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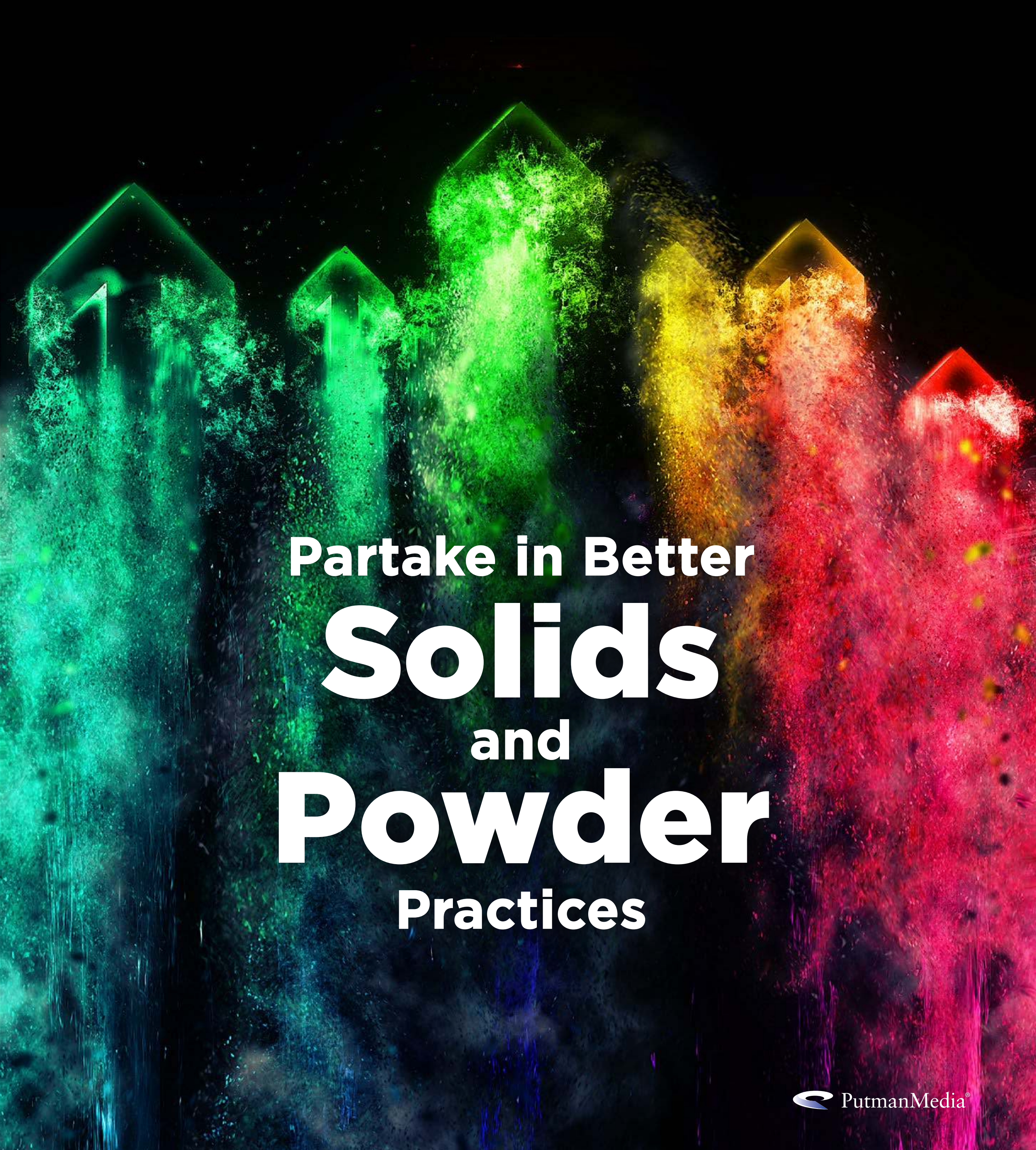

Partake in Better Solids and Powder Practices

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Profit from Your Bad Experiences

Flops and flubs frequently can foster future successes

By Tom Blackwood, Contributing Editor

Engineering schools are much better at including solids processing in the curriculum than they were when I taught. Unlike other colleges then, at least my university had more than one type of crystallizer. Our methods were crude but stressed fundamentals that later served us quite well.

