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Hoses Suit High Static Applications

Lightweight material helps minimize work injuries

TIGERFLEX™ VOLTBUSTER™ food grade material handling hoses are designed for high static applications such as the transfer of powders, pellets and other granular materials.

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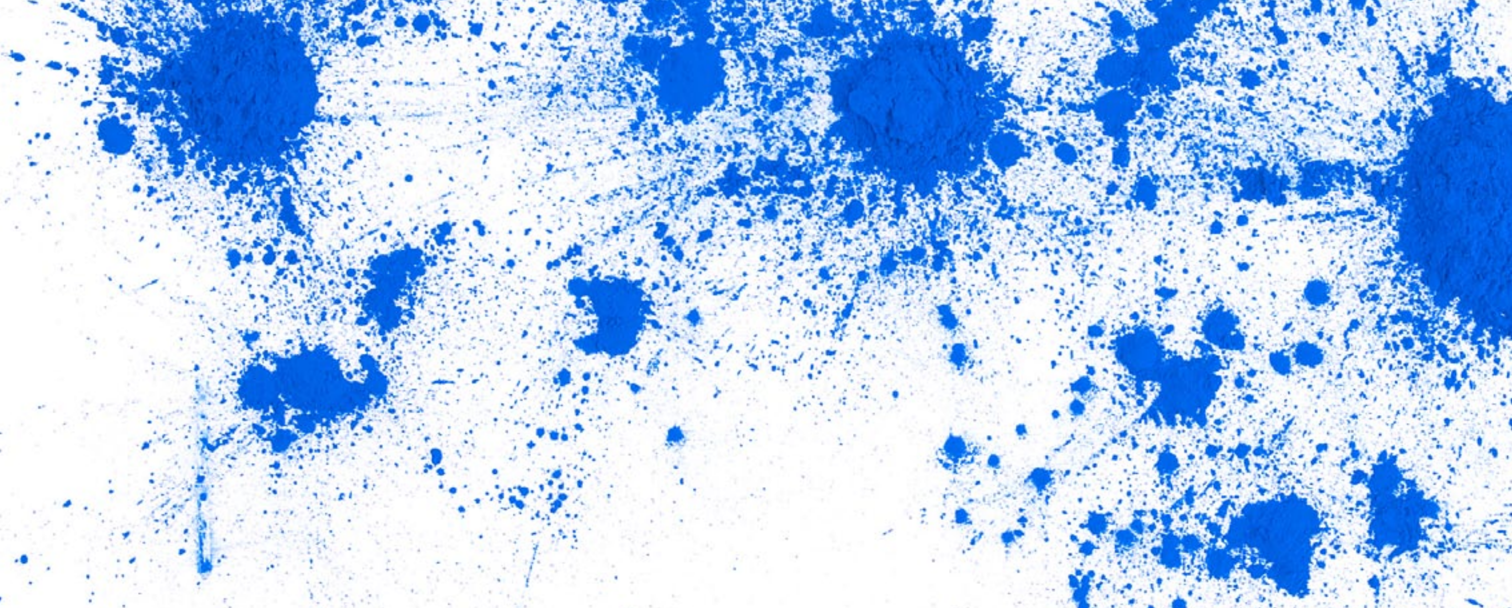


Rethink Options for Large Drivers

Variable-speed electric motors can offer significant advantages

By Amin Almasi, WorleyParsons Services Pty. Ltd.

ADVANCES IN high-speed electric motor technology along with improvements in the cost and the performance of variable speed drive (VSD) systems make direct coupling of a gearless electrical motor to a turbocompressor or pump worth considering for many services requiring large drivers. Brushless synchronous motors with two-pole rotors often suit high performance duties. Special applications may benefit from other options such as induction electric motors.

When using an electric motor driver, full power is available instantly over the entire site ambient temperature range and train speed range (including startup). The number of successive and cumulative start/stop and load cycles generally isn't critical.

