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Deftly Deal with Dangerous Dust

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Fertilizer Plant Tackles Belt Conveyor Issues

Upgrade improves efficiency, containment and safety

By Marc Gilbertson, Coffeyville Resources, and Cory Goldbeck, Martin Engineering

The Coffeyville Resources nitrogen fertilizer plant in Coffeyville, Kan., produced 814,700 tons of ammonia and 1,268,400 tons of urea ammonium nitrate (UAN) in 2017, enough to supply approximately 5% of total U.S. demand. It is one of just two such plants in North America that doesn't rely on natural gas as an energy source — and the only one that uses petroleum coke (petcoke) gasification to provide the hydrogen essential for its operations. The facility's location adjacent to a refinery gives it ready access to the large volumes of petcoke produced there. About 80% of the petcoke fuel required for production comes from the neighboring refinery.

Historically, petcoke has been significantly less expensive than natural gas on a per-ton-of-fertilizer-produced basis, and coke prices have been more stable than those of natural gas. By using petcoke as its primary energy source, the plant traditionally has been the lowest-cost producer of ammonia and UAN fertilizers in North America.

The Coffeyville operation moves most of the petcoke via conveyor; the plant maintains completely redundant systems to protect against unplanned shutdowns. The dual conveyor systems have run for many years without major failures but were beginning to show their age. In addition, the site wanted to improve material control and overall efficiency by taking advantage of advancements in conveyor technology since those systems were installed.

TRANSFER POINT
Figure 1. Upgrade eliminates belt sag and improves sealing, and includes belt cleaning and alignment systems.

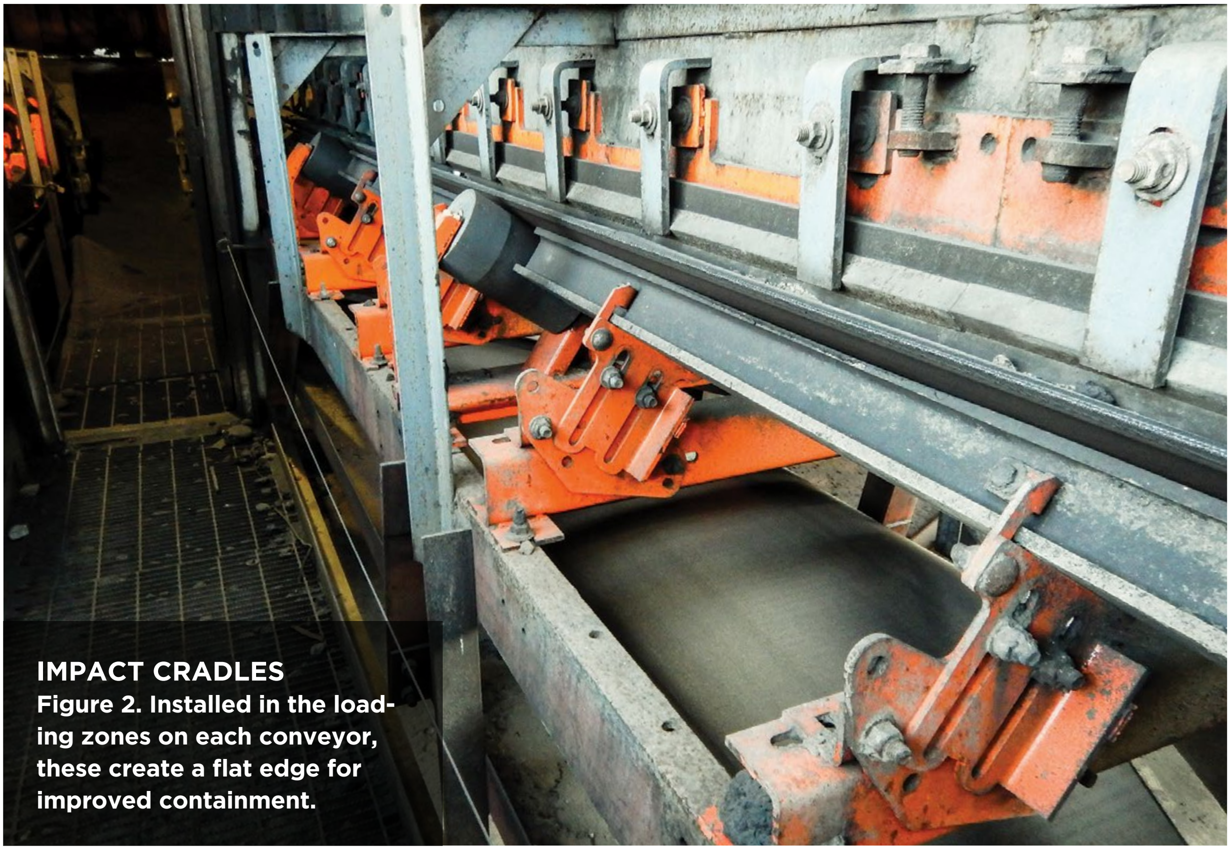
One of the primary issues to address was material containment — reducing the amount of dust and spillage that escaped from the conveyors. After walking the entire length of two sets of twin conveyors, we identified conveyors 19A and 19B as being most in need of attention; each has a 24-in. wide belt, 300 ft long. Travelling at 400 ft/min, the belts carry an estimated 1,400 t/d of petcoke to an entrained flow gasifier. The twin belts have two load zones each; these were among the main points of concern.

The spillage was significant. Waist-deep piles were accumulating each day. An average of about 90 man-hours per week was necessary to safely clean the affected areas and haul the material away. In addition, cleaning and adjusting the belts, addressing worn components and keeping the system running required another 16 hours of maintenance time each week. Belts, rollers and other components were wearing out prematurely. Given the tab for replacement parts and labor, the opportunity for cost reductions looked good.

Based on site visits, technicians determined that the containment issues were primarily a result of carryback from insufficient belt cleaning and misalignment. The skirts and tail boxes were also allowing fugitive material to escape.

STABILIZING AND SEALING

So, the plant launched a modernization project in the 4th quarter of 2015. It included upgrading the transfer points to



IMPACT CRADLES
Figure 2. Installed in the loading zones on each conveyor, these create a flat edge for improved containment.

eliminate belt sag, provide effective sealing and improve belt cleaning, as well as alignment systems to deliver continuous adjustment and maintain a consistent belt path (Figure 1). Components used were specifically designed for durability under the heavy load and impact at the transfer points.

Technicians first installed three impact cradles on both 19A and 19B, located under the belt in the loading zones (Figure 2). The cradle design features a bed of steel angles lined by energy-absorbing impact bars with a top layer of low-friction ultra-high-molecular-weight plastic. The impact beds absorb the energy, so the belt doesn't have to. They also create a flat edge for the edge seal, to prevent spillage and fugitive dust. The cradles feature wing supports that adjust to match Conveyor Equipment Manufacturers Association standard trough angles, as well as provide a 5% finetuning. This allows the cradles to accommodate the idler profiles of different manufacturers and ensure a tight belt seal.

After the impact zone, a series of 16 slider cradles were installed on each conveyor to stabilize the belt line and eliminate bounce. Transfer points can be prone to spillage as the load lands on the receiving conveyor. Once the belt leaves the impact cradle, it also can sag while the material is still settling. This compromises the skirt seal, allowing dust and fines to escape while creating entrapment points where material can get caught and gouge the belt.

