with free-flowing materials, only the spoon is used to change the direction of the stream to minimize belt abrasion and skirt side pressure. Spoons are prone to backing up or flushing if the characteristics of the bulk materials are variable. Some leeway can be designed into the spoon for variability of materials. The main drawback to using the "hood and spoon" concept is initial cost for these specially-designed components. However, where they can be applied and maintained, they will offer significant benefits in reduced dust, spillage, and belt wear.

This "hood and spoon" system works best when the bulk-material flow rate is kept as uniform as possible. The success of this system may well eliminate the need for active dust-collection systems in many operations. *(See Chapter 22: Engineered Flow Chutes.)*

CONTROL OF AIR ENTERING THE TRANSFER

The material load begins to fan out as it leaves the head pulley, and as it spreads, it tries to pull in more air. Therefore, the chute entry area should be sealed off as much as possible to prevent additional air from being induced by the moving stream of material.

A technique employed to minimize induced air is to cover the inbound portion of the conveyor for several feet before it enters the head (discharge) chute. This enclosure includes barriers between the carrying and return sides of the belt, between the return side of the belt and the chute, and between the chute and the top of the material load (**Figure 18.6**). Often these barriers are formed of rubber sheets or curtains. The idea is to close off as much area as practical to reduce the amount of air which will be pulled into the material flow as the material spreads out when it discharges from the head pulley.

Air-supported conveyors should be considered, because they have the advantage of an enclosed carrying side, which will restrict the flow of air into the discharge chute. Utilizing barriers to block the flow of air into the discharge chute will reduce the ability of the spreading material to entrain air into the material stream, air that would eventually be released when the material stream lands on another belt, storage vessel, or stockpile. It is equally important to control all other openings in the chute to minimize the open areas where air can be drawn into, or dust exhausted from, the chute. Access doors and openings around shafts and sensors need to be fitted with seals.

A technique to reduce air induction at the belt entry to a loading zone is the installation of a barrier—often formed from a dust curtain, used belting, or a sheet of rubber—between the return run and the carrying run. Placed from one side of the head chute to the other, the barrier partially encloses the head pulley, isolating it and reducing air flow. All openings in the head chute must be sealed to reduce induced air as much as possible. This could include shaft seals, inspection doors, belt-cleaner openings, and belt entry and exit areas.

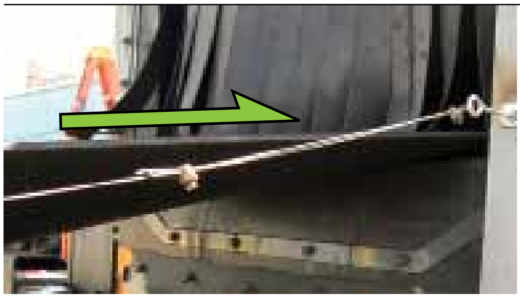

Figure 18.6

Rubber curtains can be used to form barriers to prevent air intake around the conveyor belt as it enters the transfer system.

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EXIT-AREA DUST CURTAINS

Another technique for passive dust control is the installation of dust curtains near the exit end of the transfer point's settling-zone area (**Figure 18.7**). Here, where the belt is leaving the transfer point, the rubber curtains provide a barrier, or baffle, that quiets air velocities, allowing airborne dust to fall back onto the belt. The curtains form a "settling zone" to reduce airflow and allow dust to settle out.

Most conveyors benefit from the installation of at least two curtains. Some installations, especially those where dust-collection and/or -suppression systems need to be isolated, can benefit from installing additional curtains.

These rubber curtains can be fabricated as individual curtains as wide as the skirtboard; or they can be fabricated as some fraction of the skirtboard width and then installed in alternating, or "staggered," fashion to slow airflow (**Figure 18.8**).

These curtains should be composed of 60 to 70 durometer elastomer and extend to approximately 25 millimeters (1 in.) from the top of the pile of conveyed product on the belt. The curtains are installed down through the top of the transfer-point enclusure. Curtains are often field trimmed to match trough angles and the profile of the material load.

Rather than place the curtains at the end of the covered chutework, it is better they be installed inside the covered skirtboard at a distance of 300 to 600 millimeters (12 to 24 in.) from the end of the chutework. The faster the belt speed, the further inside the chutework they should be installed. When the curtain is at the end of the steel enclosure, any material particles hit by the curtain can be displaced from the belt. By placing the curtains so the final curtain is inside the end of the enclosure, any material that contacts the curtains still has room to settle into a stable profile within the confines of the enclosed area. The curtains should be hung roughly 450 millimeters (18 in.) apart, forming an area where dust can settle or where dust-collection or -suppression systems can be applied. Use of dual dust curtains in combination with dust-suppression systems is a patented technology of The Raring Corporation (website: raringcorp.com). If curtains are used to isolate dust-suppression and/or dust-collection installations, it is better if they are located 900 millimeters (36 in.) apart.

In cases where two or more curtains are installed, the inner curtains can be solid (unslit) rubber to improve their air control capability. Only the final, or exit, curtain needs to be slit to reduce the risk of material being "kicked" off the belt.

The curtains should allow easy maintenance access to the chute and should be readily removable to allow replacement.

Figure 18.7

Another technique for passive dust control is the installation of dust curtains close to the end of the chutework, at the exit end of the transfer point's settling zone.

Figure 18.8

Dust curtains can be fabricated as some fraction of the skirtboard width and then installed in alternating, or "staggered," fashion to slow airflow.

DUST BAGS

It is important that positive air pressure—the force of air moving through and away from the loading zone—is controlled in a manner that will minimize the outward pressure against the sealing system and reduce the release of dust.

One passive approach is the installation of at least one dust-collector filter bag (**Figure 18.9**). Dust bags can be protected from weather and still provide a method of collecting dust without the need for a baghouse central-collection system; they are often used when an enlarged settling zone is not possible or there is a large amount of generated air to control. These bags filter outgoing air to minimize the escape of dust into the plant environment. These systems consist of an open port in the roof of the skirted section with a filter bag, sock, or sleeve stretched over the top of the port (**Figure 18.10**). These bags can be attached with a simple circular clamp to the rim of the port. The positive air pressure is relieved through the dust bag, and the dust is captured on the inside of the bag. A transfer point may require installation of more than one of these dust bags, depending on the size and permeability of the bag and the airflow of the transfer point.

Dust bags usually feature a grommet at the top of the bag, which allows them to be hung from overhead supports (**Figure 18.11**). While the bag could extend without the support arm, the bag might be subject to wind or lay over on its side, vulnerable to damage. In installations where these pressure-relief bags are subject to environmental influences, such as snow or rain, the bags should be installed in a protective shelter.

Every bag has a certain airflow capacity based on the permeability of the filter material and the surface area of the bag. The size and number of bags required is directly related to the bag properties. *(See Advanced Topics: Calculating the Size of a Dust Bag.)*

A dust bag is typically installed at a point one-third the length of the transfer chute downsteam from the load zone. Installation of dust curtain(s) inside the skirted area, one on each side of the bag, is recommended, because that will slow the airflow, allowing more air to exit through the dust bag.

Care should be taken to make sure there is adequate clearance above the chutework to allow for full extension of the bag and for the installation of its support structure. The dust can be released from the filter bag mechanically, by shaking manually, or even by the partial collapse of the bag when the outflow of air stops during conveyor downtime.

Dust bags might generate a static charge when used. This charge could cause a spark, which could lead to an explosion if the conditions are predisposed to it. To combat this phenomenon, bag manufacturers are weaving a stainless steel grid into the material and grounding the grid to dissipate any charge that accumulates. This

Figure 18.9

Dust bags can be protected from the weather and still provide a method of collecting dust without the need for a baghouse central-collection system.

Figure 18.10

Dust bags consist of an open port in the roof of the skirted section with a filter bag, sock, or sleeve stretched over the top of the port.

Figure 18.11

Dust bags usually feature a grommet at the top of the bag, which allows them to be hung from overhead supports.

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dissipation can also be accomplished by weaving conductive carbon fibers into the fabric. If there is a potential for explosive dust, static-dissipating dust bags must be used.

TYPICAL SPECIFICATIONS

A. Dust bags

The skirtboard cover will be fitted with one (or more) dust bags to relieve excess positive airflow and capture airborne dust. Each bag will be sized to relieve 0,5 cubic meters per second (1000 ft^3/min) of airflow in the transfer point. The bag will fit over a port in the roof of the skirtboard and be hung from a support arm attached to the cover. The bag will incorporate static-dissipation technology to reduce the risk of dust explosion. The fabric used in the bag will be suitable for the bulk material being handled.

B. Dust curtains

The settling zone of the chutework will be fitted with at least two dust curtains to reduce airflow surges and increase the length of the airflow path. The curtains will be fabricated from elastomer rubber and will hang down from the skirtboard covering. The bottom edge of the curtains will be field-tailored to match the conveyor trough angle and the profile of material on the belt. The dust curtains will be spaced 450 millimeters (18 in.) apart, and the final curtain will be mounted no closer than 300 to 600 millimeters (12 to 24 in.) from the exit of the skirtboard.

C. Settling zone

The settling zone will be fabricated from materials suitable for the bulk material being handled. The length and height of the settling zone should be calculated to reduce the transfer point air velocity to less than 1 meter per second (200 ft/min). *(See Chapter 11: Skirtboards, especially Equations 11.1 and 11.2.)*

ADVANCED TOPICS

Calculating the Size of a Dust Bag

Dust bags can vent a finite amount of air per interval of time. This airflow rate is proportional to the permeability of the filter media and the area of the bag.

SAFETY CONCERNS

To reduce the risk of explosions, the fabric of the dust bag can be woven to incorporate a grounding wire inside the weave of the fabric (**Figure 18.12**). These wires will carry any static electrical charge to the ground. The wires provide low electrical resistance, in keeping with Deutsches Institut für Normung (DIN) Standard 54345 Parts 1 and 3. Depending on location and access, it may be necessary to use lockout / tagout / blockout / testout procedures on the conveyor before performing service work on dust bags. If the dust being collected is a health risk, appropriate personal protective equipment (PPE) must be used, and appropriate disposal methods must be followed.

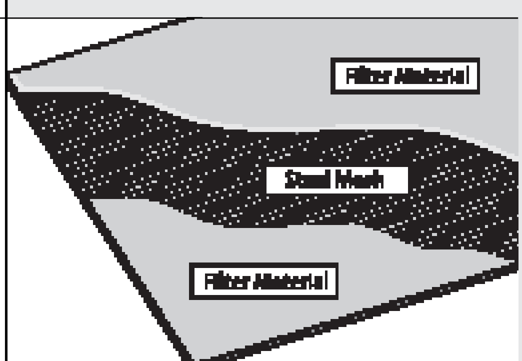

Figure 18.12

To reduce the risk of explosions, the fabric of the dust bag can be woven to incorporate a grounding wire inside the fabric.

The process of sizing a dust bag to an application is as follows:

A. Find airflow. This can be measured or calculated. *(See Chapter 7: Air Control for additional information on total airflow and specifically Equation 7.1 – Total Airflow Calculation.)*

B. Apply a reasonable safety factor to the airflow.

C. Select a filter media that will allow air through but will stop the dust present in an application.

D. Verify the need for static-dissipating fabric.

E. Find the area of the fabric by dividing the airflow required by the permeability of the fabric (**Equation 18.1**).

F. Design the bag to have the area required and to fit into the application geometry. This area can be achieved with a single or multiple bags.

WHEN PASSIVE CONTROLS ARE NOT ENOUGH

In Closing...

Because it is really not possible to totally prevent the creation of dust, passive dust-control methods can be successfully employed to suppress and capture dust. A variety of methods are available, and the use of any one system is dependent on characteristics of the conveyor, the load zone, and the conveyed material.

However, there are plenty of materials-handing systems in which material conditions and/or the design of the process will require additional dust-control systems. These systems will require active dust-management technologies, including dust-suppression and/or dust-collection systems. The choice of dust suppression and/or collection will be determined by other criteria, including the material, how it is being moved, and the next step in the process. *(See Chapter 19: Dust Suppression and Chapter 20: Dust Collection for more information.)*

Looking Ahead...

This chapter, Passive Dust Control, the second chapter in the section Dust Management, described methods of dust control that do not require external supplies such as electricity or water. The following two chapters continue this section and describe methods for active dust control: Dust Suppression and Dust Collection.