Variable-speed electric motors in the upper-megawatt power ranges (say, over 20 MW) usually have energy efficiencies exceeding 97% over the entire useful speed range (typically 70–105% of the rated speed). In a combined-cycle power plant, the electric drive's efficiency generally is 15–25% better than that of typical heavy-frame gas turbine drivers. In addition, some of today's electric motors don't need scheduled maintenance for periods of up to six years of continuous operation and even after that don't require replacement of costly parts.

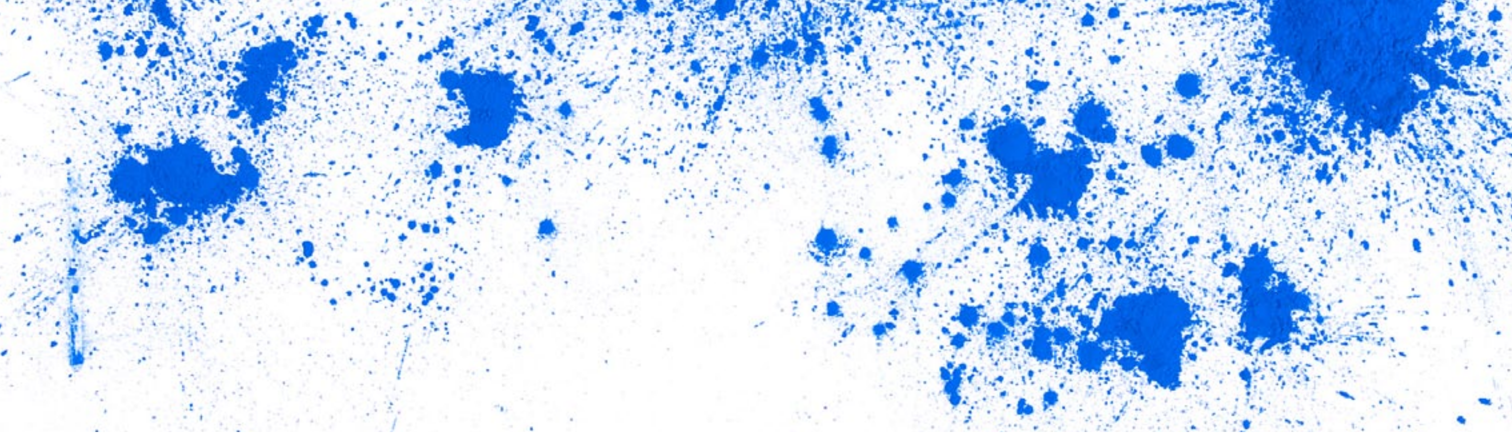
Large electric drives always are custom engineered for an application, allowing, e.g., a turbocompressor to be optimized in capacity and speed for the process, rather than being limited by a given gas turbine rating. The rotor design and overall features of the motors closely match those of electrical generators; design and manufacturing of large (over 100 MW) generators is well established, and numerous units are operating successfully. However, motors are variable speed while generators usually are constant speed, and motors suffer from oscillating shaft torques during operation (particularly when starting).

MOTOR ISSUES

When designing large high-speed electric motors, mechanical and dynamic problems must be solved carefully. Mechanical stresses, vibration level, losses and cooling restrictions can limit the capacity and the maximum speed of a large electrical motor.

In any high-speed electric motor drive application, mechanical excitations, electrical pulsations, rotor dynamics issues, balance problems and mechanical-dynamic considerations, in general, are of paramount importance in ensuring a smooth-running rotating train over the entire speed range and during all normal and transient operations. Also, prior to ordering, it's essential to know the behavior of the train during any electrical fault conditions (the most severe probably being a short circuit at the electric motor terminals). VSD-fed electric motors continuously produce some small torque oscillations over the entire speed range. So, the design phase should include careful analysis of the effects of such torque pulsations, along with other excitations, particularly torsional ones.