The slider cradles are designed for conveyor systems with speeds up to 700 ft/min and belt lengths of more than 50 feet. Typically 48-in. long, the units also are available in custom sizes. The proprietary box design allows flipping each bar over at the end of its useful life to provide a second wear surface. The result is a flat and stable belt surface throughout the settling zone, reducing fugitive material and extending belt life.

Following the cradles, 20 Trac-Mount idlers were installed on each conveyor. These rugged idlers have sliding frames on a stationary base that fits in tight spaces between belt support cradles for easy installation and service. Supplied with either steel or impact rollers, they require only eight inches of space for the 6-in. rollers and can be serviced without raising the belt or removing adjacent rollers.

DUST MANAGEMENT

The system upgrade also included 90 feet of modular chute wall, which provides a system of compatible components to build a transfer chute and wall structure. The prefabricated components make it easy to design and install transfer-point skirtboards and stilling zones to manage air flow and control dust, keeping climatic conditions outside and airborne dust inside. The components simply bolt together to reduce installation labor, requiring no field engineering or material waste and providing a precise fit to suit the specific requirements of each conveyor load zone.

To further improve containment, 184 feet of Martin's ApronSeal skirting system was installed. It offers dual-seal efficiency with a single one-piece sealing strip for any trough angle to prevent the escape of fines and dust. The unique design delivers two wear surfaces on a single elastomer sealing strip. When the bottom side of the strip against the belt is worn, inverting the sealing strip provides a second service life.

It's the first dual-sealing system for belt conveyors, incorporating a primary seal clamped to the steel skirtboard to keep lumps on the belt and a secondary or "outrigger" strip to capture any fines or dust particles that pass beneath the primary seal. The secondary seal lies gently on the belt and self-adjusts to maintain consistent strip-to-belt pressure despite high-speed material movement and fluctuations in the belt's line of travel. The skirting floats on the belt and self-adjusts to maintain an effective seal without maintenance.

TACKLING OTHER PROBLEMS

To address belt mistracking, the installation includes a Martin Tracker system to deliver immediate precise adjustment of

The total maintenance time to manage fugitive material on both conveyors now has fallen to about eight hours per week.

wandering belts. Rollers attached to the end of a sensing arm assembly ride both sides of the belt edge, detecting even slight variations in the belt path. Employing the force of the wandering belt, the arms automatically position a steering idler in the opposite direction of the misalignment. Transferring the motion to the steering idler through a unique parallel linkage requires less force to initiate the correction, enabling continuous, active and accurate finetuning of the path. The Tracker keeps the belt in alignment with automatic corrections to reduce edge damage, prevent spillage and maintain belt health.

Carryback can be a vexing problem for conveyor operators, especially when loads are heavy and materials contain moisture, which tends to cause fines to stick to the belt and get carried along the return run where vibration knocks the particles loose and deposits them on support structures, rollers and floors. To address this issue, technicians installed a dual cleaning system on the 19A and 19B conveyors. The primary unit is Martin's QC1 Cleaner HD, a heavy-duty design with a one-piece curved urethane blade that delivers excellent performance. Its simple one-pin replacement without tools minimizes service time when the blade wears out. The design maintains cleaning performance through all stages of blade life. The unit can withstand corrosive conditions and service temperatures up to 180°F.

Mounted directly after the primary cleaner is a secondary scraper, the SQC2S cleaner; it features individually cushioned tungsten carbide blades for effective cleaning without risk to the belt or splices. Patented rubber buffers maintain the cleaning pressure throughout blade life while deflecting sufficiently to allow splices to pass without harm and ensuring compatibility with reversing belts or those that experience backup at shutdown.

The two-conveyor project took about a week for each belt, with six Martin Engineering installers on site. The team completed one upgrade while the other conveyor continued running, then switched over to the second structure.

IMPRESSIVE RESULTS

The upgrade has drastically reduced the amount of dust and spillage and, with it, the labor necessary to deal with the consequences. The total maintenance time to manage fugitive material on both conveyors now has fallen to about eight hours per week; what used to be a huge maintenance task now just involves occasional sweeping. Personnel spend less time working in close proximity to the moving conveyor, reducing potential risk. The plant likely is saving about $14,000 each month on labor previously required for the conveyor systems, and now is deploying staff to more productive activities. Moreover, belts and other components are showing no signs of premature wear; their longer service life should further increase the benefits achieved.

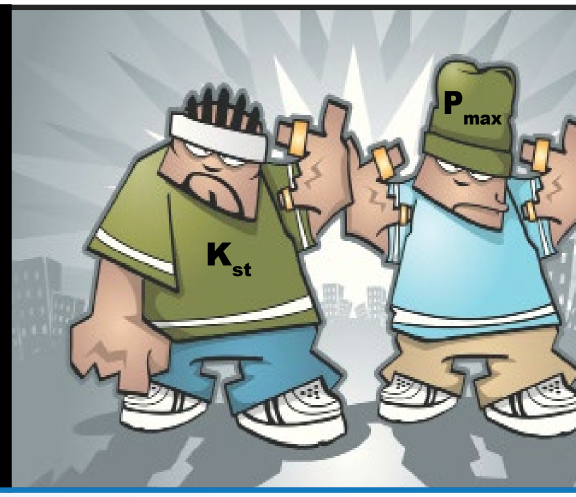
Plant management was so pleased with the results that they decided to upgrade another, shorter pair of conveyors. These two 15-ft feeder conveyors supply material to the upgraded conveyor systems. Both are 42-in. wide, running at 65 ft/min. They posed issues similar to those of the 19A and 19B conveyor systems. Martin technicians installed chute wall, idlers and skirt seal to contain dust and fines. To accompany the QC1 Cleaner HD on these systems, they put in a Durt Hawg DH2 secondary belt cleaner, an extremely durable design with steel-tipped blades for demanding conditions. As part of the settling zone modification, they also installed the EVO external wear liner along the edges of the chute wall; unlike traditional wear liners, the innovative design is mounted and serviced outside the chute wall, making it easy to inspect and replace without confined space entry.

The plant now is considering proposals to upgrade additional conveyors as well as future training and service agreements. ●

MARC GILBERTSON is operations technical superintendent at the Coffeyville Resources nitrogen fertilizer plant in Coffeyville, Kan. **CORY GOLDBECK** is territory manager for Martin Engineering, Neponset, Ill. Email them at mmgilbertson@CVREnergy.com and coryg@martin-eng.com.

Who (or What) are K_{St} and P_{max}?

(And, What do They Have to do With Combustible Dust?)



K_{St} and P_{max} Defined

While K_{St} and P_{max} sound like a '90's rap group they are actually the explosive properties derived from performing an explosion severity test. This test determines how much pressure an explosion will generate and how fast the explosion will travel.

The "Explosion Severity Test" is a standard dust test used to quantify the maximum pressure of a dust cloud explosion (P_{max}) and the speed of the pressure rise (K_{St}). The Test is generally conducted in a 20L sphere because it is directly scalable to the 1m^3 sphere, which is the original instrument used to test combustible dust. Considered to be the "gold standard" for dust testing, the 1m^3 sphere is useful for providing data whenever there are questionable results from the 20L.

Why They Are Important

Testing your dust to determine the K_{St} value & P_{max} is essential for any type of equipment design. In particular, these values are used by manufacturers to validate the design of protection systems (such as spark detection, explosion venting, explosion suppression and explosion containment).