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Equation 18.1

Area of Filter Bag Calculation

$$A = \frac{SF \cdot Q_{tot}}{P_f}$$

Given: *A dust bag must dissipate 0,25 cubic meters per second (540 ft³/min). The material permeability is 0,127 meters per second (25 ft/min). Assume a 1.25 safety factor.* ***Find:*** *The area of filter media required.*

Variables		Metric Units	Imperial Units
A	Area of Filter Bag	square meters	square feet
SF	Safety Factor	1,25	1.25
Q_{tot}	Total Airflow	0,25 m³/s	540 ft³/min
P_f	Permeability	0,127 m/s	25 ft/min

Metric: $A = \frac{1,25 \cdot 0,25}{0,127} = 2,5$

Imperial: $A = \frac{1.25 \cdot 540}{25} = 27$

A	Area of Filter Bag	2,5 m²	27 ft²

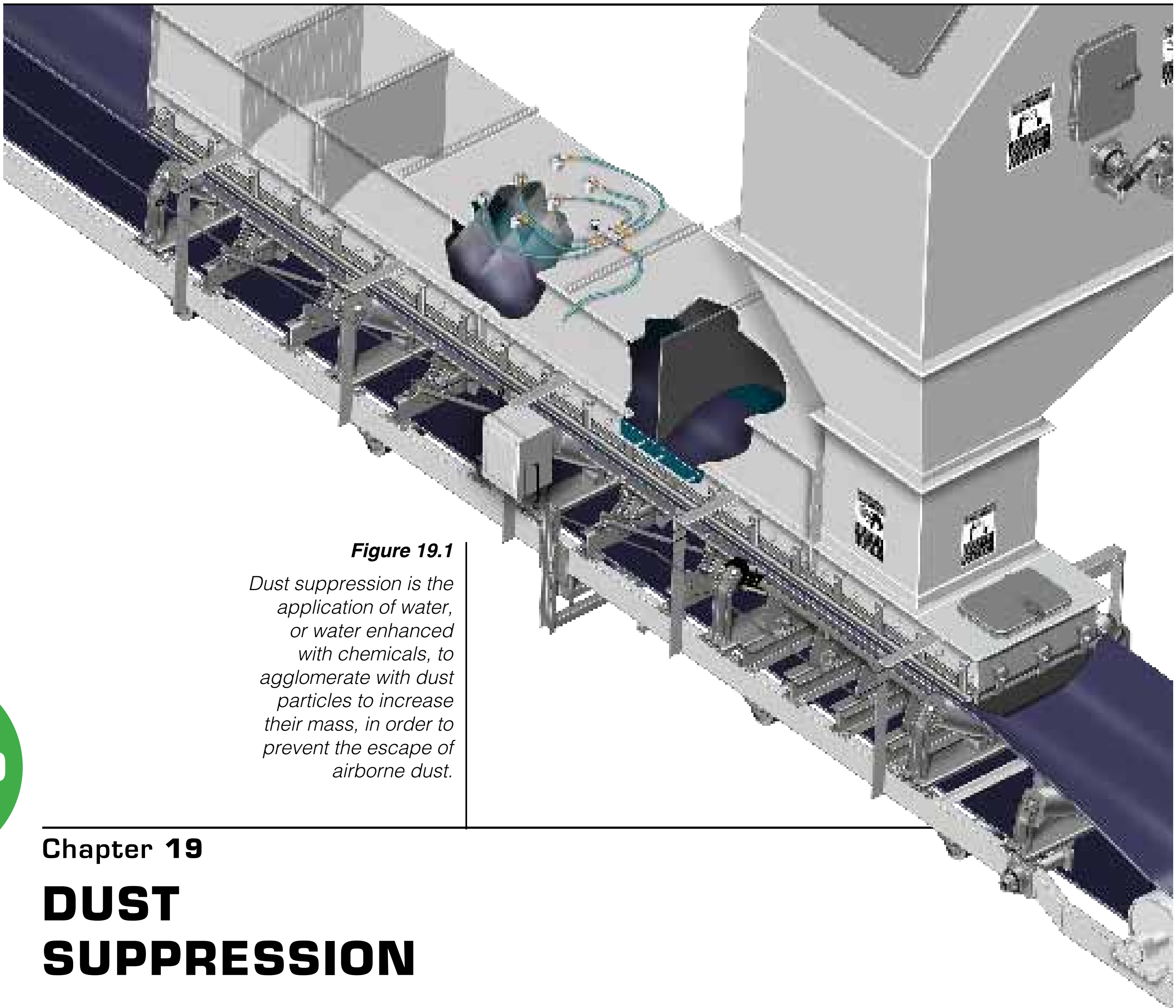

Figure 19.1

Dust suppression is the application of water, or water enhanced with chemicals, to agglomerate with dust particles to increase their mass, in order to prevent the escape of airborne dust.

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Chapter **19**

DUST SUPPRESSION

In this Chapter…

This chapter examines various types of dust-suppression systems, including water or additive-enhanced water-spray systems, foam systems, and fog systems. Advantages and drawbacks of the systems, along with general guidance on applying the various methods, are addressed. This material is intended to be descriptive, rather than prescriptive. Any application of this information should be guided by experienced professionals with knowledge of the specific application.

Dust suppression is the application of water, or water enhanced with chemicals, to agglomerate with dust particles to increase their mass, in order to prevent the escape of airborne dust. The water, or water/chemical mix, can be applied to either a body of material—to prevent fine particles from being carried off into the air—or the air above a body of material—to create a curtain, or barrier, that returns the wetted airborne fines to the material.

There are a number of systems used for this purpose, ranging from “garden hose” water-spray systems through sophisticated, engineered, and automated systems that apply water—with or without added chemicals—as a spray, foam, or fog (**Figure 19.1**).

An advantage of dust-suppression systems is that the treated material does not have to be handled again in order to be reprocessed, as it would with a dust-collection system. The suppressed dust is returned to the main body of conveyed material and then proceeds on in the process, without requiring additional materials-handling equipment to reclaim the material.

A dust-suppression system cannot be recommended in any case where the material would react adversely to the addition of moisture or to the return of the dust to the process.

DUST SUPPRESSION

Evaluating the Options

The selection of the best dust-control solution for each application depends on a number of factors. The key is an understanding of the material, the application conditions, and the level of performance required.

Some general guidelines on the applicability of the various dust-suppression methods are available (**Table 19.1**).

Installation costs and continuous operating costs for power, chemicals, and maintenance should be reviewed. Another consideration in system selection is the availability of resources like water, compressed air, and electric power.

A plain water spray may present the lowest operating costs, but it may also be the least effective solution.

Size Matters

The basic principle of dust-suppression systems is that dust particles (whether airborne or contained in the body of the bulk materials being handled) are more likely to interact with water particles of the same relative size.

When water droplets mix and agglomerate with dust particles, the resulting heavier combined particles fall back to the body of material. For maximum efficiency, a dust-suppression system’s water droplets must be kept within the specific size range of the airborne dust. If the water droplets are too large, the smaller dust particles will typically just “slipstream” around them, pushed aside by the air around the droplets (**Figure 19.2**). If the water droplets are properly sized and are provided in sufficient quantity for the given area, the droplets will bond with the material particles and drop from the air.

Table 19.1

Dust-Suppression Application Matrix							
Type of Dust-Suppression System	**Applications That Have:**						
	Transfer Point	Crushers & Mills	Stock Piles	Rail Car Dump Station	Trippers	Ship Loading	Ship Unloading
Water Spray	X			X			
Water Fog	X						
Water + Air Fog	X			X		X	
Water + Surfactant Spray	X		X	X	X	X	X
Foam	X	X	X		X	X	
Hybrid System Dust Suppression + Passive Dust Collection	X	X					
Hybrid System Dust Suppression + Active Dust Collection	X	X		X			X

Notes: *Water + Surfactant Spray and Foam are best when a residual effect is needed (multiple application points, crushers, long distances between application points, stackers, etc). Water Spray, Water Fog, and Water + Air Fog are best when a residual effect is not required. Some kinds of materials and/or processes do not permit the addition of any chemical.*

The key is to provide dust-suppression system droplets at the same size as the particles of dust and in the same vicinity to provide the best opportunity for maximum interaction between the two. With the simplest water-spray systems, additional small droplets of water are created by spraying more water. The more water that is sprayed, the better will be the opportunity that properly-sized droplets of water are created. Water-and-surfactant-spray systems improve capture efficiency by controlling the wetting ability of the water through the addition of surfactants. These surface-acting agents make the water "wetter," increasing the efficiency of capturing dust, thus allowing a reduction in the amount of water supplied. Fog and foam suppression systems rely on other methods—atomization and chemicals, respectively—to create the small droplets necessary to effectively capture the dust.

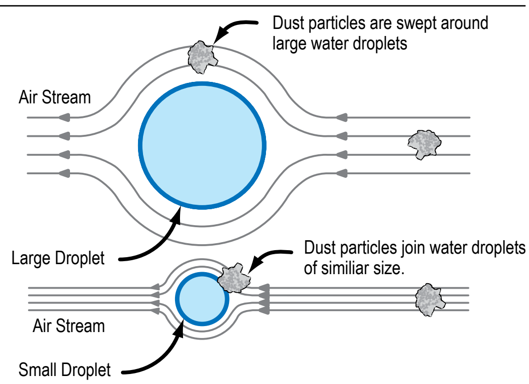

Figure 19.2

Dust particles may "slipstream" around larger water droplets but join readily with droplets of similar size.

A critical ingredient in the selection of a dust-suppression system is an understanding of the characteristics of the materials being handled. Some materials, such as cement, are incompatible with water; therefore, suppression should be avoided. Dust particles from some materials bond readily with water, whereas particles from other materials do not. The addition of a chemical surfactant can improve the ability of water to bond with these normally hydrophobic materials. A suppressant chemical supplier should be consulted to determine the effectiveness of a given chemical with any specific material. A thorough knowledge of the ramifications of adding moisture to a material and to a process must be obtained before implementation of any method of dust suppression.

WATER SUPPRESSION

Suppression with Water

Perhaps the oldest method for controlling fugitive dust is the application of water sprayed over the body of material. By wetting fine particles as they lay in the bulk materials, or as they are being carried by the air, the weight of each particle is increased, making it less likely for the particle to become, or stay, airborne. Moisture increases the cohesive force between dust particles, making them more likely to agglomerate—creating larger, heavier groupings of particles—and making it more difficult for air movement to carry off fines. This is most effective when applying the water through a series of properly-sized spray nozzles at a point where the material expands and takes in air, such as during discharge from the head pulley in a transfer chute.

Water can also be applied to create a "curtain" around a transfer point. Dust fines that become airborne will come into contact with this water "barrier," increasing their mass—removing them from the air stream.

The most effective water sprays are low-velocity systems. High-velocity sprays can add velocity to the air and the dust particles in the air. This energy is counterproductive to the task of returning the dust to the material body.

The Pluses and Minuses of Water Sprays

Water-based suppression systems become more sophisticated as the engineering moves beyond "water hose" technology in the effort to improve results. The effectiveness of water-spray systems is dependent on the velocity of the applied water, the droplet size, the size of the nozzle opening, and the location and number of spray nozzles. Techniques to improve water-spray dust suppression include a reduction in droplet size, an increase in droplet frequency, or a decrease in the droplet's surface tension, making it easier for droplets to merge with dust particles.

Water-spray systems offer some advantages. The application systems are relatively simple to design and operate. Water is generally inexpensive, relatively easy to obtain, and generally safe for the environment and for workers who are exposed to it. Dust-suppression systems utilizing water are relatively simple systems and do not require the use of costly, elaborate enclosures or hoods. Changes can be made after start-up with minimum expense and downtime. Water-based suppression systems are simple to install, less subject to problems from wind or air velocity, and, due to the large orifices in their spray nozzles, do not normally require filtered water. The systems are typically cheaper to install and use far less space than "dry" dust-collection systems.

Unfortunately, the application of water has several liabilities as well. Restrictions on fresh water consumption are common in mine operating permits, as well as in many other industrial operations. Most water suppression systems must use recycled process water, rather than more expensive potable (drinking-quality) water. This process water may have contaminants or chemicals in it that can clog or corrode the spray components. The use of water may promote accelerated corrosion of conveyor structures and components.

Another drawback is that water has only a minimal residual effect—once the water evaporates, the dust-suppression effect is gone. In addition, large droplets of water are not good at attaching to small dust particles: To increase the result, more water is often applied, which can create disposal and cleanup problems.

Various levels of moisture are added in typical dust-suppression systems (**Table 19.2**).

With Water, Less is More

A water spray may appear to be the most inexpensive form of dust control available,

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as process water is available almost free in many operations, and it can be applied through low-technology systems. This cost justification can be a false assumption, as the addition of water may adversely affect materials-handling operations. Many bulk materials are hydrophobic—they have a high-surface tension and are averse to combining with water. In an effort to achieve effective suppression, the amount of water is increased. Because the material does not mix well with water, some particles will remain dry, and others will become very wet. The dry material will continue to create dust, possibly leading to the addition of even more water, worsening the problem. The overly-wetted material will lead to handling problems, including accumulations on chutewalls, plugged screens, reduced efficiency and shortened wear-life on crushers, and carryback on conveyor belts. Excess water may promote belt slippage and belt mistracking, and it may increase the possibility of wet (hence, sticky) fines accumulating within chutes and around the transfer point. When applying water to materials on conveyor systems, a good axiom is "less is more."

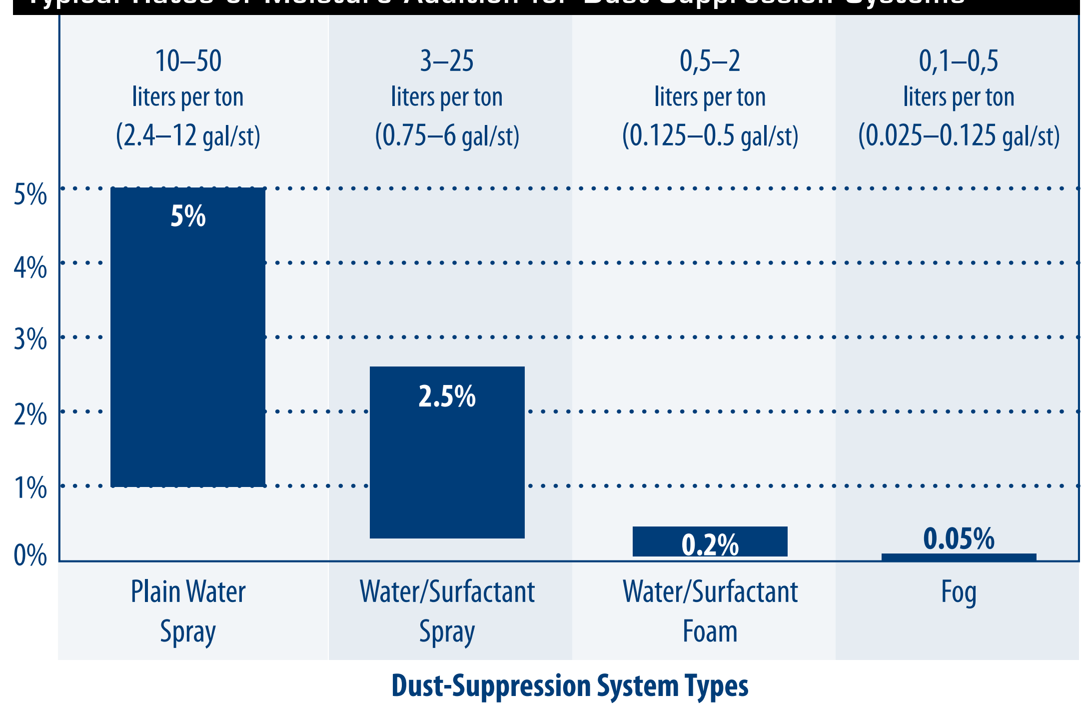
Another problem occurring in "process water" dust-suppression systems is the possibility of excessive moisture in the materials, which can downgrade performance in power-generation or other thermal-processing systems. Excessive water added to coal and coke used for boiler fuel results in a thermal penalty that can have a detrimental effect on utility heat rates. The more water added, the greater is this penalty.