A large electric motor requires a complex and heavy rotor assembly. For example, the assembly can weigh 6–35 tons for 20–120-MW units. Balancing such a rotor assembly is an extremely difficult job. (Some expensive assemblies actually have been scraped after many unsuccessful attempts to balance them.) Coarse balancing of an electric motor rotor usually gets to within 0.015–0.03 mm of mass center offset; final balancing for some high-speed electric motors, for



UNDERLYING ADVANCES BOOST MOTORS

Some major developments have made large (>20 MW) electric motor drivers possible:

- better understanding of rotor dynamics, advanced balance technologies and, more importantly, use of advanced bearing options;
- progress in materials such as high-tensile steels for motor high-stressed and critical components; and
- advanced finite-element analysis, methods, e.g., for advanced electromagnetic calculations, and improved analytical approaches to predict electric motor performance parameters.

example, may require getting to within around 0.002 mm of mass center offset. Advanced systems such as active magnetic bearings also could be used to further improve the variable-speed electric motor driver.

LCI TECHNOLOGY

Most variable-speed electric-drive systems rectify alternating current (AC) to direct current (DC) and invert DC to variable frequency AC. For a VSD system with a rated output of over 60 MW, two popular and field-proven inversion options are a load commutation inverter (LCI) and a gate commutated turn-off thyristor (GCT). Other options, such as a voltage source inverter (VSI), may not be mature enough for ratings above 60 MW. A grey area where both VSI and LCI technologies are feasible exists between 30 MW and 60 MW.

Today, LCI technology is the most popular VSD converter system. It's a mature technology; disadvantages and solutions to minimize its problems are well known. It commonly is teamed with dual-star two-pole synchronous motors with supply frequencies between 50 and 80 Hz.

If the electric power supply is interrupted (for example, due to a temporary problem in a generator or a power transmission malfunction), the turbocompressor or other driven equipment will decelerate rapidly and may trip a protection system (e.g., for lubrication oil low-pressure or anti-surging). This may prevent the unit from re-accelerating when power is restored. So, all protection system issues deserve detailed study.

The main issues for the VSD converters are:

- size (very important);
- redundancy of the equipment;
- control system details (alarms, diagnostics, reliability, etc.);
- guarantees for disturbance "ride through" capability;
- harmonic mitigation, harmonic filter and torque oscillation; and
- converter cooling-system requirements.

To provide "ride through" capabilities — a standard feature for an LCI converter with synchronous motor drive — a secure uninterruptible power supply should back up the power to the control system. The arrangement and layout of the converter system should prevent a domino effect (i.e., the loss of one part shouldn't disturb other parts as far as practical).

Like any nonlinear system, a frequency converter produces harmonic currents. Therefore, conducting a harmonic study (and usually providing a harmonic filter package) makes sense. The analysis should look at the complete electrical network (including VSD converter) over the entire frequency spectrum, calculating the voltage total harmonic distortion (THD) under all system operating and upset conditions. Usually, a network short circuit when the system is under no-load (or the minimum load) conditions constitutes the worst case.

A harmonic filter is connected to the network or to a third secondary winding of the system transformer. The choice mainly hinges on cost and usually depends on the network voltage level. For 33 kV and below, the connection most often is on the network. For 110 kV and above, a third secondary winding generally is selected. In between, the decision must be made on a case-by-case basis. (The design and manufacturing of large power transformers with three secondary windings is a difficult technical challenge; only a limited number of manufacturers are capable of implementing such designs.)

To minimize the harmonics effect (particularly on the electrical network), large LCI systems usually have 12-pulse topology. Even if an LCI system has multiple pulse rectifier configurations to reduce the harmonic current level emission, the reactive power consumption of the LCI rectifier may require use of a power-factor compensation system (usually a capacitor harmonic filter). In LCI-type converters, the harmonic excitation generates a constant nominal

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Call: (800) 427-6260 E-mail: sales@hapman.com Visit: www.hapman.com flux in the motor air gap, which could result in train mechanical excitations.

The main issues related to the harmonic filters are:

- sizing (which requires extensive data about the entire electrical network);
- possible running without one harmonic filter rank; and
- switching a filter during normal operation and over-compensation at special operating points.