The Explosion Severity Test will tell you what ST class your sample falls within, which is helpful in guiding service providers as they analyze your equipment and your facility. ST class is based on the following K_{St} values:

- ST class 0 - K_{St} value = 0
- ST class 1 - K_{St} value less than 200 bar m/sec and greater than 0
- ST class 2 - K_{St} value between 200 and 300 bar m/sec
- ST class 3 - K_{St} value greater than 300 bar m/sec

At Fauske & Associates, LLC (FAI), we have four operating 20-L chambers as well as one 1-m^3 chamber. Explosibility testing in these chambers are performed per ASTM E and EN methods. These units provide valuable data to help create dust explosion hazard mitigation strategies in various process industries ranging from, but not limited to, agriculture, wood working, pharmaceutical, plastics, cosmetics, fine chemicals as well as metal working.

Example Test Results

Sample	K_{St} Value (bar m/sec)	P_{max} (bar)	ST Class
Grain Dust	89	9.3	1
Coal Dust	85	6.4	1
Flour	63	9.7	1
Sugar	138	8.5	1
Wood Dust	224	10.3	2
Aluminum Dust	515	11.2	3
Sewage Dust	102	8.1	1
GRP Dust	216	7.6	2

630-323-8750 or dust@fauske.com to learn more about how FAI can assist with your combustible dust (DHA) testing needs

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Prevent Dust Explosions with Pressurization

Purge and pressurization systems are one of nine steps to help prevent and control such hazards

By Chris Romano, Pepperl+Fuchs, Inc.

As long as there have been industrial environments, dust has caused explosions. In the past 20 years alone, dust explosions have resulted in hundreds of deaths and injuries around the world, as well as massive property damage.

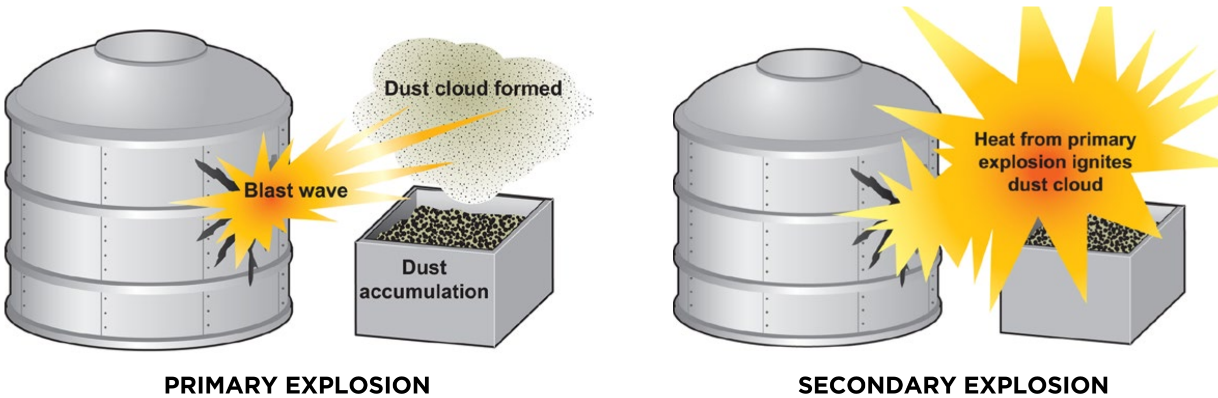
All it takes is one small spark to ignite dust under the right conditions, and a range of everyday materials can cause an explosion. Examples include sugar, corn, steel wool, aspirin, coal, aluminum, paint pigment, cornstarch, pasta, tapioca, tea and cocoa. And almost every industry faces dust explosion hazards — from agricultural to automotive to refining.

Fortunately, explosion prevention techniques are readily available for use in industrial and agricultural applications. Pressurization provides an economical way to use electronic devices in a range of hazardous locations without putting employees and equipment in danger.

WHAT IS A DUST EXPLOSION?

A dust explosion occurs when a fine dust suspended in the air is ignited, causing rapid burning. In milliseconds, gaseous products are released with a subsequent pressure rise of explosive force. Dust explosions can be categorized into two phases: primary and secondary (Figure 1).

A primary explosion takes place in a confined atmosphere, such a as a silo or part of the manufacturing plant, with the resulting shock wave damaging and often rupturing the plant. This allows the



PRIMARY AND SECONDARY EXPLOSIONS
Figure 1. A primary explosion takes place in a confined atmosphere, expelling the products of the explosion — burning dust and gases — into the surrounding area. This disturbs any settled dust and initiates a larger secondary explosion.

products of the explosion (burning dust and gases) to be expelled into the surrounding area.

This disturbs any settled dust and initiates a larger secondary explosion. The secondary explosion can cause severe damage to surrounding plant buildings. Most large-scale dust explosions result from chain reactions of this type.

CONDITIONS FOR A DUST EXPLOSION

Five conditions are necessary for a dust explosion to occur:

1. The dust must be combustible.
2. The dust must be fine. The finer the dust, the more explosive it is likely to be.
3. The dust cloud must be of explosive concentration, i.e., between the lower and upper explosive limits for that particular dust.
4. There must be sufficient oxygen in the atmosphere to support and sustain combustion.
5. There must be a source of ignition.

Typical Dust Parameters	
Cloud ignition energy	5 mJ and higher
Minimum explosive concentration	0.02 oz/ft^3 and higher
Maximum pressure developed	30 … 150 psi
Rate of pressure rise	less than 15,000 psi/sec
Ignition temperature — cloud	200 °C and higher
Ignition temperature — layer	150 °C and higher

Table 1. These values are reported by the United States Bureau of Mines. *Source: Ernest C. Magison, Electrical Instruments in Hazardous Locations, 3rd ed. (Pittsburgh: Instrument Society of America, ca. 1978), 317, Table 11-1.*

ENCLOSED SAFETY
Figure 2. Purge and pressurization systems separate general-purpose electrical devices from the surrounding hazardous atmosphere by placing them inside a common, lightweight enclosure that is cleaned and pressurized with industrial-grade air or an inert gas.

HOW TO REDUCE THE HAZARD

One common method to reduce dust explosion hazards is to prevent the combustible material from reaching an explosive concentration by removing the combustible material and pressurizing the area. This prevents the accumulation of a flammable atmosphere.

Other ways to minimize explosion risks include reducing the oxygen content and adding moisture or a dry inert material. In coal mines, it is common practice to coat the galleries and shafts with rock dust to reduce the likelihood of coal dust explosions. The inert material adds thermal capacity without increasing the energy released by combustion. Adding the inert material also increases the amount of energy required to ignite the combustible elements of the atmosphere, much like holding a lit match to a wet log.

The two objectives in Class II locations are to:

1. Keep dust away from ignition sources.
2. Prevent ignition of dust that accumulates on the device.

Pressurization effectively handles both of these scenarios for Division 1 and Division 2 areas.

WHAT IS PRESSURIZATION?

Unlike containment or prevention protection, pressurization separates general-purpose electrical devices from the surrounding hazardous atmosphere by placing them inside a common, lightweight enclosure (Figure 2). This enclosure then is cleaned and pressurized with industrial-grade air, or an inert gas, and maintained at a pressure higher than the dangerous external atmosphere, preventing the combustible material from coming in contact with the internal components.

Only pressurization is required in a Class II dust atmosphere. Purging is used in Class I or gas applications. If purging is used in a Class II area, the vent will be blocked and cause a dust cloud, leading to an unsafe condition.

Most pressurization enclosure applications require a minimum enclosure pressure of 0.10 in. (2.5 mm) of water. One psi is equal to 27.7 in. of water. In some circumstances, a minimum enclosure pressure of 0.5 in. (12.7 mm) of water is required to protect against the ingress of ignitable dust.