The Thermal Penalty for Added Moisture

There is a substantial performance penalty added to combustion and other thermal processes when the water content of the fuel is significantly increased. In applications like coal-fired power plants and cement plants, water added to the material going into the process must be "burned off" by the process. This can dramatically reduce operating efficiency and increase fuel costs.

Some bulk materials are susceptible to naturally varying moisture contents from their exposure to weather in storage or during transport. Many bulk materials, such as coal, are hygroscopic, meaning they

Table 19.2 **Typical Rates of Moisture Addition for Dust-Suppression Systems**



can absorb moisture from the air. Coals have the capacity to absorb free moisture at levels ranging from 2 to 45 percent of their weight. This absorption occurs rapidly, with from 1.5 to 5.5 percent weight gain in the first 15 minutes of exposure. A steady state occurs within 3 to 5 days of exposure. Often these natural changes are much more significant than the amount of water added by a well-designed and -maintained dust-control system. Any added water can present an added cost to the system and affect heat rate and plant efficiency; therefore, efforts to minimize moisture addition should be carefully considered.

With the thermal output of coal ranging from 16300 kilojoules per kilogram (7000 BTU/lb_m) for lignite to 27900 kilojoules per kilogram (12000 BTU/lb_m) for bituminous coal, a power plant loses roughly the heat from 1 to 1,5 kilograms per ton (1.9 to 3.3 lb_m/st) for every one percent of moisture added in the coal-handing operation. The plant must purchase, handle, and burn additional fuel to compensate for the added moisture. *(See Advanced Topics: Thermal Penalty in a Coal-Fired Power Plant.)*

Improving Water-Based Suppression

Because a water-only-spray system requires a high volume of moisture addition for effective dust suppression, it applies a high thermal penalty. Significant quantities of water can also create problems in materials handling.

Other methods to improve water-based dust suppression while limiting the addition of moisture should be considered. These solutions include generating a fine mist or "fog" spray, or using chemical additives to modify the water.

FOG SUPPRESSION

Fog Suppression Systems

The use of a water fog for dust suppression is one method to optimize the application of water to dusty materials. These systems use special nozzles to produce extremely small water droplets in a "cloud," or dispersed mist (**Figure 19.3**). These droplets mix and agglomerate with dust particles of similar size, with the resulting combined and heavier particles falling back to the material body. Fog systems are based on the knowledge that a wet suppression system's water droplets must be kept within a specific size to effectively control dust. If water droplets are too large, smaller dust particles typically just "slipstream" around them, pushed aside by the air around the droplets.

Fog systems supply ultra-fine droplets that maximize the capture potential of the water while minimizing the amount of water added to the product. Atomization reduces the surface tension of the water droplets, while increasing the number of droplets in a given area.

Fog systems generally add low levels of moisture to the material, typically in the range of 0.1 to 0.05 percent (1/10th to 1/20th of 1 percent) by weight of the material. These amounts, typically less than 0,5 liter per ton (1 pt/st), will minimize any degradation of the material.

There are two methods of producing a water fog:

A. Two-fluid atomization

One method produces fog from water and compressed air by passing them together through a two-fluid nozzle. Here the external air supply is the vehicle that fractures the water into the droplet mist used to capture the dust.

Figure 19.3

Fog dust-suppression systems use special nozzles to create a mist of fine droplets.

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The supply of compressed air provides an additional expense for the installation and operation of this system. The cost of producing the compressed air must also be considered in the economics of the system. An additional concern is the consequence of injecting additional moving air into a transfer point's dust-control equation, which can further stimulate the movement of dust. However, this method allows the use of process water that has been simply filtered to remove any materials that might plug the nozzles.

B. Single-fluid atomization

The second system uses an ultra-fine stream of water pumped through single-fluid atomizing nozzles. It does not require compressed air or any additional power supply other than the electricity used to run its pump. It does require the use of clean, fresh water—or that the process water is filtered and treated—to reduce problems with nozzle clogging. The single-fluid nozzles use hydraulic atomization to generate the fog. In this method, a small stream of water is forced under high pressure—up to 14 megapascals (2000 lb_f /in.^{2}), although more typically 34 to 69 megapascals (5000 to 10000 lb_f /in.^{2})—through a small orifice that shatters the water droplets into microscopic particles. The energy created by the high-pressure pump is used to atomize the water droplets, rather than increase the water's velocity, thereby minimizing displaced air. By eliminating compressed air requirements, the single-fluid nozzles simplify installation and reduce operating costs. To keep the small orifices clear, suspended materials must be removed from the water, and the pH of the water must be controlled. The low volume of water applied makes this relatively easy to accomplish with filtration and ionization.

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Figure 19.4

Fog suppression systems are applied near the end of the transfer-point enclosure.

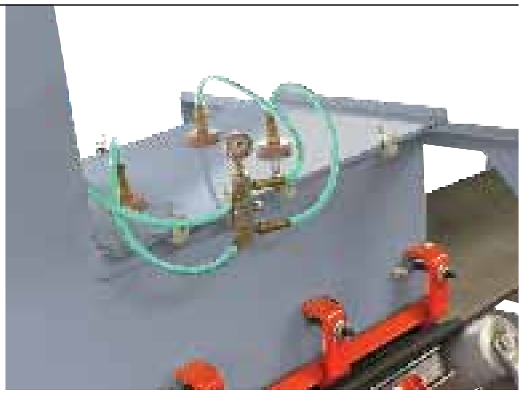

Figure 19.5

Fog-generation nozzles are installed to cover the full width of the conveyor's skirted area.

Location of Fog Systems

The installation of fog systems is a little unusual in that fog systems are designed to treat the air around the material, rather than the material itself. Therefore, the application point for the fog mist is generally near the end of the transfer point (**Figure 19.4**). This placement allows the material to settle and any pick-ups for active or passive dust-collection systems to see dust-laden air without risk of blinding the filtration media with the moistened particles.

Fog-generation nozzles are installed to cover the full width of the conveyor's skirted area (**Figure 19.5**). It is recommended that the height of transfer point skirtboard be at least 600 millimeters (24 in.) to allow the output cone of the nozzles to reach optimum coverage and fill the enclosure. The nozzle spray pattern should be designed so that airborne materials pass through the curtain of fog without putting spray directly onto the main body of material. The spray is directed above the materials, rather than at the materials.

The spray pattern from fog nozzles should not be directed onto any surface, and the nozzles should be shielded from being struck by the bulk material.

Pluses and Minuses of Fog Systems

Fog systems provide effective dust control combined with economical installation and operating costs. System operating costs are low when compared to conventional dust-collection systems.

A well-designed fogging system provides control of dust at the point of application without the need for chemical additives. This is especially important for processes such as the conveying of wood chips destined for papermaking. Many mills are concerned about the application of any chemical that might negatively affect the pulp or degrade the quality of finished paper. As fog systems add water without any additives, they protect the integrity of the process.

With fog systems, total moisture addition to the bulk material can be as low as 0.1 percent to .05 percent. This makes fog suppression systems attractive in industries such as cement and lime production that cannot tolerate excess moisture.

Because of the small orifice size of the nozzles, potable (drinking-quality) water is typically required for fog suppression systems. Filtration to remove suspended materials from the water supply is normally necessary. Nozzles can plug if the water supply is contaminated or if the water-treatment system is not serviced at required intervals. Preparations such as drains and heat-traced plumbing should be provided for plants in cold-weather environments.

Another consideration prior to choosing a fogging system is the air volume and air velocity at the open area surrounding the transfer point or chute. Fog systems using single-fluid nozzles (those that do not require compressed air) tend to be more compatible with engineered systems that control the air movement through a transfer point. These systems should not be used in "open area" applications. For truly effective performance, fog dust-suppression systems require a tight enclosure around the transfer point to minimize turbulent, high-velocity air movement through the system. Since droplets are small, both fog and dust could be carried out of the treatment area onto surrounding equipment by high-velocity air leaving the chute.

Another potential drawback of fogging application is that this form of dust treatment is application-point specific. Dust control is achieved only at the point of application; there is little or no residual, or carry-over, benefit. Although one system can often control more than one transfer point, several fogging devices may be required for a complex conveyor system with multiple transfer points. The capital expenditure may preclude fogging if the conveyor system is too extensive.

ADDING CHEMICALS

Adding Chemicals to Water

It is a common practice to "enhance" the dust-suppression performance of water by adding surfactants—surface-acting agents. The addition of these chemicals will improve the wetting characteristics of water, reducing overall water usage and minimizing the drawbacks associated with excessive moisture addition.

If dust from coal, petroleum coke, or a similar material falls onto a puddle of water, the dust particles can, if undisturbed, lie on top of the pool for hours. This phenomenon takes place because these materials are hydrophobic—they do not mix well with water. Since it is not practical to alter the nature of the dust particles to give them greater affinity for water, chemicals are added to alter the water particles, so they attract, or at least join with, the dust particles more readily.

By adding surfactants, the surface tension of water is reduced, allowing dust particles to become wet. Surfactants are substances that, when added to water, improve the water's ability to wet surfaces and form fine droplets. Surfactants lower the water's surface tension and overcome the internal attraction between the molecules of water, ultimately resulting in improved droplet formation.

To understand surface tension, imagine a drop of water lying on a smooth, flat surface. It will usually form a liquid bubble with well-defined sides. It is the surface tension of the water that prevents the droplet walls from collapsing. A drop of water that has been mixed with a surfactant—such as dishwashing soap—will not form a liquid bubble, because its surface tension has been drastically reduced. The "walls" of the droplet cannot support the weight of the droplet, because the forces holding the walls together have been altered. This is the reason surfactant technology is applied to dust control. If the water droplets no longer have a surface that is a barrier to contact with the dust fines, then random collisions between droplets of water and dust will result in the wetting and enlargement of the fines to the point they will drop out of suspension in the air.

Choosing a Surfactant

The number of surfactants and surfactant blends currently in use is quite extensive. A number of specialty chemical companies have products formulated to address specific dust-control needs. Choosing the correct product and addition rate for a given application requires material testing as well as an understanding of the process and the method of application.

Objections to chemical-additive-enhanced water suppression systems include the ongoing costs of purchasing chemical additive. Costs can be higher, particularly when considering amortization and depreciation of the equipment. In addition, these systems require regular maintenance, which adds labor expense to the continuing operating costs.

As contamination of the materials, or the process, can be a concern in some industries, the additive chemical must be reviewed in this light. It is important that chemical additives are compatible with the process, with the bulk materials, and with system equipment, including the conveyor belting. Although the use of a surfactant reduces the amount of water added to the dusting material, water/surfactant sprays may still add more water than is acceptable. It is common practice for a chemical supplier to provide samples to the customer for testing the effects on the end product.

Application by Spray or Foam

Once an efficient wetting agent has been selected, the decision must be made whether to apply the material as a wet spray, as discussed above, or as foam. Both systems offer advantages. Generally speaking, the moisture-addition rate of a wet-spray system is higher than that of a foam-generating system. Although the dilution rate is lower for the foam suppression system, the expansion of the foam allows it to provide effective suppression with less moisture added to the materials (**Table 19.3**). Recent developments have improved surfactant technology to the point that some mixtures can be applied as a spray at the lower moisture levels of a foam system while providing good dust suppression. This provides the benefit of limited moisture addition with minimal chemical cost, due to the higher dilution rates with the spray-applied surfactants.

Table 19.3

Maximum Typical Moisture-Addition Levels

	Water Spray	Water with Surfactant	Foam	Fog
Nominal Rate of Moisture Addition	5%	2.5%	0.20%	0.05%
Water Addition	5455 l/h (1200 gal/h)	2725 l/h (600 gal/h)	218 l/h (48 gal/h)	54,5 l/h (12 gal/h)
Chemical-to-Water Ratio	N/A	1:5000	1:100	N/A
Chemical Usage Rate	N/A	0,44 l/h (0.096 g/h)	2,2 l/h (0.48 g/h)	N/A

FOAM SUPPRESSION

Foam Dust Suppression

The use of surfactants with water will improve the likelihood that fines will collide with droplets and that these collisions will result in suppression of the dust. It stands to reason that the objective is to maximize the surface area of available water droplets to make as much contact with dust fines as possible, thus limiting the amount of water needed. To do this, some suppliers offer dust-suppression systems that create chemical foam (**Figure 19.6**). As the moisture is in the form of foam, its surface area is greatly increased, improving the chance for contact between dust and water. Some foam bubbles attract and hold dust particles together through agglomeration. Other bubbles burst on contact with dust particles, releasing fine droplets that attach to smaller, more difficult to catch, and more hazardous to human health, dust particles. With moisture addition of 0.2 percent to 0.4 percent, foam systems add only 2 liters per ton (2 qt/st) of material. At these levels, foam suppression systems typically add less than 10 percent of the moisture that straight water-only spray systems apply.

Consequently, foam systems are welcomed where water supplies are limited or where excessive water can downgrade material performance, as in coal-fired power plants. In addition, the reduced water means fewer problems with screen clogging and materials adhering to mechanical components and enclosures.

Adding air to the surfactant and water blend and passing this compound through a mixing device creates the foam. Adjustment of the air/water/chemical ratio and other controllable factors allows the application engineer to generate foam ranging from very wet to "shaving cream" dry, in order to create the most efficient foam for each application. Well-established foam can expand the surface area of a quantity of water by 60 to 80 times. This allows for effective dust control with lower rates of moisture addition.