For example, I assigned an experiment that required getting the flow rate of a slurry using an instrument in the process. My challenge to the class was: How do we know if the instrument is accurate? My students thought it over and finally, in despair, concluded that the old bucket-and-stopwatch method would work. They had travelled all the way from the Orient to apply the same method used at home. Don't dwell on the negative in such situations, though — knowing the basis of your actions actually makes a bad experience a good one. We must look at those past episodes to progress, especially in solids processing.

When I worked in industry, my chemist colleagues often remind me that I'm a chemical engineer, not a chemist. However, that never has stopped me from putting in my two cents. I haven't forgotten my chemistry and have used it in a very profitable manner.

We were developing an emissions reduction process that would use conventional tailgas-cleaning methods. It was very expensive and not certain to reach the goal. Many years earlier, I had worked on a particulate control project and discovered that cyclones hold a large inventory of solids that could cause the device to clog up. However, if the solids are reactive, they will be consumed in the cyclone. Our emission was very reactive and only became a fine particle in the combustion process. Designing the cyclone to maximize residence time allowed the particles to react and agglomerate there. The project cost less than 20% that of the original plan and met all goals. Don't forget about chemistry.

Many companies commonly overspend the budget on equipment, rationalizing that the extra expense promises longer life and additional features. I even heard one engineer say that a dollar spent on capital resulted in a dollar of profit. That's certainly no longer the case. So, instead, spend the time during development to check for alternative routes that can eliminate poor equipment choices and bad experiences. For instance, in my September 2018 column ("Conquer Crystallization Challenges," https://bit.ly/36Fdf2C), I outlined five options to explore when looking at a new crystallization process. Often, a chemist will focus exclusively on tried-and-true methods and fail to consider other options. Normally, generating super-saturation and maintaining a slow growth is the standard. It's easy to overlook seeds and sonication, as well as removing excess nuclei to raise the particle size distribution (PSD). Sometimes, the extra time to make a large crystal isn't worthwhile when you can easily filter and agglomerate a smaller size to produce a better bottom line.

The trouble with solids is that fines don't follow the other particles and can even cluster to behave like a larger particle. You can prevent segregation by doing the correct shear-testing experiments and knowing the frictional characteristics of your particles. We had a bin that had been used on another product. The two materials had roughly the same particle size, density and PSD, so the plant felt the bin would work with the new material. Well, it didn't. Addition of vibrators didn't help. The facility was about to abort the conversion when I noticed the discharge rotary valve didn't have a vent and was feeding solids erratically. It looked like the rotary valve was fluidizing the solids, which then collapsed. We cut off the cone and fashioned a crude vent/hopper. Lo and behold, the material flowed properly. It turns out the PSD was more of a $\chi 2$ shape and had more fines at the low end of particle size than the previous material. Shear testing of the new material would have shown the need for the larger opening ahead of the rotary feeder and that the vibrators were a waste of time.

Getting good results in solids processing requires experience and, sometimes, we can learn from the bad to produce a good result. ●

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Don’t Fall Short with Transfer Chutes

Understand key points about these bulk-material-handling units

By Amin Almasi, mechanical consultant

Transfer chutes guide and control bulk materials moving from one piece of equipment or place to another, for instance, from one conveyor to the next. These chutes find wide use in many configurations and arrangements.

While chutes are important components in material handling systems, they usually don’t get adequate attention. As a result, they often create bottlenecks in the systems and require extensive maintenance and repair. It is far cheaper to carefully engineer and manufacture a chute than to deal with the consequences of a poorly designed or fabricated one. So, here we will discuss practical pointers on engineering, operation reliability and maintenance of chutes.