But in all cases, a higher enclosure pressure should be maintained to create a reasonable safety factor. In rare circumstances, enclosure pressures as high as 2.5 in. (63.6 mm) of water may be required to offset sudden atmospheric pressure fluctuations, such as those created near missile launchings or other applications with quick atmospheric pressure changes.

For Division I applications, loss of pressurization requires disconnect of power to the enclosure. For Division 2, loss of pressurization allows power to remain on, provided an audible or visual alarm notifies the operator of the condition. Motors, transformers and other devices subject to overload must be provided with automatic means to deenergize them if temperature exceeds the design limits. Using cooling devices in the enclosure also should be considered. Vortex coolers provide an inexpensive solution.

The need to place general-purpose equipment in hazardous locations is not new, yet in the past three decades the need has intensified dramatically. Most modern electronic equipment is expensive and delicate, requiring environmental protection that cannot be provided by explosion proof enclosures or intrinsic safety barriers. Purge and pressurization technology offers the safest and most economical means of installing electrical equipment in a hazardous location, as well as protecting this delicate equipment from corrosive environments.

PREVENT AND CONTROL HAZARDS

Follow these nine steps to prevent and control dust explosion hazards:

1. Maintain effective housekeeping. If dust is not there, it cannot ignite as a layer or be dispersed as a cloud. Maintain handling equipment to keep dust inside. Clean up any dust that escapes. Even small accumulations of dust (as small as 1/32 in.) can create a dust explosion hazard if spread over sufficient surface area.

2. Conduct workforce training and education courses regarding recognition and control of combustible dust hazards.

3. Design machinery and plants to minimize damage if an explosion occurs. Use flame arresters to prevent flame spread and vents to relieve pressure and reduce structural damage.

4. Use intrinsically safe wiring practices.

5. House electrical equipment in pressurized cabinets.

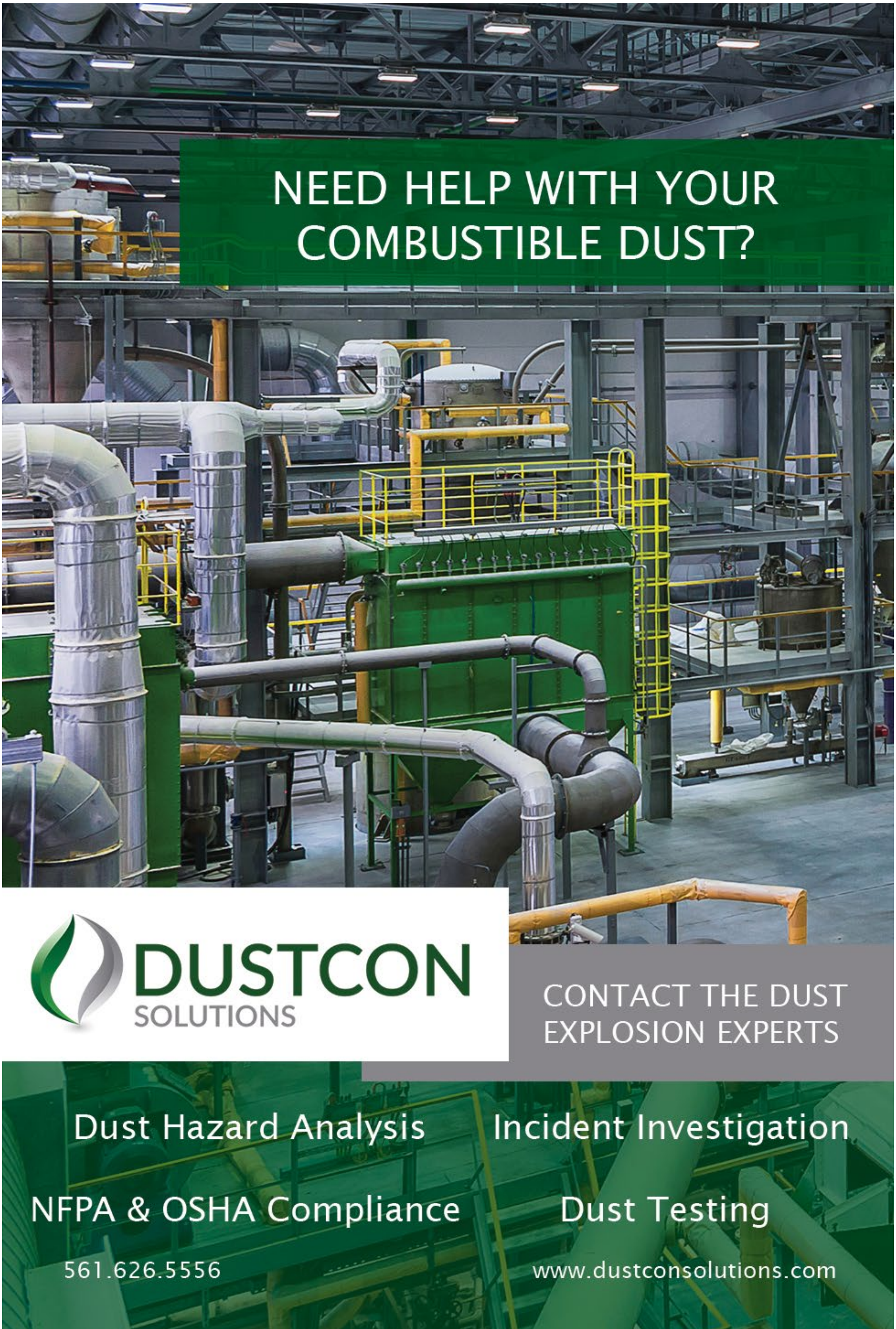
6. Detect the early pressure rise when an explosion occurs in a closed system and quench it with an inerting material,

7. Safety Data Sheets (SDSs) rarely address how explosive materials are; they merely state that the materials may explode. Moreover, not all SDSs can be relied on to address even the possibility of explosion, leading to eventual mishandling of materials if users assume that they cannot explode. Frequently, product manufacturers are not sufficiently aware of their materials' volatility, so they do not test them. Sometimes, a product may not be explosive in the form in which it is supplied, but it can become explosive once a user processes it. This can happen in grinding and pulverizing operations or through abrading by friction in pneumatic handling systems.

8. Knowing materials' minimum ignition energy (MIE) and minimum ignition temperatures (MIT) often is fundamental to arriving at HAZOP and risk management decisions. Materials with high ignition energy or temperatures are much more difficult to ignite than materials with low values, except in the event of open flames or welding incidents. The MIT for dispersed dust principally is used to ensure that surface temperatures cannot cause the dust to ignite. The MIT value measurement of the dust cloud is one criterion for selecting suitable electrical equipment in dusty atmospheres. The MIT value of the powder layer is also a relevant parameter.

9. Many accidents happen during maintenance on a machine or area. Make sure the area is clean of all combustible dust and all material that could catch on fire. Accidents often happen when a minor fire starts from welders in an area that is clean, but the process of controlling the fire causes a dust cloud from another area to migrate to the fire, leading to secondary explosions. Ensure that all suspended lights, beams, etc., are cleared of combustible dust. ●

CHRIS ROMANO is product portfolio manager for Purge and Pressurization at Pepperl+Fuchs, Inc. Chris can be reached at cromano@us.pepperl-fuchs.com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Factor in a Sampling Plan

Before completing a dust hazard analysis, conduct a sampling plan to improve prevention and mitigation strategies

By Timothy L Cullina, P.E., Fauske & Associates, LLC

If you were creating a feature film on combustible dust, which would be the prequel — the sampling plan or the dust hazard analysis (DHA)?