The system for the application of foam for dust suppression begins with mixing water with the foam-generating chemical. The water and additive are metered together through a proportioning pump, and the resulting mixture is pumped through a flow regulator to feed the system (**Figure 19.7**). A second flow regulator controls a supply of compressed air. The water/chemical solution and air arrive via separate hoses at a foaming canister, where they mix to create foam. The foam then travels through hoses to the application nozzles installed in the wall or ceiling of the equipment or transfer point (**Figure 19.8**).

Limitations of Foam Suppression

While many applications benefit from foam technology, there are some liabilities to the process. Surfactants that produce the most desirable foaming are not always the best wetting agents for the materials being treated. Some suppliers focus on chemicals to produce stable foam, without considering whether the resultant foam is

Figure 19.6

Foam dust suppression generates "dry" foam that expands the surface area of water 60 to 80 times its previous surface.

Figure 19.7

In the proportioning system, water and surfactant are mixed, and the resulting solution and compressed air are sent independently to foam canisters.

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of any value in overcoming the hydrophobic nature of the material. It is critical the chemicals provide effective wetting of the material handled before foam generation is considered.

Foam generation requires compressed air. If a supply of compressed air is not readily available at the application site, a compressor must be installed and maintained.

Figure 19.8

The water/surfactant solution and air are combined in the foaming canister and supplied to the application nozzles.

Overall, foam-application equipment is slightly more expensive than conventional water-spray equipment and normally requires additional maintenance.

Finally, the amount of surfactant required to generate foam is somewhat greater than the amount of chemical typically added in a wet-spray system. The volume of surfactant in a given body of water is higher; however, due to the foam's expansion, the amount of moisture applied to the material is lower. The additional cost for this increased concentration of the additive chemical may be offset by a reduction in thermal penalty on fuel performance resulting from a substantial decrease in additional moisture (**Table 19.4**).

RESIDUAL CHEMICALS

Residual Chemical Suppression Agents

Surfactants wet the dust fines, so the particles agglomerate, thereby preventing

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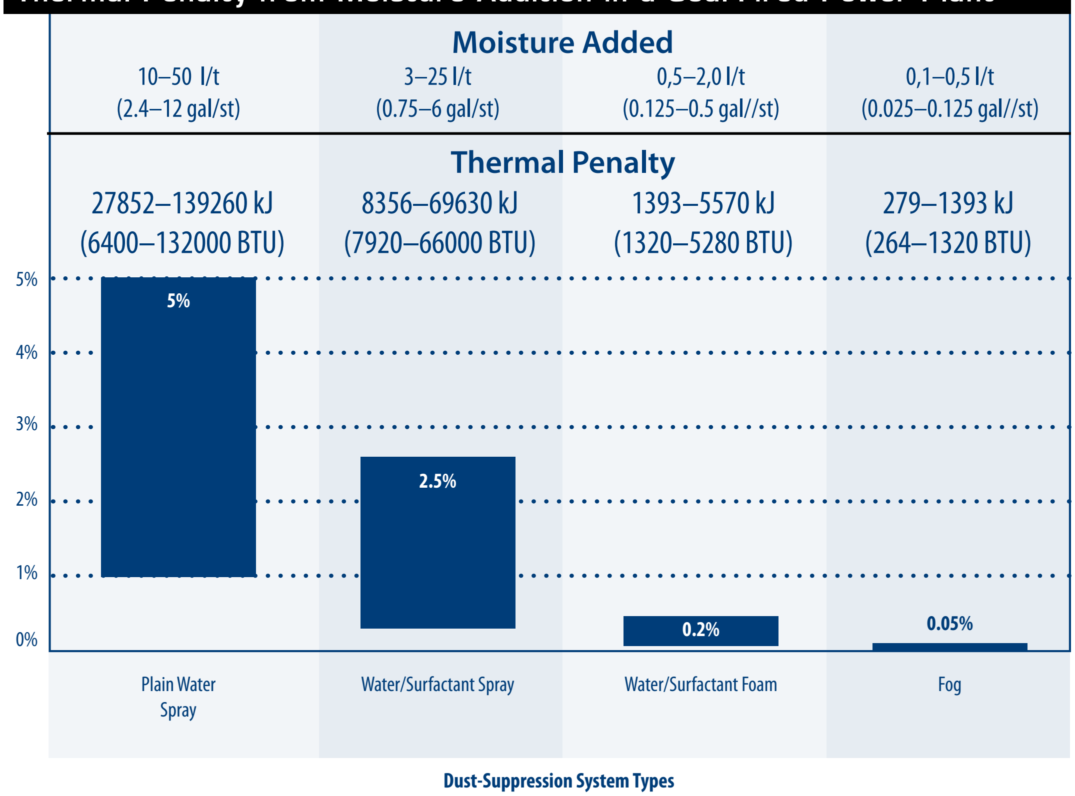
Table 19.4 **Thermal Penalty from Moisture Addition in a Coal-Fired Power Plant**



Note: Moisture Added—liters per ton (gal/st); Thermal Penalty—kilojoules (BTU) them from becoming airborne. Once the solution evaporates, the suppression effect of normal surfactants is gone. In many cases, however, dust suppression is required not only as the materials move through multiple transfer points, but also after the materials reach the storage bins, railcars, barges, or stock piles. In these cases, it is wise to consider using a water/surfactant spray or foam system with a longer-lasting residual effect. Residual dust suppression is valuable when considering dust suppression for:

A. Large areas with multiple application points
B. Long distances between application points
C. Stackers or trippers
D. Crushers or mills
E. Elevated transfer points where it would be difficult to apply dust suppression

A well-designed residual suppression system makes it possible to control fugitive dust over a wide area by applying the solution at a few strategic points. In contrast, using water and/or fog systems for large areas will require multiple application points, including several pump stations; longer water, chemical, and air lines; higher pumping capacity; and more application nozzles—all of which can make the system considerably more expensive and, in some cases, not as effective.

Coal conveyed from unloaders to open storage piles might remain there for extended periods of time. Material stored in open stockpiles is subject to variations in climate, including wind, sun, and precipitation. The heat of the sun can evaporate moisture out of stored material, making it more likely to become wind-blown. Wind erosion creates large amounts of dust that can settle on nearby houses and yards. When stored coal is reclaimed, it may be dry and present greater dusting problems than it did during initial handling. Dusty materials, such as calcined coke or iron-ore pellets, may require dust control from the point of production to the point of end use. This could amount to several weeks and several thousand kilometers (miles) apart. In such cases, it may be more economical to apply a residual surfactant/binder to the materials than to apply surfactants and water at multiple sites throughout the materials-handling system. There are a variety of residual binders available.

Longer-Lasting Effects

The objective of a residual, or binder, suppressant is to agglomerate fines to each other, or to larger particles, and then hold the structure together, even after the moisture evaporates. In some cases, a hygroscopic material, such as calcium chloride, is used, which retards the ability of moisture to leave the treated material. The advantage to this approach can be a low treatment cost. More conventional binders include lignin, tannin, pitch, polymers, and resins. When combined with surfactants to aid wetting, these compounds coat larger particles and then act as a glue to attract and hold dust fines.

Application of residual binders tends to be more expensive than surfactant applications, because they must be applied with higher concentrations. Although binders are less expensive per kilogram (lb_m), they are typically applied at dilution rates ranging from 50-to-1 to 200-to-1 (2.0 percent to 0.5 percent).

It is important to mention that, with the use of a residual chemical, a plant can reduce the number of application points required, reducing, in turn, the amount of maintenance required.

When choosing a binder, it is especially important to know the effects the binder will have on transfer equipment and conveyor belts. If the binder adheres well to the material, it may do the same to the handling equipment. Proper application of the product becomes critical, because overspray of the binder onto process equipment or empty belts can result in considerable production and maintenance problems.

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An important consideration in selecting a binder is the effect the chemical will have on both the material being treated and the environment. If the binder is applied to material going into a stockpile, and that stockpile is exposed to rain, portions of a water-soluble binder may end up in the runoff and provide an environmental concern. Most chemical manufacturers provide only binders that are compatible with the environment; however, this is an issue that should be raised with the chemical supplier.

SYSTEMS AND PLACEMENT

Hybrid Systems: Adding Suppression to Containment or Collection

The selection of a dust-control system should be based on the material, the causes of dust generation, and the specifics of the point(s) of application. A complete dust-generation analysis is important in order to detect not only the most problematic fugitive-dust-generation points, but to identify the true causes of dust generation and escape, in order to control the situation.

In some cases, a hybrid system combining a dust-suppression system with other dust-management systems—passive or active dust collection or containment—should be considered. This may yield the best possible performance with minimal installation, operation, and maintenance costs. It is important to consult with a specialist in the application of dust-suppression and -control systems to develop a solution for any specific application.

Figure 19.9

The location of the application point is critical to the success of any dust-suppression system.

Figure 19.10

Foam suppression is most effective when applied where the material is in turmoil, as at the discharge of a crusher or conveyor.

Location, Location, Location

In any dust-suppression system, it is important to select the best application point(s), not only to increase effectiveness, but also to reduce the costs of installation, operation, and maintenance. The sites chosen for nozzle placement and the pattern of delivery are as important, if not more important, than the selection of the chemical to be applied (**Figure 19.9**). Even the best-designed program will fail if the suppressant chemical is not delivered in the correct location to allow mixing of the suppressant and the dust fines.

Success of the suppression effort at the transfer point relies on properly mixing the materials and the suppressant. Whether the suppressant is simply water or a surfactant/water mixture as a spray or foam, it is best to locate the suppression system at the point the materials leave the head pulley. As the materials leave the head pulley, they spread out, and air is entrained into the stream of conveyed materials. The suppressant will be drawn into the materials by this negative air pressure. As the suppressant and the conveyed materials tumble through the chute, they will continue to mix, providing effective dispersion.

Foam suppression is normally most effective when applied at the discharge point of a crusher or conveyor, where the body of material is in turmoil and expanding (**Fig-**

ure 19.10). Here, the forces of the material movement will fold the suppressant into the material stream as it moves through the transfer point and down the conveyor belt. The application of suppressant at this point allows the foam to penetrate into the material stream and capture individual particles, rather than remaining on the external layer of material.

The Importance of Water Quality

Water quality plays an important role in the effectiveness of any dust-suppression program. The ability to generate acceptable foam is largely dependent on the quality of the water used. Depending on the dust-suppression system used, it is important to filter the water, removing particles between 5 and 40 microns, and to have the water as close to neutral pH as possible.

If the characteristics of the water available in the plant are known, the proper systems to filter the water can be applied. This knowledge will also make it easier to prevent possible failures—including the plugging of nozzles and premature failure of pumps—and to maintain the required flow rate.

SYSTEM MAINTENANCE

Without a doubt, one of the most common causes of failure for dust-suppression systems is a lack of preventive maintenance. Nozzles must be checked, filters cleaned, pumps oiled, chemical levels checked, application settings verified, and flow rates for water and air adjusted on a routine basis, or even the best system is doomed to fail. It is important to rely on

SAFETY CONCERNS

Central to any consideration of safety with dust-suppression systems is a proper regard for the relationship between water and electrical systems that power the suppression system and, indeed, the entire conveyor. Systems should be properly grounded, and water should not be sprayed directly onto them.

As many dust-suppression systems move water or air under some level of pressure, it is important to be wary of the plumbing system, whether it is pipe, hoses, or some combination. Pump or line pressure must be maintained at proper levels, and proper relief mechanisms must be available. Prior to work being performed on any piping system, care must be taken to make sure that pressure in the lines is relieved and electricity to the pump(s) is properly locked out.

Dust-suppression systems in cold-weather climates should incorporate measures to keep the system operating in freezing conditions, or the system should be designed to operate only when the temperature is above freezing. Systems should be designed to ensure they do not create safety risks, such as ice patches—on roads, walkways, or stairs—or frozen bodies of material inside a vessel that would require employee entry into confined spaces to remove material blockages.

Suppliers of chemical additives must provide all applicable Material Safety Data Sheets (MSDS) that spell out all safety concerns, health risks, and environmental issues.

It is important to follow established lockout / tagout / blockout / testout procedures when installing and maintaining dust-suppression systems.

the manufacturer's instructions for guidance on the proper service intervals and procedures for system components.

Some suppliers of dust-suppression equipment and chemicals now offer routine service as a part of their system package. It is wise to consider this solution, as it will free in-house maintenance and operating personnel for other duties, while guaranteeing the operation of the dust-suppression system.

TYPICAL SPECIFICATIONS

The following typical specifications pertain to foam dust-suppression systems only.

A. Foamed mixture

The conveyor loading zone will be equipped with a dust-suppression system that applies a foamed mixture of suppressant chemical and water to minimize the escape of airborne dust.

B. Additive

The dust-suppression system will work by the metering of a dust-suppression additive into a supply of water, generating a foam mixture of water and supplement, and applying this mixture over the body of material. This mixture will encourage the agglomeration of fine particles and inhibit the driving off of airborne dust.

C. Pump module

The dust-suppression system will include a pump module, containing a proportioning pump [0 to 76 liters per minute (0 to 20 gal/min)] with the addition of 0.2 to 1.5 percent additive, a regulator [170 to 520 kilopascals (25-75 lb_f /$in.^2$)], a gate valve, and a flow meter [0 to 76 liters per minute (0 to 20 gal/min)].

Figure 19.11

The nozzles should be placed on the top side of the transfer chute's stilling zone. Dust curtains should be placed on each side of the nozzles to slow the air stream, allowing the fog to remove dust from the air.

D. Foaming chamber

The air and water/additive mixture will be combined in a foaming chamber. The inlets for the air and water/additive lines will be equipped with check valves to prevent backflow. An air gauge located on the foaming chamber will allow control of air pressure to create fully-developed foam.

E. Nozzles

The produced foam will be applied to the material on the conveyor through up to eight "duckbill" nozzles connected to uniform hose lengths. The nozzles will be held in position in the chutewall to allow a simple of removal for maintenance.

TYPICAL DUST-SUPPRESSION APPLICATIONS

Dust-Suppression Application 1

A belt is transporting mine refuse. This belt is properly supported in the load zone, and the transfer chute is effectively sealed. An anemometer reading at the outlet of the conveyor loading zone shows that the exit velocity of air is 0,25 meters per second (50 ft/min).