DESIGN ISSUES

Ensuring smooth flow of bulk materials without any accumulation or plugging anywhere depends on the proper size and slope of chutes. Different guidelines exist for the cross-section, sizing, slopes and dimensions of chutes. Minimum cross-sectional area of chutes often is specified as 5–8 times the area of cross load of the preceding conveyor (or upstream equipment). Avoid any ratio below 4.5.

Undersized chutes have resulted in blockages and other problems. In practice, chutes should be able to store some volume of material in case of emergency, for instance, malfunction, a temporary stop of the next conveyor or equipment or a surge in upstream conveyor/equipment.

Avoid direct impact of bulk material on the next conveyor belt or piece of equipment. While a very steep angle is not desirable, the slope should suffice to ensure good flow of the bulk material. The optimum angle of inclined surfaces of chutes depend on the specific service and bulk material. However, as a rough guideline applicable to many materials, using a surface inclined at 65° or even 70° of valley angle will properly guide bulk materials. Valley angles below 55° are risky. In addition, the chute design should have a minimum amount of throat constriction and have sufficient support.

Unfortunately, many traditional designs for chutes don't meet these cross-section and valley angle guidelines, undermining prospects for smooth and trouble-free flow of bulk materials. Indeed, such chutes often provide poor performance.

The bottoms of chutes are frustums of cones or truncated pyramids to aid the discharge of materials. Good chute design requires more than having the correct cross-sectional area and slope.

When bulk material discharges to a chute and impacts the chute surface, its velocity decreases. The larger the impact angle, the bigger the change in velocity. Sliding friction with the chute surface can decrease the material stream velocity even further. If the friction between the bulk solid and the chute walls and wear liners becomes too great, bulk material flow may halt on the chute surface, creating a plugging condition; this not only can cause operational problems but also can present a set of new dangers such as risk of fire or explosion. In addition, flow issues such as "arching," "ratholing," etc., can occur. Poor chute performance also can lead to material spillage, considerable dust generation and many other operational problems.

Moreover, when flow abruptly resumes again such as when arches and ratholes collapse, sudden dynamic forces act on the chute or surrounding equipment. These forces can cause structural damage. Also, the development of eccentric flow channels within a chute, particularly due to multiple or offset outlets, can result in non-uniform loading along the outer walls of the chute that may cause wrinkling or buckling of the chute.

The internal surface of a chute must contend with constant abrasion from the flow of material and can suffer wear and damage. Sometimes, such degradation is very fast and can be catastrophic. So, providing replaceable liners made of suitable abrasion-resistant material nearly always is necessary to cope with the impact and erosion. The selection of lining material depends on the service and application. Alloy steel is widely used but ceramic, rubber and other types of linings are available.

NEW TRANSFER CHUTES
Figure 1. Sturdy chutes already are in place as belt conveyor is being constructed.

ENSURING ADEQUACY

The engineering, manufacturing and operation of a chute depends on knowing the properties of the bulk material in relation to the flow surfaces. Serious flow problems can result from not having accurate data or not testing the actual bulk material transported and the actual lining considered for the chute. Data from the testing of the specific bulk material and the particular construction materials, such as alloy steel or ceramic liners, are critical. These data will help predict the flow of the material through the chutes and, thus, enable coming up with a design to reduce wear on components and eliminate the escape of fugitive material like spillage and airborne dust.

Chutes should be strong and rigid to resist massive forces and potential erosion and corrosion (Figure 1). For commonly used applications, chutes usually are constructed from steel plates of 8-, 10-, 12- or 16-mm thickness or more. Specifically, small and medium chutes (bunkers, hoppers, etc.) generally use 8-, 10- or 12-mm plates. Large chutes (or silos) might need thicker plates, sometimes even 16- or 20-mm ones, depending on load calculations and modelling.