Combustible dusts are fine particulates that present a deflagration hazard when suspended in air. You've seen that movie and know the characters, plot and staging from all the reruns. Oxygen plays itself on the enclosed stage when the Fugitive Shape Shifter, interpreted by a local Particulate Solid, reprises the villain's role, eluding good housekeeping and dispersing onto the scene where the hot Ignition Source and Friends spark about.

How will this episode end? Will local kid, Pea Solid, and the beautiful Eye Source make explosive fireworks together? Or will Pea Solid steer clear and go straight to complete the process? That depends. How well did the sampling plan and the DHA inform the facility?

Industry experts, a.k.a., the people who write the National Fire Protection Association (NFPA) Standards, recognized that a DHA needs direction, and a written sampling plan would provide a start when they included this requirement in Chapter 5 of the NFPA 652 Standard:

A sampling plan shall be developed and documented to provide data as needed to comply with the requirements of this chapter (Hazard Identification) ...shall include the following:

1. *Identification of locations where fine particulates and dust are present*

2. *Identification of representative samples*
3. *Collection of representative samples*
4. *Preservation of sample integrity*
5. *Communication with the test laboratory regarding sample handling*
6. *Documentation of samples taken*
7. *Safe sample collection practices*

These writers must have thought of the sampling plan as the prequel. The sampling plan is like a movie screenplay and identifies the steps to ultimately managing the risks associated with combustible dusts. Ideally, the sampling plan should be devised and documented before valid samples are taken and tested; otherwise, it would be called a sampling history.

But, for most of us, life and work and dust are not that clean and simple. The problem is where and how to begin knowing that sampling mistakes and omissions can lead to lost time and wasted money — or worse, incorrect risk assessment and an unhappy ending.

Unless you're in "the business," you rarely see the screenplays to the movies you pay to see.

Is the same true of the sampling plan and the DHA? Screenplays describe the scenery, provide comments on expressions and give actors cues to movements and messages. Let's imagine a sampling plan as screenplay.

THE SCREENPLAY

Here you're the writer, the director and maybe even a minor character or an extra in the background, but, please, do not be a tragic hero.

Imagine the shot. You're filming on location. The screen play identifies the locations and describes the scene laid out before the cameras:

- It takes place on the factory floor.
- Hot lights with illuminated dust halos hang above.
- White over grey two-tone ventilation ducts cross overhead, disappearing off stage.
- Silver sprinkler heads sprout from grey over black, water pipe blending into the dark ceiling above the out-of-focus small black tress-work that supports the roof.
- A pedestal fan whines off to the side.
- Moveable three-step stairs provide access to the top of a round mixing vessel, hatch opened, faint vapors visible, gone briefly and then back again.
- Parallel trail marks reveal the wheeled path of the stairway across a well-dusted floor.
- Extras move about wearing dust masks and look away while pouring bags into other mixing vessels.
- Noise fills the air with a steady mechanical din.

The antagonist waits in the wings.

Quiet on the set… and … "Action!"

From stage left enters an orange-trimmed forklift sporting a beer keg-like fuel tank mounted behind the driver. It's used to deliver a well-stacked pallet of 50-lb. bags held in place by a partially torn wrap of grimy, stretched plastic. Bags have been removed, and others of a different color have been added. The side bar instructs the camera to zoom in on one of the added bags neatly stenciled, WHEAT FLOUR. The bag below has a script type spelling out Maltodextrin.

"CUT!!"

Then the screenplay flops unforgivingly into the producer's round file as he mutters, "Rubbish," and then adds "No one, not even Harry Potter, is going to believe in evil flour."

ASSESS A POTENTIALLY DANGEROUS SETTING

So, forget the analogy, but keep the vision and imagination. Light halos tell us dust is in the air. Wheel tracks from the mobile stairs indicate dust on the floor. Light dust clouds rising from the manholes during powder loading suggest failed or absent dust collection at the mixing vessels.

The descriptions in the screenplay (sampling plan) identify where the potential enclosures, ignition sources, fuels, dispersers and oxidizers are. Alfred Hitchcock called them "MacGuffins." We call them sides of the explosion pentagon.

To know what and how to sample, identify and write down the combustible dust hazards that each process component makes possible, even if you think they are improbable. The components include ducts, conveyors, silos, bunkers, vessels, lights, fans, forklifts, the inside of the process equipment and the fugitive emissions that get out. This doesn't mean testing everything, unless you really need to test everything. This is simply identification. Vetting comes later. Remember: no dust, no hazard.

Each facility compartment, whether building, room or box containing combustible particulate solids, should be evaluated. Attention also should be given to identifying hidden areas where accumulations may go unnoticed. This approach applies to the out-of-sight tops of tall equipment, ducts, ledges and pipes. Remember: dust hides.

The same can be said of oxygen and the ignition source. Because getting rid of the oxygen takes more than just a little effort, unless you're applying a lot of effort on oxygen displacement, consider that it is present. Ignition sources are not always controlled as easily as we want and should almost always be considered a potential.

At each point through the process, identify whether a fire (no dispersion necessary), a deflagration (no enclosure required) or an explosion hazard may exist. Remember: know dusts, know hazards. In our screenplay analogy we'd make note of the following "MacGuffins":

How many dusts?	3 identified: flour, dextrose, fugitive, more are likely in use
Enclosures?	The room, the mixing vessels, the bags
Ignitions Sources?	Overhead lights, propane forklift, mixer blades, fan motor/blades, electrostatic discharge
Dispersion Actions?	Pouring into tanks, forklift traffic, wind (including from fan), Earthquake?
Oxygen?	Plenty, Ambient air

Know what happens to raw materials in the process by following the money. That is, follow the raw material, the products they become and the waste left behind. Does the material start as a powder or larger solids? Does it become a smaller particulate, potentially fugitive dust? Does the material change chemical makeup and change its hazard? Are there different sizes of the same material at different process stages? When is the material wet and when is it dry?

The dust has two environments — inside equipment and outside. Consider each environment on its own and with its own hazards. One process simply may be a series of different spaces with sources of fugitive dusts. The other, equipment process, is where material gets smaller or larger, wetter or drier, conveyed mechanically or pneumatically, heated or cooled, reacted, mixed, sieved, molded, cut or manipulated in other ways that may alter the material. Do process enclosures change volumes, head spaces, freeboard, pipe or duct sizes during the process? What fresh hazard are introduced or eliminated by any of these changes?

The NFPA Standards writers must have been thinking a sequel. Nothing states sampling must be before the DHA. If you have dust, inside equipment or out, it's probably safe to assume that two and maybe even three of the five sides of the explosion pentagon are in place: the dust (fuel), its enabler, oxygen and a potential ignition source lurking nearby. Looking at each situation this way brings you face to face with your risk much more quickly, and while it may not be the deciding factor for testing or not, it should get you thinking about how to reduce the risk.

FOLLOW YOUR PROCESSES FROM START TO FINISH

Is there rail delivery of particulate materials to silos? Pellets usually are too large to present a flash fire or explosion hazard, but pellet handling creates a potentially ignitable dust. These pellets do not require independent sampling or testing, but if the dust is not contained and becomes a flash fire or an accumulation hazard, this location and material should be identified as a candidate fugitive material sample. This same particulate may be collected upstream in the process and therefore may not be required to be sampled at receiving. If this is the case, document it.