Material.................................. Mine Refuse

Transfer Point.................. Effectively Sealed

Air Speed.................... 0,25 m/s (50 ft/min)

Suppression Method ....Fog

This is a good application for a fog system, because the material is not sensitive to water, containment is good, and air velocity is below 1,0 meters per second (200 ft/min). *(See Chapter 17: Dust Management Overview, Figure 17.10.)*

The nozzles should be placed on the top side of the transfer chute's settling zone. Dust curtains should be placed on each side of the nozzles to slow the air stream, allowing the fog to remove dust from the air (**Figure 19.11**).

Dust-Suppression Application 2

A belt at an aggregate plant is transporting limestone. The transfer point has no enclosure.

Material........................Crushed Limestone

Transfer Point............ Open (No Enclosure)

Air Speed.................................... Unknown

Suppression Method .... Foam

This is a good application for a foam system, because the material is not sensitive to moisture, but there is no chute to control the air movement.

The foam could be applied to the limestone as it comes off the head pulley, while the material is in turmoil. This will allow the moisture to cover all surfaces of the material. Covering all surfaces with moisture will prevent the generation of dust when the material lands on the receiving belt (**Figure 19.12**).

Dust-Suppression Application 3

The conveyor is transporting coal. The transfer chute is properly sealed and supported. An anemometer reading at the end of the settling zone shows that the exit velocity of the air stream is 1,5 meters per second (300 ft/min).

Material..Coal

Transfer Point...........Sealed and Supported

Air Speed.................1,5 m/sec (300 ft/min)

Suppression Method .... Foam

This is a good application for a foam system, applied in combination with a reconstruction of the conveyor's transfer point(s). The high air velocity indicates that the transfer-point enclosure is not large enough to slow the air. High velocity usually means large amounts of dust will be generated. The transfer point should be lengthened and the height increased, to slow the air and allow the dust to settle.

The material is sensitive to moisture, so the amount of water should be minimized. The foam could be applied to the material while it is in turmoil. This will allow the moisture to cover all surfaces of the material. Covering all surfaces with moisture will prevent the generation of dust when the material lands on the receiving belt.

The moisture will also have a residual effect and may keep the coal moist all the way to the stackout conveyor (**Figure 19.13**).

Dust-Suppression Application 4

A bucket elevator is offloading coal from a barge. There is no "transfer chute," so the unloader is exposed to air currents.

Figure 19.12

Applying foam while the cargo is in turmoil allows the moisture to cover all of the surfaces of the material to prevent dust generation.

Figure 19.13

The moisture will have a residual effect and may keep the coal moist all the way to the stackout conveyor.

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Table 19.5

Thermal Penalty in a Coal-Fired Power Plant

	Metric	Imperial
Unit to measure heat/ energy	Kilojoule (kJ)	British Thermal Unit (BTU)
Weight of water	1 kg/l	8.33 lb_m/gal
Energy to vaporize water	2675 kJ to vaporize 1 kg (about 0,5 l) of water from Standard Temperature and Pressure (STP)	1150 BTU to vaporize 1 lb_m (about 1 pt) of water from STP
Coal unit	ton (1000 kg)	short ton (2000 lb)
Water required to raise moisture content of unit of coal by 1%	10 kg (10 l)	20 lb_m (2.4 gal)
Heat required to burn this 1% of additional water off the unit (ton/ st) of coal	26750 kJ (2675 kJ/kg x 10 kg)	23000 BTU (1150 BTU/lb_m x 20 lb_m)
Heat content of coal Source: *Coal Data: A Reference* published by U.S. Department of Energy, Energy Information Administration. *Metric conversion by Martin Engineering.*	Bituminous = 27900 kJ/kg Subbituminous = 20900 kJ/kg Lignite = 16300 kJ/kg	Bituminous = 12000 BTU/lb_m Subbituminous = 9000 BTU/ lb_m Lignite = 7000 BTU/lb_m
Amount of coal required to provide the heat required to burn off 1% water from 1 ton (1 st) of coal	Heat Required (kJ) divided by Heat Content (kJ/kg) = kg	Heat Required (BTU) divided by Heat Content (BTU/lb_m) = lb_m
	26750 / kJ/kg = kg	23000 / BTU/lb_m = lb_m
	Bituminous 0,96 kg Sub-bituminous 1,3 kg Lignite 1,6 kg	Bituminous 1.9 lb_m Sub-bituminous 2.55 lb_m Lignite 3.3 lb_m
Summary	It takes from 0,96 kg to 1,6 kg to burn off 1% of water added to a ton of coal.	It takes 1.9 lb_m to 3.3 lb_m of coal to burn off 1% of water added to a st of coal.
In percent	This is 0,0096 to 0,016 of the coal (1/10 to 1/6 of 1 percent)	This is 0.0095 to 0.0165 of the coal (1/10 to 1/6 of 1 percent)
Railcar contents	91 tons (91000 kg)	100 st (200000 lb_m)
Loss from every carload	~87 to 146 kg	~190 to 330 lb_m
Loss from every 120-car unit train	~10440 to 17500 kg/trainload or between 1/10 and 1/5 of a carload/train	~22800 to 39600 lb_m/trainload or between 1/10 to 1/5 of a carload/train
If this 270-megawatt (362000-hp) plant receives 60 unit trains per year:		
Annual loss	~625000 to 1,1 million kg or ~625 to 1100 tons or 6 to 12 carloads/year	~1.35 to 2.4 million lb_m or ~684 to 1188 st or 6 to 12 carloads/year

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Material...Coal
Transfer Point..................................... None
Air Speed....................................... Ambient
Suppression Method ....Water with Surfactant

This is a good application for water-with-surfactant suppression, because the material is not sensitive to water, and containment around the material is poor. Water with a surfactant additive allows larger water drops than water alone and will not be as affected by air currents. The nozzles should be placed around the excavator to allow the water/surfactant mix to "rain down" on the barge as it is unloading (**Figure 19.14**).

ADVANCED TOPICS

Thermal Penalty in a Coal-Fired Power Plant

A 270-megawatt (362000-hp) power plant might burn approximately 82 tons per hour (90 st/h), 24 hours per day, seven days a week. This turns into 13776 tons per week (15120 st/wk). Even allowing a two-week maintenance outage, the annual coal consumption of this plant would be more than 688000 tons per 50-week-year (759000 st/50-wk-yr).

The plant receives its coal in unit trains composed of 120 cars, each with a capacity of 91 tons (100 st). With the total train capacity of 10920 tons (12000 st), the plant will need to receive roughly 1.25 trains per week, or 5 trains a month. That is approximately 60 trains per year. These figures will vary depending on the type (heat output) of the specific coal used.

Thermal penalty is the amount of coal that must be burned just to remove the moisture added to the coal by the dust-suppression system. It is equal to between 1,0 and 1,6 kilogram per ton (1.9 to 3.3 lb_m/st) for each one percent of water added to the coal.

At the rate of 0,1 of 1 percent of coal used to eliminate this one percent additional moisture, the plant will lose the heat

Figure 19.14

An unenclosed bucketwheel reclaimer is a good application for a water-surfactant dust-suppression system.

from 10440 to 17500 kilograms (22800 to 39600 lb_m) of coal per trainload, or roughly 0,1 to 0,2 of a carload. That amounts to 6 to 12 railcars per year—perhaps 1 railcar per month—burned just to drive off the added moisture (**Table 19.5**).

DUST SUPPRESSION: ONE PIECE OF THE PUZZLE

In Closing...

Dust suppression is best suited to enclosed spaces of reasonable size. It becomes difficult to apply and control any of the various forms of dust suppression in open areas or inside large structures such as railcar or haul-truck dumps. Acceptable results in these applications may require a combination of confinement, suppression, and collection.

Dust suppression cannot stand alone as the complete answer to controlling fugitive materials. Properly chosen, engineered, and maintained, a dust-suppression system can provide a critical portion of the total material-management program.

Looking Ahead...

This chapter about Dust Suppression is the third chapter in the section Dust Management, following Dust Management Overview and Passive Dust Control. The following chapter, the final chapter related to dust management, continues the topic of active dust control by focusing on Dust Collection.

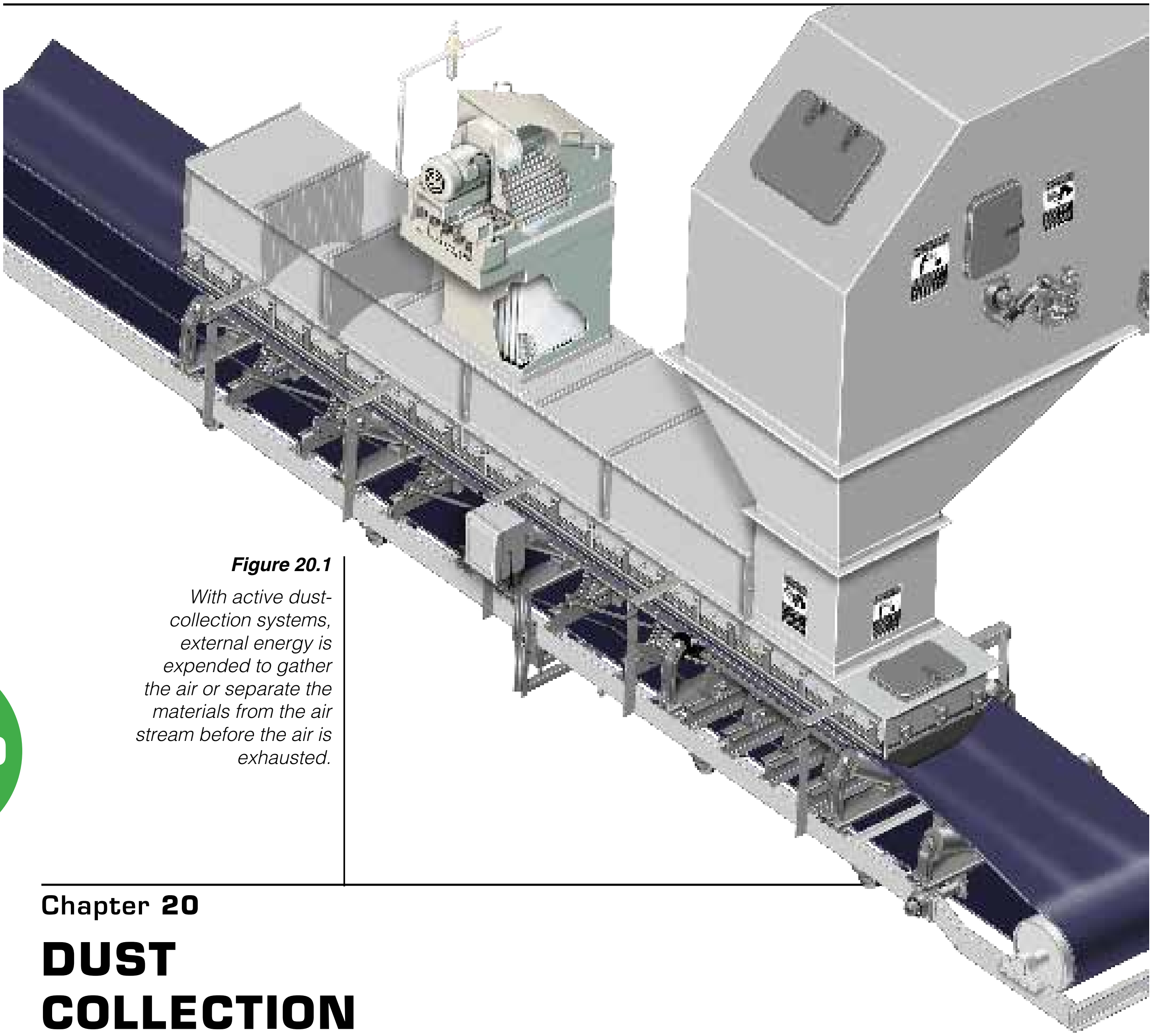

Figure 20.1

With active dust-collection systems, external energy is expended to gather the air or separate the materials from the air stream before the air is exhausted.

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Chapter **20**

DUST COLLECTION

In this Chapter…

In this chapter, we discuss the five main types of active dust-collection systems, looking at advantages and disadvantages of each. We also compare central, unit, and insertable dust collectors. Sizing and placement of dust collectors, along with some of the downfalls of dust-collection systems, are included. Advanced topics include selection and application of an insertable dust-collection system as well as three types of air velocity and their relationship to dust management.

Dust collection—the passing of dust-carrying air through some form of filtration or separation system—is the final piece in the dust-control system.

There are both active and passive dust-collection systems. A passive system merely allows air to move through the filtration system, whereas active systems work like a vacuum cleaner to pull or push air through a filtration method to remove the materials. *(See Chapter 18: Passive Dust Control for information on passive collection methods.)* This chapter discusses active dust-collection systems (**Figure 20.1**), in which external energy is expended to gather the air or separate the materials from the air stream before the air is exhausted.

DUST COLLECTION

Dust-Collection Systems

Mechanical dust-collection systems are installed to pull dust-bearing air away from a dust source, such as a conveyor loading zone; separate the dust from the air; and exhaust the cleaned air. A typical dust-collection system consists of four major components (**Figure 20.2**):

A. Exhaust hood(s) or pickup(s) to capture airborne dust at the source(s)

B. Ductwork to transport the captured air/dust mixture to a collector

C. Collector, filter, or separation device to remove dust from the air

D. Fan and motor to provide the necessary suction volume and energy

Considerations for Dust-Collection Systems

Dust-collection systems vary widely in design, operation, effectiveness, space requirements, construction, and costs for operation and maintenance. The selection of a system should include a review of the following factors:

A. Dust concentration

In bulk-materials handling operations, the dust concentrations typically range from 230 to 23000 milligrams per cubic meter (0.1 to 10.0 lb_m/ft^3) of dust, and the particle size can vary from 0,2 to 100 microns (µm is one millionth of a meter). The selection of a collector should be based on the level of cleanliness, or efficiency, required.