Ease of maintenance is a key consideration. Chutes often are constructed in flanged sections connected with bolting. The number and sizes of bolts are important. As an indication, common chutes use M16 or M20 bolts. Sections requiring removal for maintenance most often are fitted with lifting eyes or lugs located in convenient positions. Frames, flanges, supporting structures or head integral with plate fabricated items should be made from thick plates or properly selected profiles; such flanges typically are fabricated from 16- or 20-mm (or even thicker) plates.

A chute usually comes with a large hinged inspection door — generally at least 600 mm × 600 mm — to enable the clean-out of blockages and to ease inspection and maintenance; necessary maintenance tools may mandate even larger dimensions. The inspection door should be dust tight as well as easily opened and closed without the use of tools.

Gates find wide use in material handling systems to control flow of material in transfer points and different chute systems. They may be placed on the bottom or side of bins, tanks, hoppers or similar equipment to feed materials onto conveyors or other material-handling equipment. However, gates also have other applications — for instance, a flop gate can enable feeding from a single source to two locations. Gates come in many different types and models; they can be manually operated or powered by electric motors or pneumatic actuators. All too often, gates suffer operational problems because of lack of adequate attention to their design, engineering and operation.

Using a proper simulation method to observe and verify the flow of bulk materials in chutes is extremely important. Many simulation and modelling methods, such as discrete element modelling, suit this purpose. These can provide an excellent way to understand material stream flow behavior in a given configuration and enable ensuring optimum material stream trajectory. To reduce wear, you should minimize free fall heights and changes in the direction of material flow. This not only decreases impact forces but also attrition, dusting and fluidization of fine materials. You also can limit dusting by keeping the material in contact with the surface, concentrating the material stream, centering the stream and ensuring it stays in the direction of flow, and maintaining as constant a velocity as possible through the equipment.

It also is necessary for the entire cross-sectional area of the outlet to be active. Any system or equipment used in the outlets should be capable of continuously withdrawing bulk material from the entire outlet. A restricted outlet (e.g., due to a partially open slide gate) will result in funnel flow with a smaller active flow channel regardless of the outlet configuration.

BELT CONVEYOR CONSIDERATIONS

When feeding a bulk material containing a mixture of fine and lumpy material to a

Each service and application has an optimum chute angle — usually between 60° and 75°.

belt conveyor, you can arrange the chute to first deposit the fines on the belt. This bed of fine material then acts as an impact absorbing layer for the more-severe lumpy material.

Off-center or improper loading of the belt is a major problem that poor chutes can create. A chute should place bulk materials in the center of the belt. The direction of the material down the chute should match the direction of the belt travel. The speed of the discharged materials should equal as closely as possible the belt speed. The speed of the bulk material as it leaves the chute depends on the velocity of the material entering the chute, the chute angle, the fall, the material density and the flowability of the material. To increase the speed of material, use a steep chute angle — but angles above 75° result in a rapid decrease in the forward speed. Conversely, reducing the chute angle raises the material speed in the direction of belt travel — but angles less than 55° cause slow flow of the material through the chute.

Each service and application has an optimum chute angle; this optimum angle usually is between 60° and 75°. Heavier materials, because they flow more quickly through the chute, can get by with a relatively smaller chute angle, while light materials require a steeper angle. Lumpy materials tend to tumble and bounce in steep chutes, impeding the material flow. Therefore, while increasing the chute angle is desirable for light materials, for lumpy ones you should limit the chute angle to not more than 70° to prevent this tendency.