In the absence of fugitive dust, there still may be hazards during receiving. Silos that receive pellets also receive the dusts from pellet damage. Cloud formation will occur in the silo, making this dust a candidate for sampling and testing. Is this handling damage particulate the same or smaller? When the same material exists in several different places, the sample with the smallest size particle can represent them all.

The DHA should acknowledge that this is an explosion risk, and therefore ignition source control is critical to explosion protection. Bonding and grounding are important ignition source controls. Explosion venting can be provided but is not required by NFPA on enclosures with problematic, difficult-to-protect geometries, such as tall, narrow silos. The sampling plan won't necessary address these protections, but knowing this advises the sample selection and testing.

A straightforward approach is to screen all area and process samples identified before collecting them to narrow the field based on different combinations of raw materials and particle size, before testing. Samples of fugitive dust should be collected and tested to identify the risk level in the areas that require concurrent housekeeping efforts to keep area accumulations less than $^{1}/_{32}$ of an inch each day.

MIXING AND SIZE REDUCTION/GRINDING

For any number of unit operations, internal considerations will need to look at the potential for ignition by hot spots, tramp materials, sparks or other means to determine effective protection measures. If the fugitive material collected is not representative of the in-process particulate, then collecting an in-process sample is required, but only if this particulate is smaller.

DUST COLLECTION

Dust collectors typically have the finest dust clinging to filters. Sampling from the dust collector should include, if possible, dust from the filter and from the collection bin.

SAMPLING PROTOCOL CONSIDERATIONS

Careful notes should be taken at each sample collection time and location. Taking a picture makes good documentation reference. Include complete material identification, sample location, date, time, method of collection and any unusual conditions at the time. Material sample temperature and moisture content and ambient temperature and humidity may be useful for in- plant interpretations but is not required for dust explosion testing.

ALTERNATE TESTING STRATEGY

One strategy is to test the smallest particulate from each process material type of concern, but even this can quickly get prohibitively expensive if you process dozens or hundreds of materials. If all your materials are likely to have a K_{St} less than 200 b m/s, consider using that K_{St} value as the design parameter. Finally, a dust collector sample should be collected for testing.

RECOMMENDED TESTS

For materials that are of uncertain potential combustibility and explosibility, a go/no-go test series can be performed to make these determinations. When known combustible dusts are involved, this step may be unnecessary unless special circumstances exist such as a predominance of large particulate handled or samples mixed with large quantities of inert materials in which you want to establish that the sample is not combustible.

It must be representative of actual conditions, or there may be more than just regret if an explosion event occurs. Criminal neglect or intent investigations may follow. All samples should receive particle size analysis and moisture content determination.

Other common tests include:

- explosion severity test (K_{St} and P_{MAX}– ASTM E1226),
- minimum ignition energy (MIE – ASTM E2019), and
- minimum explosible concentration (MEC – ASTME1515).

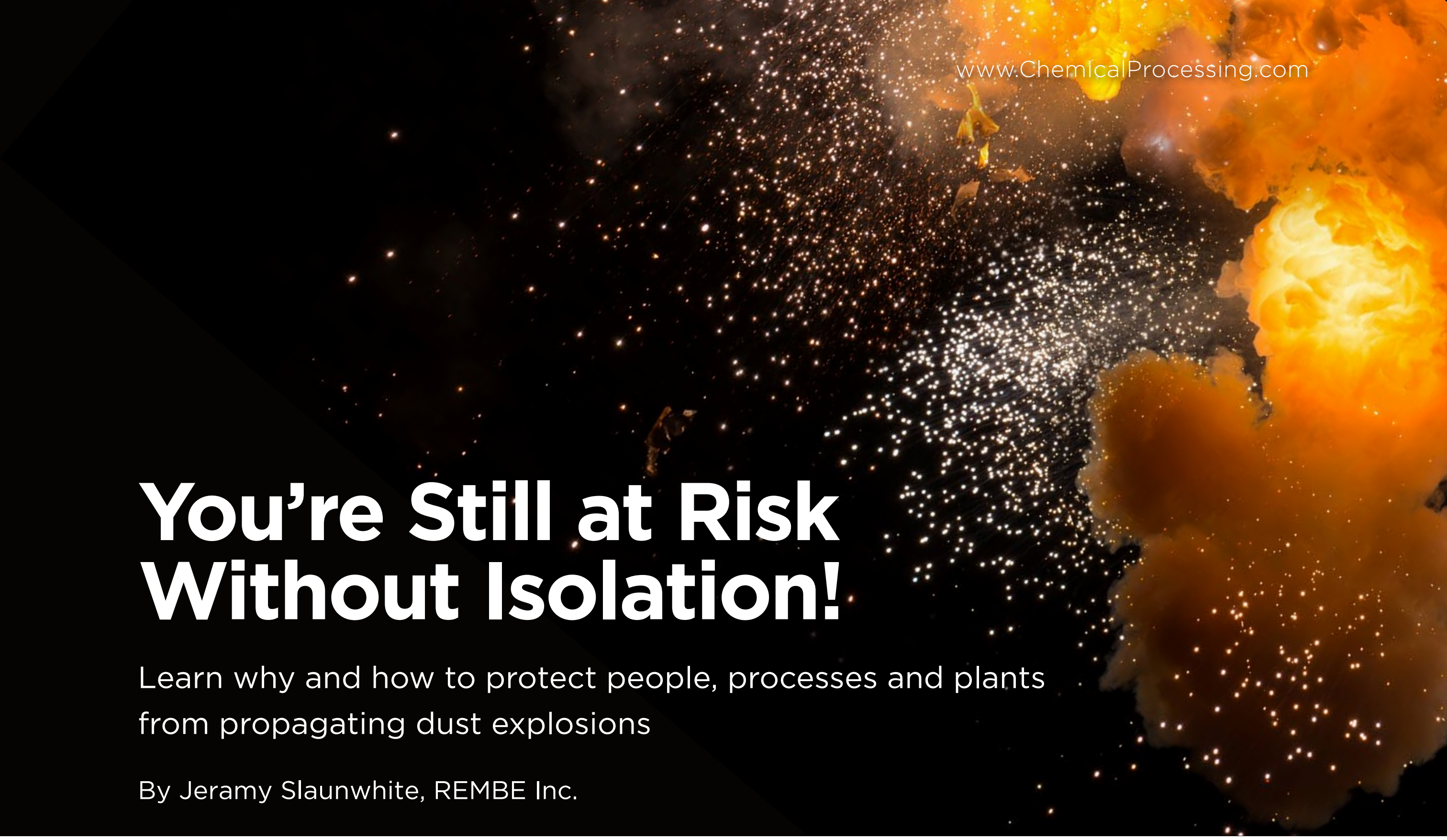
Additionally, you must consider whether other tests may be of value depending on the potential ignition sources in your facility. They may include layer ignition testing (LIT) if there are hot surfaces where dust may accumulate or the limiting oxygen concentration (LOC) test if this means of ignition control is a practical consideration for the unit operation. For nonconductive materials, static charging and relaxation parameters may be useful.

Do not hesitate to discuss your test results with your testing lab or other consultants and DHA providers to ensure your understanding of the results.

But wait! You might ask, if I figure this all out now, what does the DHA guy do? Good question. Clearly, the sample plan is like a first draft of the DHA. Sample plan development should anticipate the need to evaluate test results with the location, equipment and dust conditions identified such as when unacceptable airborne emissions and accumulations of fugitive dusts or process contained dust clouds and accumulations may be exposed to ignition sources.