B. Characteristics of the air stream

The characteristics of the polluted (or dirty) air can have a significant impact on collector selection. Factors include temperature, moisture content, and relative humidity.

C. Characteristics of the dust

The properties of the dust itself are important to the choice of a dust-collection system. Moderate to heavy concentrations of many dusts, such as silica sand or metal ores, can be abrasive, hygroscopic, or sticky in nature. The size and shape of particles will determine the applicability of fabric collectors; the combustible nature of many fine materials rules out the use of electrostatic precipitators.

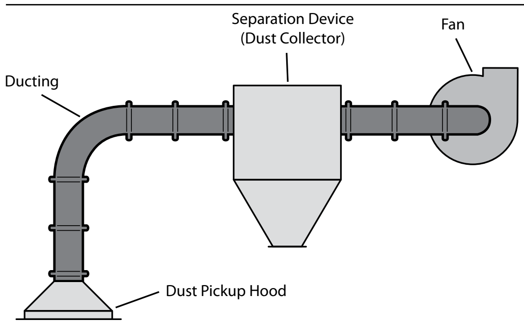

Figure 20.2

The basic components of a dust-collection system include pickups, ductwork, filter device, and fan and motor.

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D. Method of disposal

The method to dispose of collected dust will vary with the nature and amount of the material, the overall plant process, and type of collector used. Collectors can unload continuously or in batches. Dry materials can create secondary dust problems during unloading and disposal. The disposal of wet slurry, or sludge, can be an additional materials-handling problem for a wet collector. Sewer or water pollution problems can result if wastewater is not properly treated.

COLLECTION TECHNOLOGIES

Dust-Separation Technologies

There are a number of specific "hardware" approaches used to remove dust from the air, each with its own benefits and drawbacks. The five main types of active dust-collector systems used in the industry include:

A. Inertial separators (usually called cyclones)

B. Wet scrubbers

C. Electrostatic precipitators

D. Cartridge filter collectors

E. Fabric dust collectors (often called baghouses)

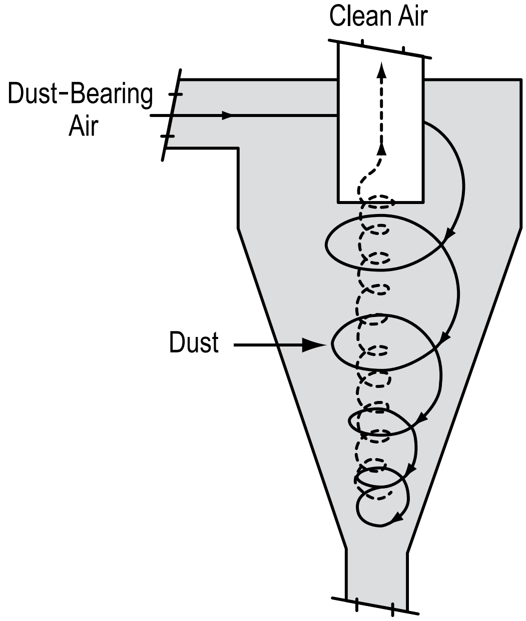

Figure 20.3

Cyclone dust-collection systems create a vortex—an internal tornado—that "flings" the dust out of the air stream.

Inertial Separators

Inertial separators separate dust from the air stream using a combination of centrifugal, gravitational, and inertial forces. These forces move the dust to an area where the forces exerted by the air stream are minimal.

The three primary types of inertial separators are:

A. Active settling chambers

B. Baffle chambers

C. Cyclones or centrifugal collectors

Active settling chambers operate under the assumption that confining the airflow to slow it will allow the airborne particles to fall out of the air. Baffle chambers, similar to active settling chambers but with baffles to slow and redirect the air, also allow the airborne particles to fall out of the air. Active settling and baffle chambers are not widely used as a sole collection method for a plant or process, due to their size requirements and poor efficiencies.

Cyclones are the most commonly used of these inertial-separator systems. They create a vortex—an internal tornado—that "flings" the dust out of the air stream (**Figure 20.3**). This whirling airflow created inside the structure creates a centrifugal force, throwing the dust particles outward toward the unit's walls. After striking the walls, particles agglomerate into larger particles and fall out of the air stream into a collection point, or discharge outlet, at the bottom of the unit.

There are single-cyclone separators that create two vortexes in one enclosure. The main vortex spirals coarse dust downward, while a smaller inner vortex spirals up from the bottom, carrying fine particles upward toward a filter. Multiple-cyclone units contain a number of small-diameter cyclones operating in parallel, with a common inlet and outlet. These units each create the two vortexes seen in the single-cyclone separator. These multiple-cyclone units tend to be more efficient, because they are taller—

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providing greater time for air to remain inside—and are smaller in diameter—providing greater centrifugal force. Cyclones must maintain a high rate of airflow in order to maintain the separation process.

To improve the efficiency of some cyclones, particularly those handling fine particles, the collecting surface of these units may be wetted with water.

Inertial-separator systems are often used as pre-cleaners to reduce the workload on more efficient dust-collection systems, because they do not provide an adequately efficient collection of fine, or respirable, particles. Performance suffers in high-humidity conditions. In the absence of plugging problems, these systems can operate with low maintenance costs, because they have no moving parts.

Wet Scrubbers

In wet-scrubber systems, a liquid (most commonly water) is sprayed down into the stream of dust-bearing air (**Figure 20.4**). The dust particles are captured by water droplets and fall out of suspension in the air. The dust and water mixture is released out the bottom of the collector as slurry and passes through a settling, or clarification, system to remove the materials.

An advantage of wet scrubbers is that they can be used in high-temperature applications. There is little chance for the dust to escape and become airborne again, and there are minimal fire and explosion hazards associated with scrubbers. Scrubbers also provide the opportunity to collect both particulate matter (dust) and gases, so they provide a dual benefit for some operations.

Wet scrubbers have some disadvantages, also. One disadvantage is that these systems have high operating and maintenance costs and may require freeze protection for cold-weather operations. For heavy dust conditions, these systems often need a precleaner, such as a cyclone. These systems will have high power requirements. There may be corrosion problems from the handling of the water and the material slurry. Water treatment is usually required for the contaminated water from the system. Recovery of the materials from the scrubber waste is typically difficult.

Electrostatic Precipitators

Electrostatic precipitators are often used to handle large volumes of dust-laden air at wide ranges of temperature and pressure. These systems apply a negative electrical charge, ionizing the particles as they pass into the collection area (**Figure 20.5**). The charged particles are then attracted and adhered to positively-charged electrode plates positioned inside the collection zone. "Rapping," or vibrating, of these electrodes then discharges the agglomerated dust by allowing it to move downward on the plates by gravity.

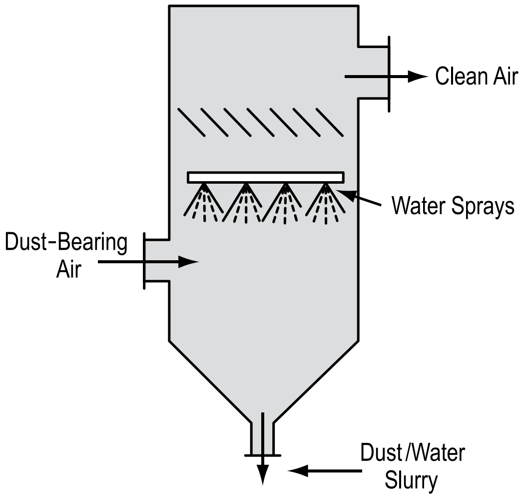

Figure 20.4

In wet-scrubber systems, a liquid (most commonly water) is sprayed down into the stream of dust-bearing air. The dust particles are captured by water droplets and fall out of suspension in the air.

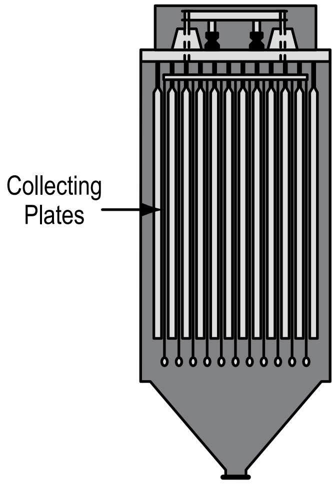

Figure 20.5

Electrostatic precipitators apply a negative electrical charge, ionizing the particles as they pass into the collection area. The charged particles are then attracted and adhered to positively-charged electrode plates positioned inside the collection zone.

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The four main components of all electrostatic precipitators are:

A. A power supply, to provide high-voltage, unidirectional current
B. An ionizing section, to impart a charge to particulates in the air stream
C. A means of removing the collected particulates
D. A housing to enclose the precipitator zone

There are two main types of precipitators:

A. High-voltage, single-stage

   Single-stage precipitators combine ionization and collection into a single step. They are commonly referred to as Cottrell precipitators.

B. Low-voltage, two-stage

   Two-stage precipitators use a principle similar to single-stage precipitators; however, the ionizing section is followed by a collection section.

Precipitators can be 99 percent effective on dust, including sub-micron particles, but they do not work well on fly ash from combustion of low sulfur coal, due to its high electrical resistivity. They work on other materials, including sticky and corrosive materials, in high-temperature or in high air flow environments, with minimal energy consumption. These systems require a large capital investment. Safety measures are required to prevent the exposure of personnel to the system's high voltage. Precipitators can cause an explosion threat when combustible gases are collected around the electric system.

Cartridge Filter Collectors

Cartridge filter collectors place perforated metal or plastic cartridges containing a pleated, non-woven filter media inside the dust-collector structure. The filter media used in these systems provides a larger collection surface area in a smaller unit size than other dust-collection systems. As a result, the size of the overall system can be reduced.

These systems are available in single-use systems—changing the filter while off line—and pulse-jet cleaning systems—allowing continuous-duty cleaning.

The drawbacks of these systems include the relatively high cost of replacement cartridges. High moisture content in the collected materials may cause the filter media to blind (become plugged), and the system itself requires higher levels of maintenance than other collection methods. Cartridge filters are generally not recommended for abrasive materials or applications where high temperatures are seen.

Fabric Dust Collectors

Perhaps the most common dust-separation technology is the use of fabric collectors, which are placed in structures commonly called baghouses (**Figure 20.6**). Fabric collectors use filtration to separate dust particulates from airflow. They are one of the most efficient and cost-effective types of dust collectors available and can achieve a collection efficiency of more than 99 percent for particulates 1 µm or less.

Fabric collectors utilize the dust itself to help perform filtration. A "cake" of the collected dust forms on the surfaces of the filter bags and captures dust particles as they try to pass through the bags.

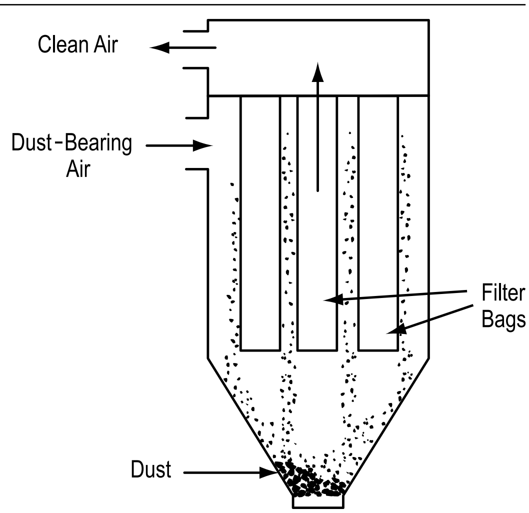


Figure 20.6

The most common dust-separation technology is the use of fabric collectors, which are placed in structures commonly called baghouses. Fabric collectors use filtration to separate dust particulates from airflow.

The bags—constructed of woven or felted cotton, synthetic, or glass-fiber material in a tube or envelope shape—need to be cleaned periodically, to reduce the level of dust cake and allow air to be drawn through the bag without overworking the exhaust fan.

Basic Principles

There are three basic principles of fabric dust collector, or baghouse, operations:

A. Cleaning efficiency depends on the dust-cake buildup on the filter surface: Performance is better from a filter with some cake buildup than from a new filter.

B. The quantity of airflow depends on the filter medium's permeability, the amount of dust in the airflow, the amount of buildup before filter cleaning, and the power of the reverse-cleaning blow.

C. The more permeable the filter cloth, the less efficient its collection, with or without a dust cake.

Collectors can be designed for "upflow" —in which dirty air passes up through the collector with clean air exiting the filters at the top of the collector—or "downflow"—with dirty air entering at the top and passing down through the collector with clean air exiting at the bottom. The downflow design operates in favor of the cleaning action and is generally more efficient.

Filter Cleaning

The cleaning of filters in a baghouse can be performed on-demand—when the filter is fully loaded, as determined by a specified pressure drop across the filter media. Automated cleaning can be performed off-line—when the collector is shut down—or on-line—which allows for uninterrupted collector operation.

Three common methods of cleaning are:

A. Mechanical shaking

With mechanical shaking, the air passes from the inside to the outside of the bag, with the dust captured on the inside of the bag. The bags are cleaned by shaking the top mounting bar from which the bag is suspended. This is performed off-line: The system needs to be stopped for cleaning.

B. Reverse airflow

With reverse-air systems, the bags are fastened at the bottom. Air moves up through the bag from inside, with the material collecting on the inside. Bags are cleaned by injecting clean air into the dust collector in a reverse direction, so the bag partially collapses, causing the dust cake to crack off the bag wall and fall into the hopper bottom. The system needs to be stopped for cleaning.