In many instances, the material may enter the chute at a very high velocity. A relatively low chute angle would limit, and possibly could retard, the material speed. However, opting for such a chute angle isn't recommended practice unless the exit speed is close to that of the belt. An alternative means of limiting high lump velocities is to hang baffle bars or similar devices in the path of the lumps. ●

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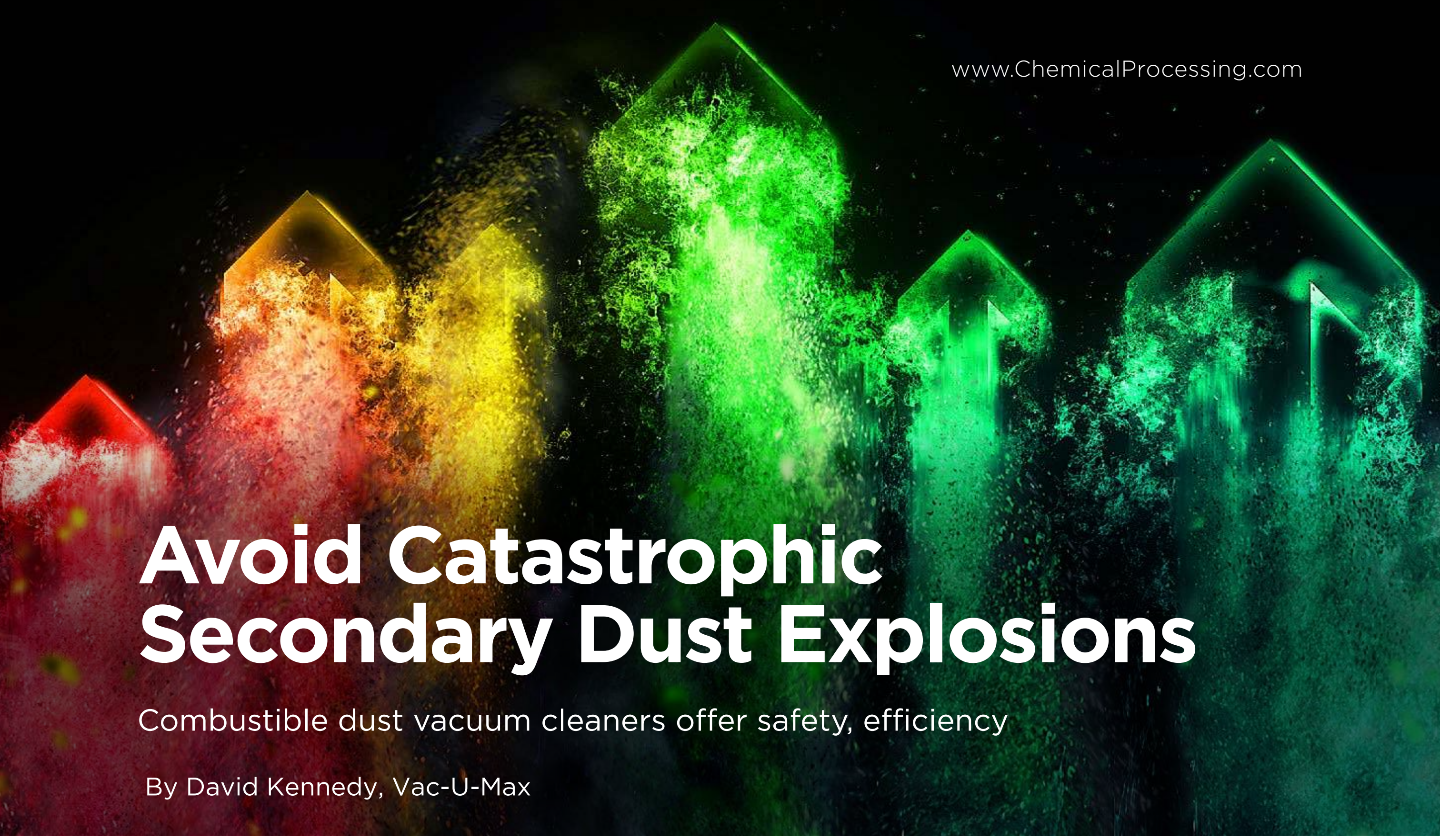