From here, prevention and mitigation strategies can be developed. As the dust consideration complexity increases, the number of factors to consider also increases and brings the sampling plan and the DHA closer to a singularity. ●

TIMOTHY L CULLINA, P.E., Risk Management Services for Fauske & Associates, LLC can be reached at Cullina@Fauske.com



You're Still at Risk Without Isolation!

Learn why and how to protect people, processes and plants from propagating dust explosions

By Jeramy Slaunwhite, REMBE Inc.

Protection against the effects of a combustible dust explosion is a two-part approach: pressure protection and deflagration isolation. Explosion protection systems prevent the process vessel from exposure to critical failure pressure resulting from rapid internal combustion. Deflagration isolation systems are designed to limit the spread or propagation of a deflagration, which can cause secondary deflagrations or explosions in interconnected process equipment or buildings containing additional combustible dust.

Secondary explosions and deflagration propagation historically are more dangerous and fatal than primary equipment explosions. A primary explosion's damage and effects typically are limited to the equipment and possibly the surrounding area due to deflagration vent discharge or vessel rupture.

The pressure wave and fireball from a non-isolated dust explosion can travel through mechanical or pneumatic conveying arteries rapidly, causing dust layers within a plant to become suspended and ignited. This often much larger secondary deflagration can continue to suspend and ignite residual dust while filling the area with an accelerating fireball and pressure. With enough fuel (which can be a very thin layer), the secondary (or subsequent) deflagration can fill the interior building space, causing catastrophic failure as a full explosion as shown in Figure 1.

Secondary deflagration events in connected vessels also typically are more violent. The

SECONDARY DUST EXPLOSION
Figure 1. A secondary dust explosion in an aluminum manufacturing plant caused six injuries and one fatality.

pressure wave from a deflagration within a primary vessel can propel unburned dust (fuel) into a nonisolated vessel. The initial propagating pressure wave, much like a turbocharger on a combustion engine, can cause precompression in the secondary vessel depending on the geometry. Ignition of the secondary event can produce amplified pressure and explosive results.

Secondary explosions also can occur within ducts or pipes when a primary deflagration propagates. As the pressure wave and fireball travel through a fuel-containing duct, continuous combustion can produce elevated pressure within the duct's containment. This pressure accumulation or pressure piling can cause catastrophic failure of the duct material or transition to detonation as the velocity of the deflagration exceeds the speed of sound. The energy release and violence of a detonation can be of extreme magnitude and related to a dynamite explosion.

Deflagration isolation is critical to protect against the possible effects of a propagating combustible dust deflagration. Deflagration isolation is recommended on any pathway of a vessel with an explosion hazard. This can be the conveying inlet, outlet, hopper discharge, feed lines, etc. The greatest risk often is the material inlet as it contains the source of combustible dust and most often is connected to upstream areas or vessels posing a secondary explosion hazard.

INLET DEFLAGRATION ISOLATION

Deflagration isolation systems must either create an inherent barrier to the pressure and deflagration fireball or be sufficiently fast-acting to decouple the protected area before the flame front can propagate. A typical deflagration can become fully developed within the order of 50 milliseconds. Isolation devices must be reliably capable to function in this extremely short time window.

There are several proven methods of deflagration isolation on pneumatic material inlet lines. They generally are divided into two categories: active isolation and passive isolation.

ACTIVE ISOLATION

Active isolation methods include electronic detection (typically pressure, spark or fire or a signal from an open explosion vent), a controller and an inline actuated device that creates the isolating barrier. Active isolation devices can be either chemical or mechanical.

Chemical isolation creates an internal material barrier of a deflagration suppressant medium — usually sodium bicarbonate — through rapid injection from pressurized canisters mounted on the pipe or duct. The chemical barrier extinguishes the propagating deflagration combustion similar to a dry-type fire extinguisher.

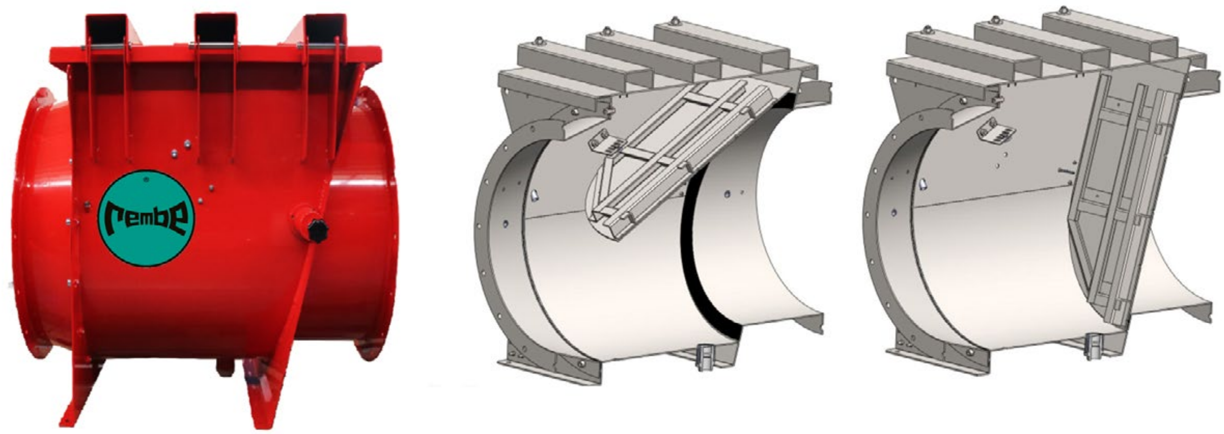
Active mechanical isolation methods consist of fast-acting mechanical valves that close upon detection. Active mechanical isolation valves include pneumatic-driven pinch valves, sliding knife gates and actuated float valves as shown in Figure 2. The response and activation of these devices must be fast enough to fully close ahead of a propagating deflagration travelling up to 100 m/s.

ACTIVE MECHANICAL ISOLATION DEVICES
Figure 2. Active mechanical isolation devices include quench valves (top image) and knife gate valve (bottom).

Active isolation systems and devices must be tested, designed and manufactured to operate within the fast response and reliability requirements of deflagration isolation scenarios. National Fire Protection Association (NFPA) 69-2019 Chapter 11 provides recommendations for deflagration control by active isolation.

PASSIVE ISOLATION

Passive deflagration devices provide a barrier to deflagration propagation



PASSIVE ISOLATION
Figure 3. Passive isolation flap valves operate similarly to check valves.

without external energy or detection requirements. Typical passive isolation techniques on pneumatic conveying inlet lines are float or flap-type valves that close and lock from the pressure wave of a deflagration that precedes the fireball.

Float valves consist of an internal poppet suspended on a support rod parallel to the direction of flow. The deflagration pressure wave imposes force on the poppet face, causing it to translate along the support and seal against the circular upstream opening and lock in the closed position.

Flap-type isolation valves consist of an internal pivoting plate, or flap, that is open during process flow but closed and locked under the force of an opposing flow pressure wave, similar to a typical check valve as shown in Figure 3.

Isolation flap valves often are often favored in practice due to their relative cost and operational requirements as compared to float-type isolation valves. Because of the application's ease of use and popularity, many manufacturers and suppliers offer a variety of flap isolation valve models, each with unique designs, features, certifications and limitations.

The following paragraphs provide an empirical overview of the parameters that influence the differences between various isolation flap valves. This is not a direct side-by-side comparison of available flap valves but rather the range of variance in defining characteristics.