C. Reverse jet

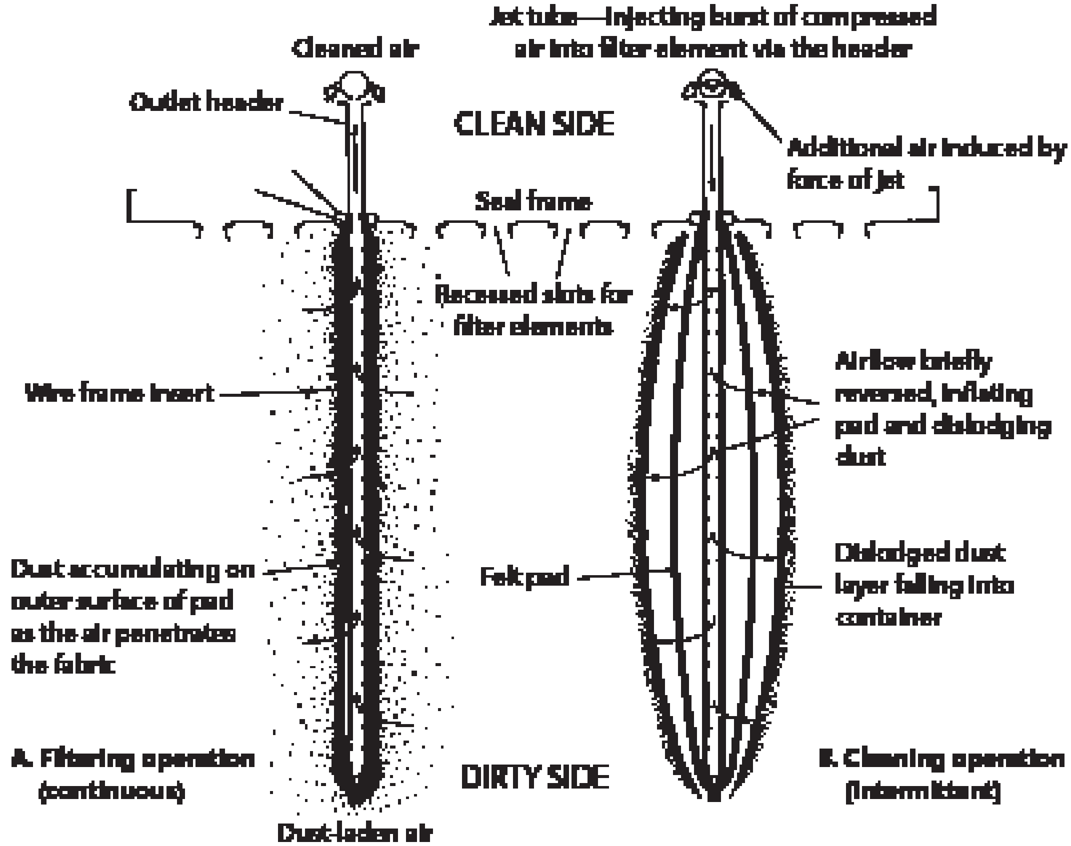
Reverse-jet systems provide for on-line cleaning. With this reverse-jet system, the filter bags are fastened from the top of the baghouse and supported by metal cages. Dirty air flows from the outside to the inside of the bags, leaving the dust on the outside of the bag. The cleaned air moves up through the bag and exits at the top of the cage (**Figure 20.7**). Bags are cleaned by discharging a burst of compressed air into the bags at the top. A venturi nozzle at the top of the bag accelerates the compressed air. Since the duration of the compressed-air burst is short (typically one-tenth of a second), it acts as a rapidly moving bubble, which flexes the bag wall and breaks the dust cake off, so it falls into the collection hopper (**Figure 20.8**).

Reverse-jet systems provide more complete cleaning than shaker or reverse-air cleaning designs. The continuous-cleaning feature allows them to operate at a higher air-to-media ratio, so cleaning efficiency is higher, and the space requirements are lower than for other designs.

A baghouse collection system with fabric filters can be up to 99 percent effective in removing respirable dust emissions. The filtration bags are relatively inexpensive

Figure 20.7

With this reverse-jet system, the filter bags are fastened from the top of the baghouse and supported by metal cages. Dirty air flows from the outside to the inside of the bags, leaving the dust on the outside of the bag. The cleaned air moves up through the bag and exits at the top of the cage.



compared to other methods, and the large number of manufacturers in the marketplace ensures competitive pricing. The disadvantages of these systems include problems in applications above 260 degrees Celsius (500°F) or in high-humidity conditions. Some systems require entry into the baghouse for replacement of filter bags, with employee exposure to a confined space—with high dust levels and the possibility of a spark igniting an explosion being major concerns.

Figure 20.8

Reverse-jet systems provide for on-line cleaning. With reverse-jet cleaning, the filters are cleaned by discharging a burst of compressed air into the bags at the top. This air flexes the bag wall and breaks the dust cake off so it falls into the collection hopper.

Fans and Motors

The fan and motor system supplies mechanical energy to move contaminated air from a dust-producing source through a dust collector. Centrifugal fans and axial-flow fans are the two main types of industrial fans used to move air through dust-collection systems.

These fans are driven by electric motors. Both open and totally enclosed motors are available in models that are dust-ignition-proof and rated for hazardous duty, to guard against fire hazards in potentially hazardous dust-laden environments.

Suppliers of dust-collection systems will have recommendations for suitable fan and motor size and type.

CENTRAL, UNIT, AND INSERTABLE

Central Systems

The central method of handling dust collection from the total air for a conveyor system would be to connect all the individual collection points by means of ducting to a single dust collector that is installed at a single, remote location (**Figure 20.9**). This collector contains fans, filters, and a collection hopper. The filtration system would handle all the dust extracted from the entire conveying system, collecting it for disposal, or feeding it back onto the conveyor or into the process at a convenient point.

Central systems are particularly suitable when the process has all dust-generating points operating at one time, and/or it is desirable to process all dust at one site. It is also useful when there is limited space near the conveyors for dust-collection and -processing equipment or where the explosion risk requires the dust collector to be positioned at a safe distance. In some processes, it is better to remove fine particles from the main material flow. Central dust collectors may be preferred when handling hot dust, because its temperature may be reduced as the dust travels to the central collector or by adding "fresh air" into the flow.

The drawbacks of the central dust-collection system are its requirements for more complex engineering and lengthy systems of ducting. As all dust-gathering points (pickups) must operate at once, the central method may present higher operating costs. The need to service any one component requires that the entire system be shut down. The fan motor needed for a central collector could be much larger, due to the increase in static pressure and the losses from ductwork as the system grows. The collected dust will require an additional materials-handling system, which—if not properly sized and operated—can, in turn, create its own dust problem.

Unit Systems

Unit systems consist of small, self-contained dust collectors applied at individual, or conveniently grouped, dust-generation points (**Figure 20.10**). The collector units are located close to the process machinery they serve, reducing the need for ducting. Typically, these unit dust-collection systems employ fabric filters for fine dust, with cyclone collectors used for coarse dust applications.

The unit systems benefit from reduced ducting and the resulting reduction of engineering and installation expense. These systems offer reduced operating expense,

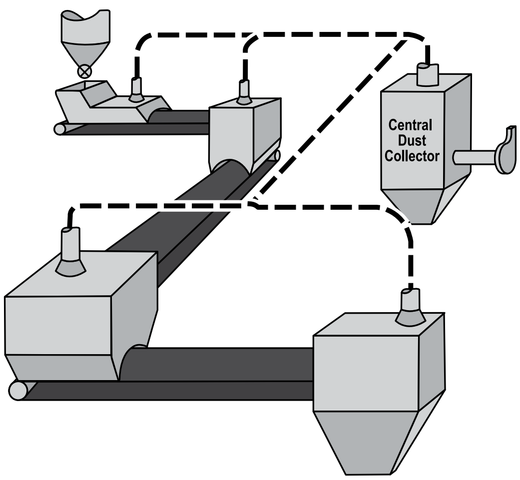


Figure 20.9

A central dust-collector system uses a single collector system (baghouse) to remove dust from a number of different points or operations in the plant.

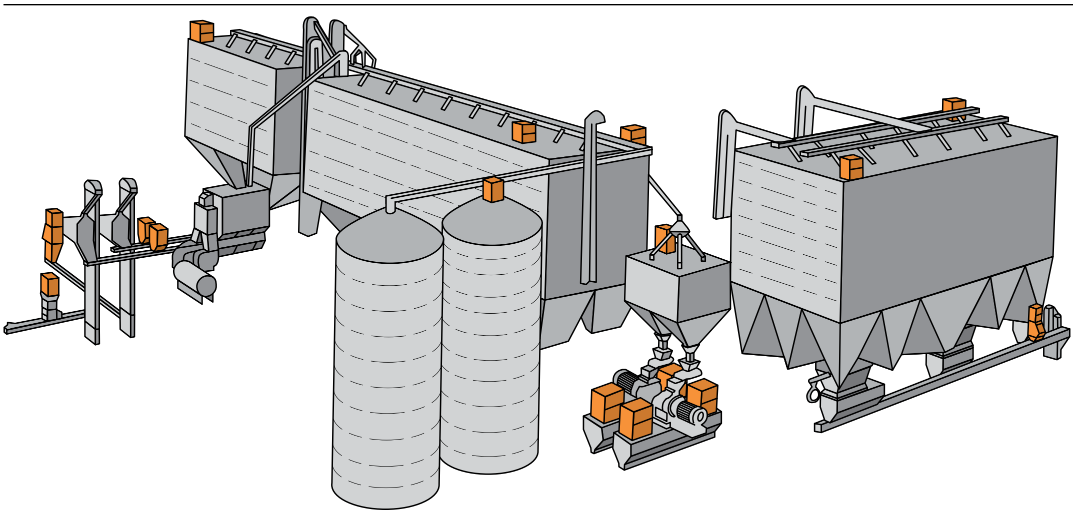


Figure 20.10

The unit system places smaller dust collectors near individual or closely grouped dust-generation points. (Note: Dust collectors are shown in orange.)

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because some of the units may need to run only intermittently. Each unit can be serviced independently, without the need to shut down the entire dust-collection system.

The unit method requires space adjacent to each dust source. The disposal of dust from each of the unit collectors may require additional dust-handling mechanisms.

The advantages of unit collectors include low space requirements, the return of collected dust to the main material flow, and low initial cost. However, their individual dust-holding capacities, servicing facilities, and maintenance periods are sacrificed to achieve this small size.

Figure 20.11

Insertable systems place insertable dust collectors within the dust-generating equipment, such as conveyor transfer points.

Figure 20.12

Insertable dust collectors control contamination at its source. Installed above transfer points or other dust sources, they are small and self-contained, consisting of a fan and some form of dust filter.

Figure 20.13

Insertable collectors are suitable for individual, isolated, or portable dust-producing operations, such as bins, silos, transfer points, or mobile conveyors.

Insertable Collectors

An extension of the unit concept is the insertable system, in which the dust-collection system is incorporated within the dust-generation point itself (**Figure 20.11**). The filter is built into the enclosure around the dust-creation point, with the aim of controlling the dust at its source. The dust is not "extracted;" it is collected and periodically discharged back into the material stream within the enclosure.

Insertable dust collectors control contamination at its source. Installed above transfer points or other dust sources, they are small and self-contained, consisting of a fan and some form of dust filter (**Figure 20.12**). These collectors can use the positive pressure of the conveyor air, or they can be fan powered. The systems are designed to allow the filter bags or cartridges to be arranged vertically, horizontally, or at any angle. Insertable collectors eliminate ducting, reducing installation costs as well as energy costs during operation. They are suitable for individual, isolated, or portable dust-producing operations, such as bins, silos, transfer points, or mobile conveyors (**Figure 20.13**).

A principal advantage of this system is the elimination of ductwork. The insertable system is often more economical than centralized or unit systems, unless there are many points in close proximity that require dust control. As the static pressure is much lower, and there are no losses in pressure due to the ductwork, the fan motor is normally smaller than with other systems. The insertable system will operate only when needed—when the piece of equipment it is installed upon is running—reducing energy requirements. The dust is returned to the process at the point of generation, so there is no need for a separate dust-handling and disposal system.

Drawbacks to the insertable system include the use of compressed air to clean the filter. The compressed-air systems at many plants are already operating at a capacity, so addition of the system-standard reverse-jet cleaning system may overtax the plant air system. In addition, the use of compressed air to return dust to its source can cause a puff of airborne dust to escape from the system's entry and/or exit areas.

SIZING AND PLACEMENT

Filter Material and Size

After specifying a style of dust-collection system, the next step is selecting the material for the filter media. Selecting a filter media of the correct material and size is a critical function. Advancements in filter design allow the designer to pinpoint the proper style and material for an application based on the specifications of the dust to be collected. For example, if the collected dust is at a temperature that is near the limits of a standard filter, a high-temperature medium can be selected. With combustible materials, an antistatic filter media should be used.

Many filter manufacturers publish lists of air-to-cloth ratio for their various products. The air-to-cloth ratio is defined as the flow of air in cubic meters per second (ft^3/min) divided by area of filtration media in square meters (ft^2). The proper air-to-media ratio depends on the type and concentration of dust and the type of filter media. These lists should serve as guidelines, to be modified by variables such as dust particle size, process temperature, and moisture presence. A representative of a system supplier can provide detailed application information.

Most filter media require a dust cake on their surface to attain the desired collection efficiency. Too many people think that the cleaner the bags, the lower the emissions. This is not true: Over-cleaning the dust bags will lose the benefit of a dust cake on the filter and, therefore, reduce the operating efficiency.

Dust-collector manufacturers typically offer a valuable option in a Delta P (ΔP) controller, a device that automatically "pulses the baghouse" to clean the filters when the pressure differential—the difference between the clean and dirty sides of the filter—increases above the recommended value.

Dust Pickup Size and Location

An old saying goes, "The three most important things for a retail business are location, location, and location." The same is true in dust collection: The most critical element in the design of the dust-collection system is the location of the pickups.

It is important that the material fines be allowed a chance to settle, either of their own accord or with the addition of a dust-suppression system, before the dust-collection points are reached. Otherwise, energy will be wasted removing dust that would have quickly settled on its own, and the dust-collection system will be larger and more expensive than would otherwise be necessary. The location should be selected to minimize the capture of coarse particles, which settle quickly, and instead capture only fine dust.

For transfer points, multiple dust-collector pickup points are usually required (**Figure 20.14**). The main dust-collection pickup point is positioned approximately two times the belt width after the load point to collect three-fourths of the volume of moving air. Often, a secondary dust-collection pickup is located at the belt entry area of the transfer point (at the tail box and directly before the load zone). This pickup should take in approximately one-fourth of the total calculated air movement (**Figure 20.15**).