Avoid Catastrophic Secondary Dust Explosions

Combustible dust vacuum cleaners offer safety, efficiency

By David Kennedy, Vac-U-Max

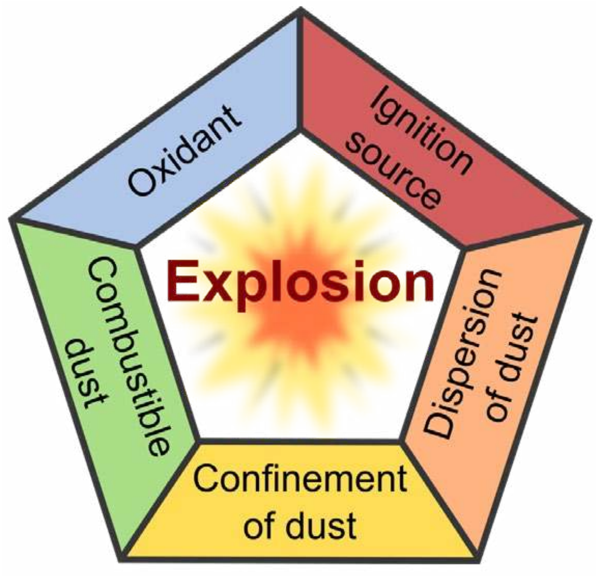
Standard industrial vacuum cleaners are vulnerable to ignition, making them unsuitable for combustible dusts. Whenever powder flows in one direction through a plastic vacuum-cleaning hose, it can create significant static electric charge. If a charged, ungrounded hose used to vacuum combustible dust powder were to come into contact with a grounded object, the static electricity could arc and trigger a violent explosion.

Another danger is static electricity buildup on individual dust particles that have been sucked into the vacuum, which is another reason why combustible dust vacuum cleaners need redundant grounding in five different ways, eliminating the possibility of any type of explosion from the vacuum cleaner.

Combustible dust vacuum cleaners, designed to remove fugitive combustible dust safely and efficiently, include portable drum-style vacuums, stationary continuous-duty central vacuum systems and portable breakaway vacuum cleaners — an economical alternative to central vacuum cleaning systems.

THE MAKINGS OF A DUST EXPLOSION

Fugitive dust, or particulate matter (PM), basically is any solid or liquid suspended in the air through wind or human interaction. While half of all fugitive dusts are greater than 10 microns (human hair is 70 microns) and settle on surfaces rather quickly, the other half are smaller than 10 microns (not visible to the naked eye) and can remain suspended in the air for days or weeks, settling on the tops of equipment, rafters and ducting.



DUST EXPLOSION PENTAGON

Figure 1. Dust explosions require five elements, fuel (combustible dust), oxidant (oxygen), ignition source, dispersion (dust cloud), and confinement.

NFPA 652 defines combustible dust as "a finely divided combustible particulate that presents a flash-fire hazard or explosion hazard when suspended in air or the process-specific oxidizing medium over a range of concentrations."

Combustible dust flash fires occur when a fourth element, the suspension of fuel (dust) into an environment, is introduced to the three elements of the fire triangle: fuel (combustible dust), ignition source (heat) and an oxidizer (usually air).

Dust explosions occur when a fifth element, an enclosed space, is present, forming the dust explosion pentagon (Figure 1) comprising fuel (combustible dust), ignition source (heat), an oxidizer (usually air), dispersion of dust particles (in sufficient quantity and concentration) and a confined area (vessel, area or building).

Catastrophic secondary explosions occur when the force from a primary blast wave from an explosion dislodges fugitive dust from surfaces and disperses it into the air, producing dust clouds that ignite, creating a domino-type effect throughout a facility.

If you mitigate the accumulation of fugitive combustible dust to limits below a sufficient quantity and concentration, secondary dust explosions are unlikely.

SAFETY GUIDELINES

While each combustible dust has different thresholds that constitute sufficient quantities and concentrations that lead to explosions, OSHA guidelines state, " in general, a thickness greater than $^1/_{32}$ of an inch is cause for concern when the surface area covered by settled dust exceeds five percent of the floor area in a given room."