NFPA 69 REQUIREMENTS

NFPA compliance has become a familiar phrase with respect to explosion protection equipment, which demonstrates the industrial world's education and awareness of combustible dust hazards and safety. The NFPA standards on combustible dust hazards have been either legally adopted or assumed as industrial best practices by many jurisdictions across North America and beyond.

As written, the NFPA standards are compilations of recommendations and best practices for fire and explosion safety. They are not regulations, codes or law unless written into jurisdictional code regulations. NFPA is not a certification agency and provides no such analysis, testing or certifications. "NFPA certified" is a misappropriation where often "NFPA Compliant" is perhaps implied.

NFPA compliance implies that the equipment (or design, installation, procedure, etc.) meets the minimum associated recommendations in the respective NFPA publication section. NFPA compliance ensures a degree of diligence was applied to the equipment's design and intended function; however, recommendations also can be generally broad to cover a primary intent irrespective of design variations so as to not limit manufacturer diversity.

The specific requirements for isolation flap valves are covered in NFPA 69 Section 12.2.3. Included are specific design considerations and criteria. The flap valve design and application criteria are as follows:

- The valve flap shall close under the anticipated pressure of a deflagration.
- Upon deflagration driven closure, the flap shall lock and seal against the passage of flame and burning material.
- There shall exist a means of inspecting the flap plate and seal.
- Upon closure, there shall be an immediate shutdown of the protected process.
- There shall be a means of ensuring material accumulation inside the valve does not compromise the closure and sealing of the flap. This can be either by documented risk assessment and periodic internal inspections or automatic continuous signal with interlock to shut down the process.
- The ductwork between the valve and the protected vessel is rated for at least two times the design reduced vented pressure of the vessel.
- The valve design methodology and application range are tested and certified by an independent and recognized testing organization.

Compliance with the majority of the NFPA 69 flap valve design criteria generally is consistent across the majority of commercially available isolation valves and executed with minor variations. The significant difference between isolation flap valves is with the tested and certified application ranges.

CERTIFICATION

Isolation valve performance range and application limit certification parameters required by NFPA 69 Section 12.2.3.5.1 are as follows:

1. Minimum and maximum location placement distances from the expected ignition source
2. Minimum and maximum K_{st}
3. Maximum number of flow direction changes (elbows)
4. Maximum dust loading
5. Maximum air velocity
6. Range of allowable P_{red} within the protected enclosure where the ignition might occur

It also is required that the performance parameters and design methodology be tested and certified by an independent and recognized testing organization. Because the recognized testing organizations for explosion protection equipment in North America have limited availability, European certification generally is accepted.

EUROPEAN CERTIFICATION

The various recognized independent testing and certification groups in Europe must perform tests according to EN standards. The European standard for explosion isolation check valves is EN 16447. EN 16447 has three primary test modules:

A. Test for explosive strength
B. Test for flame isolation
C. Functional test

Module A, the test for explosive strength, certifies the maximum explosion pressure the valve can sustain without failure. This test is executed at least once per largest valve size of identical geometry and construction.

Module B, the test for flame isolation, ensures the valve closure will prevent the spread of flames past the flap. An effective test requires the flame to reach the valve flap to ensure flame isolation. The test must be carried out with the worst case permitted elbows or fittings or otherwise assumed as straight pipe of minimum five times the diameter.

A successful test permits usage with dusts with an equal or greater maximum experimental safe gap (MESG) than the dust used and reported in the test. MESG is defined as the maximum thin opening that will stop flame propagation in a dust or gas cloud and is determined as a function of the dust's minimum ignition energy (MIE) and minimum ignition temperature (MIT) according to the following equation:

$$MESG = [MIE\ (MIT+273) / 273]^{0.157}$$

where MESG(mm), MIE(mJ), MIT(K)

(Eckhoff, Dust Explosions in the Process Industries, 2003)

Module C, the functional test, evaluates the explosion isolation system's effectiveness under limiting configurations similar to the performance parameters of NFPA Section 12.2.3.5.1. The EN 16447 Module C test setup and execution must reflect the following:

- General ability to isolate an explosion
- Minimum and maximum distances from the protected vessel
- Protected vessel's minimum volume
- Presence of anything other than straight pipe between the valve and the protected vessel and immediately after the valve (fittings, fans, elbows, etc.)
- Push vs. pull flow through the valve
- Valve inclination
- Dust characteristics, including metal/non-metal, K_{st}, P_{max}, MESG (MIE, MIT)
- Vessel's P_{red}
- Dust concentration
- Flow rate

With such an inclusive list of variables, many with a wide application range, this leads to an unimaginable number of possible configurations. As such, every tested and certified explosion isolation valve is unique. The most common variance with significant limitations is the material characteristics, specifically the minimum and maximum Kst limits. Application of an explosion isolation valve outside of the tested and certified performance range carries the risk of failure to completely and effectively isolate a propagating fireball from an upstream protected area.

SUMMARY

Evaluating, selecting and applying an explosion isolation flap valve must include more than a claim of certification or compliance. NFPA compliance implies that the actual combustible dust hazards are understood and confidently managed within acceptable risk tolerance. Due diligence falls on persons involved with the design and application of explosion safety devices for material handling systems. This is highlighted by NFPA 652-2019 Section 9.3.3.1.1: "Where used to handle combustible particulate solids, systems shall be designed by and installed under the supervision of qualified persons who are knowledgeable about these systems and their associated hazards."

Explosion isolation devices are not a one-size-fits-all solution. Reliable and compliant protection requires the right tool for the job. With attention to the details and qualifying the available equipment, the right match can be easily made. Reaching out to experienced professionals for assistance in making appropriate product selections is always recommended and encouraged.

JERAMY SLAUNWHITE is an explosion safety consultant at REMBE Inc. He can be reached at jeramy.slaunwhite@rembe.us.

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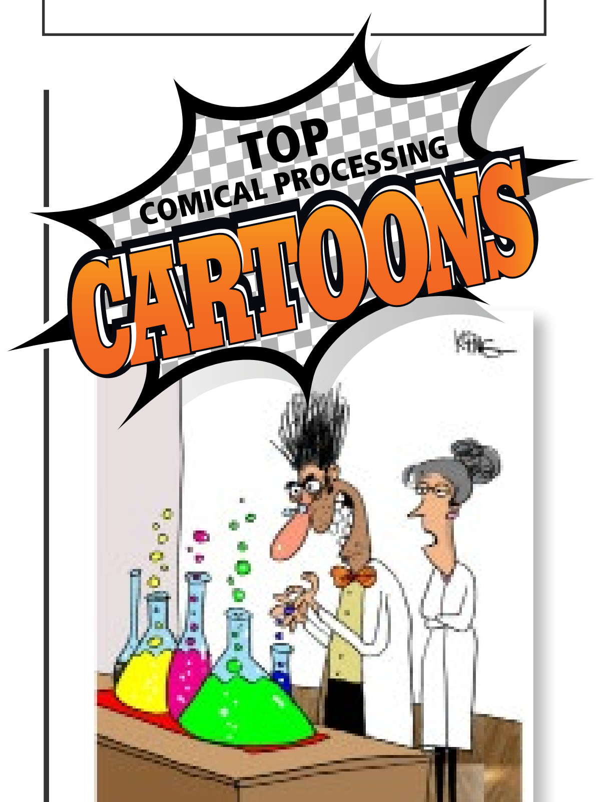

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