The Size of a Collection System

The American Conference of Governmental Industrial Hygienists' book *Industrial Ventilation* is a widely-used resource for information on dust-control systems. Originally published in 1951, this book offers standard calculations for many dust-control

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situations, including conveyor transfer points. However, while the specifications provided in *Industrial Ventilation* may prove useful in some circumstances, this volume should not be considered a reference for conveyor systems. Experience has shown that much of the data in *Industrial Ventilation* is no longer appropriate for transfer points. Reputable suppliers who have practical field-experience in designing, installing, and maintaining dust-collection systems for belt conveyors have developed new and more sophisticated methods of sizing and placing dust-collection systems.

DOWNFALLS

Downfalls of Dust-Collection Systems

Dry collection systems to clean dust-laden air work well in both warm and cold climates. These dust systems, regardless of the selection of a central, a unit, or an insertable collection system, may require a large amount of space for equipment and ductwork, making them expensive to install. Operating and maintenance costs are multiplied as the size of the system increases. Changes or alterations required after system start-up may be hard to implement without modification of the entire system. Even filter bag replacement can be costly and time-consuming. A leak in a filter bag can affect the efficiency of the entire collector; it can be difficult to identify and replace the leaking filter. If the collected dust must be returned to the material flow, care must be taken to prevent the dust from becoming re-entrained into the air, requiring collection at the next pickup point.

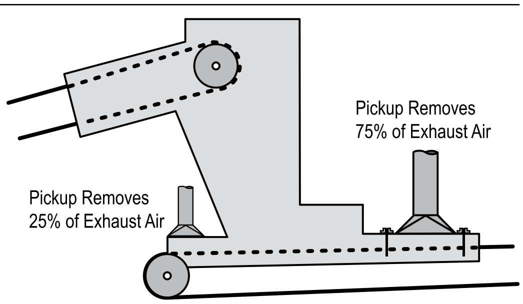

Figure 20.14

Many transfer points require more than one dust pickup location, with the main pickup positioned approximately two-thirds of the belt width after the load point.

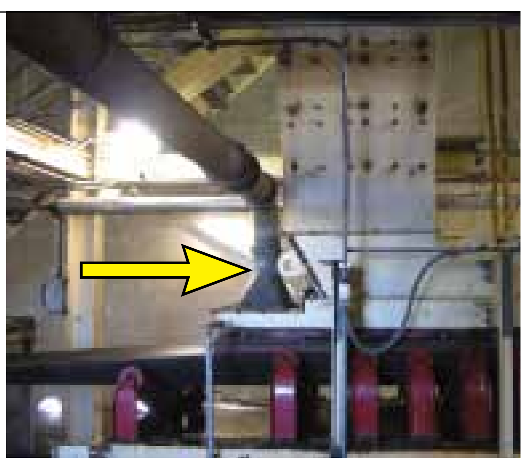

Figure 20.15

A secondary dust pickup is located at the belt entry area of the transfer point (at the tail sealing box and directly before the load zone).

Perhaps the biggest problem in sizing a dust collector is the variation in the properties and quantities of the bulk materials being conveyed. The dust-collection system must be designed and operated for the worst conditions, even though those conditions are expected to occur on only rare occasions.

Handling of Collected Materials

The final requirement in any dust-control system is providing a mechanism to dispose of the dust after it has been collected. The steps that must be considered include removing the dust from the collector, moving the dust, storing the dust, and treating the dust for reuse or disposal.

The handling of collected material can be a problem, particularly if the material is to be returned to the process. Care must be taken to avoid affecting the process through the introduction of an overload of fine particles at any one point. In addition, collected dust must be returned into the main material body in a manner that avoids re-energizing the dust so it would need to be collected again at the next pickup point. Because the collected dust particles are small enough to readily become airborne again, they are often subjected to an extra combining process. The collected dust can be put through a mixer, pug mill, or pelletizer before re-introduction to the general material-handling system. In some industries, collected dust cannot be re-introduced to the process and, therefore, must be sent to a landfill or otherwise disposed of as waste material.

SYSTEM MAINTENANCE

Consultation should be made with dust-control system suppliers to determine the proper service intervals and procedures to maintain efficient operation.

It is important that dust-control systems be designed to allow efficient access to the enclosure and to allow inspection and service of filter bags and other components.

TYPICAL SPECIFICATIONS

A. Dust collector

The conveyor transfer point will be equipped with a dust-collector system to capture airborne particles and return them to the main body of material without the use of additional dust-handling equipment.

B. Transfer-point location

This dust collector will be installed inside the transfer-point enclosure, so it can operate without ducting or the high-powered fans that would be required to move dust-laden air to a central baghouse.

C. Integral fan

The dust collector's integral fan will pull dust-laden air through its filter elements on the inside of the enclosure.

D. Filter bags

The dust-collection system will incorporate a set of wire-frame mounted, envelope-shaped filter bags for optimum airflow and thorough cleaning. This filter system will capture 99 percent of all particles larger than one micron. The filters shall be serviceable from the clean-air side of the collector unit.

E. Reverse-jet cleaning

Periodic cleaning of the filters will be accomplished with an automatic reverse jet of compressed air into the filter bags. This will create a momentary reversal of air flow, inflating the filter element to dislodge the accumulated dust. The collected filter cake will return to the main material stream.

F. Access doors

A removable access door will allow access to the clean-air chamber.

G. Safety measures

To minimize the risk of explosion or fire, a spark-free fan with a motor rated for the appropriate hazardous duty, grounded dust filters, and a stainless steel lining inside the dust-collection hopper should all be utilized with any dust-collection system.

SAFETY CONCERNS

As noted elsewhere in this book, there are significant risks of fire and explosion in any enclosed area, such as inside a dust collector, where airborne particulates can become concentrated. *(See Chapter 17: Dust Management Overview.)*

It should be noted that many dust-collection systems constitute enclosed spaces requiring confined-space entry permits and procedures. The corresponding precautions should be taken when dispatching personnel to inspect or maintain the filters or other components.

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TYPICAL DUST-COLLECTION APPLICATION

A belt at a concrete plant is suffering from an excessive amount of dust escaping from the transfer chute. The transfer chute is well constructed but cannot be expanded in any way.

Material. . . . . Cement

Transfer Point . . Good, but not expandable

Airflow. . . . . 0,75 m^3/s (1600 ft^3/min)

Collection Method . . . . . . Insertable Dust Collector

This is a good application for an insertable dust collector. There is a dust problem. The transfer point is already established, but it can not be expanded to utilize passive dust control. The airflow is too large to use a passive filter bag.

The insertable will place the collected dust back onto the conveyor as larger solids, eliminating the need for a secondary operation to handle the collected dust. An insertable will also keep the relatively valuable cargo on the conveyor belt.

The insertable would be installed on the conveyor belt transfer point near the outlet of the transfer chute. It would pull the excess air and dust through a set of filters. At regular intervals, air would be pulsed through the filters, and the now-agglomerated dust particles would fall back onto the conveyor.

ADVANCED TOPICS

Selection and Application of an Insertable Dust-Collection System

An insertable collector is a self-contained piece of dust-collection equipment. To properly size one, total airflow, combustibility of the material, and basic size restraints of the area on top of the transfer chute need to be known. The designer also needs to know the air-to-cloth ratio recommended for the material and the collector being considered. This value can be obtained from the collector manufacturer and is usually based on the material conveyed.

Below are two examples demonstrating the process needed to select an insertable collector and the effect the air-to-cloth ratio has on that selection:

A. Anthracite coal chute

Given: An anthracite coal chute generates 50 cubic meters per minute (1750 ft^3/min) of air; the collector requires an air-to-cloth ratio of 2,75 meters per minute (9 ft/min) for this coal

Find: The basic requirements of an insertable dust collector

Solution: To find the total area of filter media required, divide the airflow by the air-to-cloth ratio; consider the combustibility of the material

Given that the material is coal, this application would require an insertable dust collector that is rated for the appropriate hazardous duty.

Answer: This application would need an insertable dust collector that could pull 50 cubic meters per minute (1750 ft^3/min), have 18 square meters (194 ft^2) of filter media, and be rated for the appropriate hazardous duty.

B. Sub-bituminous coal chute

Given: A sub-bituminous coal chute generates 50 cubic meters per minute (1750 ft^3/min) of air; the collector requires an air-to-cloth ratio of 2,1 meters per minute (7 ft/min) for this coal

Find: The basic requirements of an insertable dust collector

Solution: To find the total area of filter media required, divide the airflow by the air-to-cloth ratio; consider the combustibility of the material

Given that the material is coal, this application would require an insertable dust collector that is rated for the appropriate hazardous duty.

Answer: This application would need an insertable dust collector that could pull 50 cubic meters per minute (1750 ft^3/min), have 24 square meters (250 ft^2) of filter media, and be rated for the appropriate hazardous duty.

The 24 square meters (250 ft^2) insertable dust collector unit will be substantially larger than the collector in the previous example, so physical room—area on top of the transfer chute—must be verified.

Air Velocity and Dust Management

Understanding and controlling the speed of the air—pick-up velocity, capture velocity, and transport velocity—will greatly influence the amount of dust that becomes airborne.

Pick-Up Velocity

A material's pick-up velocity is the speed of the surrounding air required to lift the dust particle from a resting position into the air stream. The pick-up velocity for a material is dependent on the size and moisture content of its fine particles. The pick-up velocity for most materials is in the range of 1 to 1,25 meters per second (200 to 250 ft/min), with smaller, drier dust particles closer to the low end of the speed range, and larger, wetter dust particles closer to the high end.

Capture Velocity

Once the dust particle is suspended in the air, the amount of air speed required to gather the moving dust particle into the dust-collection system is called capture velocity. The capture velocity is dependent on how far the dust particle is located from the capture device (pickup) and the size and moisture content of the dust particle. Most properly designed collection hoods require the capture velocity to be in the range of 1 to 3,5 meters per second (200 to 700 ft/min), with the higher capture velocities required for heavier, wetter dust particles and lower capture velocities for lighter dust particles with less moisture.

There is a simple formula to determine the capture velocity of dust particles based on their density and diameter (**Equation 20.1**).

It is possible to calculate the exit velocity of air from a given transfer point and then work back to calculate the size of particle that would fall out in the air stream before it leaves the transfer point.

Transport Velocity

Transport velocity is the speed of the air required to keep an airborne dust particle in suspension in the ducts transporting the dust to the dust collector. These transport velocities are based on the size of the dust particle (**Table 20.1**).

DUST COLLECTION: ONE PIECE OF THE PUZZLE

In Closing...

This chapter has presented only an overview of the capabilities and considerations of dust-collection and -control equipment. It would be wise to consult with suppliers specializing in this equipment to receive specific recommendations.

While valuable additions to materials-handling systems, dust-collection systems are only one piece of the dust-management puzzle. The more successful a transfer point is in minimizing the amount of induced air and in loading cargo in the direction and at the speed of the receiving belt, the less airborne dust will be created. The more successful the enclosure and sealing of a conveyor or transfer point, the less fugitive dust will be released. The more successful a dust-suppression system, the less dust will be present in the air to be collected. Successful application of the principles of enclosure and suppression work to minimize the required size of a dust-collection system—and reduce the wear and tear and the risk of overload on that system. A pyramid composed of the three systems—enclosure, suppression, and collection—allows a plant to be successful

Equation 20.1

Capture Velocity of Dust Particles

$$v_t = k \cdot \rho_s \cdot D^2$$

Given: *A particle that is 0,006 meters (0.020 ft) in diameter and has a particle density of 800 kilograms per cubic meter (50 lb_m/ft^3).* ***Find:*** *The capture velocity of the particle.*

Variables		Metric Units	Imperial Units
v_t	Capture Velocity of a Falling Particle in Still Air	meters per second	feet per second
k	Conversion Factor	3,187 X 10^3	15.6 X 10^3
ρ_s	Particle Density	800 kg/m^3	50 lb_m/ft^3
D	Diameter of the Particle	0,006 m	0.02 ft

Metric: $v_t = 3{,}187 \times 10^3 \cdot 800 \cdot 0.006^2 = 91{,}8$

Imperial: $v_t = 15.6 \times 10^3 \cdot 50 \cdot 0.02^2 = 312$

v_t	Capture Velocity of a Falling Particle in Still Air	91,8 m/s	312 ft/s

Table 20.1

Dust Transport Velocities Based on Dust Particle Size

Material	Metric	Imperial
Fine Light Dusts *(flour, PRB, coal)*	10 m/s	2,000 ft/min
Fine Dry Dusts and Powders *(foundry sand, cement)*	15 m/s	3,000 ft/min
Average Industrial Dust	18 m/s	3,500 ft/min
Coarse Dust *(quarry dust)*	20 to 23 m/s	4,000 to 4,500 ft/min
Heavy or Moist Dust *(underground coal)*	23 m/s and more	4,500 ft/min and more

in controlling the amount of dust released into the environment.

Many dust-control projects have produced less than expected results when equipment is misapplied or simple “rules of thumb” are used for sizing systems. Successful selection, installation, and maintenance of dust-control systems require specialized knowledge, which is available from equipment suppliers or their authorized representatives.

Looking Ahead...

This chapter on Dust Collection is the fourth and final chapter in the section on Dust Management. The following chapter begins the section on Leading-Edge Concepts with a discussion about Clean, Safe, and Productive Conveyors by Design, followed by Engineered Flow Chutes in Chapter 22 and Air-Supported Conveyors in Chapter 23. Chapters 24 and 25 focus on Belt-Washing Systems and Material Science.

REFERENCES

20.1 *Dustcollectorexperts.com* offers a detailed and useful tutorial on various dust-collection systems. This noncommercial web site provides background information and links to a number of suppliers of dust-collection equipment.

20.2 Mody, Vinit and Jakhete, Raj. (1988). *Dust Control Handbook (Pollution Technology Review No. 161)*, ISBN-10: 0815511825/ISBN-13: 978-0815511823. Park Ridge, New Jersey: Noyes Data Corporation.