Many facilities appear to be free of concentrations of dust at eye level, but the culprit behind many secondary dust explosions is the accumulation of dust in out-of-sight places such as overhead beams, joists, duct work and the tops of equipment. According to OSHA's National Emphasis Directive on Combustible Dusts CPL 03-00-008 section IX.E.3.c (https://bit.ly/3eJgBo0), all surfaces need to be included in the hazard evaluation as the available surface area of bar joists, steel beams, tops of machinery and rough wall surfaces serve as significant dust accumulation points.

As of September 2020, NFPA 652 requires organizations that deal with combustible dusts to have a dust hazards analysis (DHA) on hand that identifies and evaluates fire, flash fire and explosion hazards throughout a facility as well as safeguards in place that adhere to the general requirements for mitigation, including "housekeeping thresholds for dust accumulation levels."

INTRINSICALLY SAFE VACUUM

Figure 2. This compressed-air-operated combustible dust vacuum cleaner tackles extremely fine powders.

VACUUM CLEANING METHODS

Broadly speaking, vacuum cleaning is the preferred method to remove combustible dust accumulations. Sweeping creates airborne dust, moving that dust somewhere else, but industrial vacuums suck up and contain all the dust.

Prior to the OSHA's National Emphasis Program (NEP) on Combustible Dust, some facilities would attempt to use shop-type vacuums similar to what people have in their garages to remove combustible dust from surfaces. Those types of vacuums not only create sparking hazards but are ineffective at sucking up fine dust particles or heavy materials, often creating their own dust clouds when operating.

With combustible dust present in a facility, the use of an intrinsically safe vacuum that adheres to Class II, Div. 2 design may be necessary even in non-Class II, Div. 2 areas (Figure 2). Early in the NEP, OSHA issued numerous citations for using standard vacuum cleaners where Class II, Div. 2 equipment is required.

Every plant has unique processes and thresholds when it comes to combustible dust. There is no one-size-fits-all vacuum cleaning application and no single standard or one industrial vacuum cleaner that can meet the requirements for all combustible dusts. Companies need someone with intimate knowledge of how chemicals react in

VACUUMS FOR HAZARDOUS ENVIRONMENTS

Figure 3. Compressed-air-operated industrial vacuum cleaners are ATEX tested and certified for hazardous area locations, and do not release thermal or electric energy.

certain environments and with experience in NFPA standards to help choose the right combustible dust vacuum cleaner.

In some applications, small portable air- or electric-powered drum-style units will suffice, while others require large electric and diesel-powered units for multiple users and filtration systems capable of capturing particles that are invisible to the naked eye. Somewhere in between are portable breakaway systems that combine the portability of drum-style units and benefits of central vacuum cleaning units without the cost.

AIR-OPERATED VACUUMS

While intrinsically safe electric industrial vacuum cleaners are available, the most economical solution for cleaning combustible fugitive dust are air-operated vacuums (Figure 3).

Beyond the fact that air-operated vacuum cleaners use no electricity and have no moving parts to create spark hazards, well-built air-operated vacuum cleaners are grounded in five ways beginning with the air line that supplies compressed air to the units. Because most plants have compressed-air lines made from iron that conduct electricity, air-operated vacuums use static conductive high-pressure compressed-air lines.

In addition to static conductive air lines, static conductive hoses, filters and casters are used to further reduce risk. Some have a grounding lug and strap that ravels from the vacuum head down to the drum to eliminate the potential for arcing (Figure 4).

Air-operated vacuums for combustible dust are safer in terms of grounding. They

CENTRAL CLEANING SYSTEM

Figure 4. This central vacuum cleaning system has source capture and reclaim into bulk bag for potential reuse, recycle or disposal.

Stationary central vacuum systems are ideal for environments requiring continuous 24/7 operation.

also work more efficiently in the industrial environment than commercial or industry-specific vacuum cleaners such as agricultural vacuums, which are great for farm use but not necessarily suited to rugged industrial applications in which environmental safety, ergonomics and productivity matter. Vacuum cleaners designed to withstand rigorous 24/7 operation can deliver consistent performance that adds to a company's bottom line in heavy-use industrial facilities.

These units are easy to maneuver and support one operator up to 50 ft away from the vacuum. They also provide excellent suction for overhead cleaning in hard-to-reach areas with the use of wand extensions, reducing the time and mess involved in more manual cleaning methods that disperse dust.

CENTRAL VACUUM SYSTEMS

If portable intrinsically safe vacuum cleaners are the "muscle cars" of the combustible dust world, then central vacuum cleaning systems (Figure 4) are top-of-the-line luxury vehicles.

Stationary central vacuum systems are ideal for environments requiring continuous 24/7 operation and the simultaneous use of up to 20 pickup points. These systems use powerful stationary industrial vacuum cleaners that have strategically placed piping throughout a facility connecting hoses to a common line.

When designing a central vacuum cleaning system, factors that must be taken into account include:

- material cleaned (such as abrasiveness, corrosiveness, flammability or explosion hazard);
- volume collected;
- bulk density;
- particle size;
- filtration goals;
- maximum temperature;
- total number of pickup points;
- number of simultaneous operators;
- hose size;
- longest vertical and horizontal tubing runs from vacuum;
- available floor space; and,
- collection container considerations.

Some manufacturers use regenerative blowers as a vacuum source in central vacuum systems that have the airflow but not the simultaneous vacuum. Regenerative blowers look appealing because they show a lot of airflow for a given horsepower, but they

BREAKAWAY VACUUM SYSTEMS
Figure 5. These portable units provide an economical alternative to central vacuum systems.

do not generate enough vacuum to move material over distances in tubing when vacuum pressure goes up, i.e., when the job gets harder, performance is lost.

Traditionally central vacuum systems require a bag house with either a chemical suppression system or an explosion venting system to meet NFPA and OSHA standards, which often leads to outdoor installation, bringing other challenges such as air and construction permits.

Some smaller central vacuum systems can service as many as three operators at once with piping runs up to 200 ft while conforming to NFPA standards for indoor installation because the "dirty volume" is less than 8 ft^3.

This allows for installed units without the need for an explosion vent or chemical suppression system. These smaller indoor installations can avoid air permitting requirements with many local municipalities, while returning HEPA-filtered air into the plant environment.

BREAKAWAY VACUUM SYSTEMS

In larger less centralized facilities where sizing a central vacuum system would be cost prohibitive due to power necessary to suck dusts from one end of the facility to the other, breakaway central vacuum systems are a cost-effective solution.

Breakaway vacuum systems operate much like central vacuums with fixed tubing networks, but units are portable (much like the portable air-operated vacuums) and use several smaller tubing networks. For instance, if a user is working in a 100 x 200 sq ft area and there are two more areas in another building, individual tubing networks are created, and the vacuum cleaning unit can break away from one tubing network and be rolled to the next network, and so on.

Breakaway vacuum systems avoid costs and delays that may occur with central vacuum cleaner applications, providing the convenience of a multi-inlet central vacuum, with the energy efficiency and flexibility of a portable vacuum.

Like the smaller central vacuums and the portable air-operated vacuums that allow for indoor operation, because breakaway vacuum systems have a filter separator and collector less than 8 ft^3, it does not need an explosion vent to use it in Class II, Div. 1 and 2 areas, per NFPA standards and OSHA regulations.

With the largest models of breakaway systems able to move 5 tons/hr of powder from 30 ft away (Figure 5), these units can generate high vacuum and excellent airflow, so they can pull massive amounts of material over distances.

Central vacuum cleaning systems with strategic tubing networks and portable vacuum cleaners allow manufacturers the ability to use the vacuums to clean up spills and perform regular cleaning to mitigate buildup of combustible dusts in hard-to-reach areas, maximizing return on investment. ●

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