Harmonic studies should provide drive output current spectra, harmonic details (order, amplitude and phase), and how these vary with the compressor train speed. In multi-drive installations, the superimposition of individual harmonics and the sizing of harmonic filters for an entire installation require special calculations and simulations. Calculated harmonic levels must be compared against standard limits (for example, those in IEEE 519). The harmonic study contains two parts: one dedicated to calculating the electrical natural frequencies, and the other aimed at minimizing the harmonic distortion to optimize the design of the harmonic filters. The study should determine potential resonances in the entire system. Power generators usually give rise to some harmonics that could interact with VSD systems. Restrictions should be imposed on train torque ripple (usually under 1–2% peak-to-peak) to preserve the torsional stability. The THD of the line-side voltage should be within certain limits (most often 2–3%) to minimize disturbances to the other electrical loads connected to the same plant electrical network.

VSI TECHNOLOGY

LCI technology suffers from some well-known drawbacks — e.g., high torque ripple, poor power factor, relatively high losses and harmonic pollution. These disadvantages can make LCI-based variable-speed drives inadequate to reach the increasingly demanding performance required in some applications. In such cases, a VSI may provide the solution for turbocompressors and pump drivers.

Indeed, quadruple-star four-pole synchronous motor technology fed by four pulse-width modulation (PWM) multilevel VSIs is getting considerable attention. Based on today's targets for low torque ripple and low harmonic distortion (particularly low grid-side harmonic pollution), the PWM-VSI-based variable-speed-drive design has been selected for several large turbocompressor projects. A cascaded multilevel converter topology usually is chosen. Each

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converter phase is obtained by series connecting several transistor cells. The choice of this topology makes it possible to attain some important goals like:

- voltage output (converter output to an electric motor) that approaches the sinusoidal waveform as the number of cells is increased — providing the possibility of operating the electric motor at a near-unity power factor;
- tolerance to single cell faults by implementing a faulty-cell bypass function; and
- low harmonic injection.

In fact, with LCI-based drives, having more than two supplying converters may be theoretically feasible, although this may pose commutation overlapping issues.

In the PWM-VSI technology four converters commonly are used. The decision to supply the electric motor with several (four or more) three-phase converter units naturally leads to the splitting of the stator winding into independent three-phase sets, each to be fed by a converter. The stator design needed for this purpose often is referred to as "split-phase" because it results from splitting the winding into multiple star-connected three-phase sets. The most common arrangement uses four converters; the associated electric motor design is known as quadruple-star winding. The phase currents contain harmonics of orders 5, 7, 11, 13, 17 and 19; all the resulting space harmonic fields in the electric motor air gap are very low because of the mutual cancellation effects.

Today, turbocompressors and pumps may benefit from a new electric drive option based on a VSI-fed quadruple-star 100-Hz four-pole synchronous electric motor. Compared to traditional LCI-based options, it provides particular advantages:

- torque ripple typically lower than 1–2% peak to peak;
- very low vibrations owing to the four-pole design;
- high fault tolerance due to the four-star four-converter topology; and
- high electric motor efficiency, usually above 98%.

Because of the large number of phases (12) and the four-pole design, even for high power levels the stator winding can be done with coil technology (instead of complex/expensive "Roebel" bar construction) with noticeable manufacturing and cost benefits. The 100-Hz supply frequency doesn't give excessive core losses. Stator phase currents may show fifth and seventh current harmonic distortions as a consequence of the electric motor internal electromotive force. However, these harmonic distortions don't negatively impact torque performance. The design also could be scalable to relatively high power levels (above 50 MW) by increasing the number of supplying converter units and possibly expanding the electric motor driver size.

OTHER CONSIDERATIONS

Transformers play an important role in any VSD system. Inrush current limitation requirements and protection philosophies of transformers are important.

A VSD electric motor system employs various cooling water pumps. A cooling pump's normal operating point should be as close as practical to the pump's best efficiency point (BEP). Rated cooling flows preferably should be within 20% of the BEP flow. The cooling-pump characteristic curve is very important for a trouble-free, smooth and proper operation. A cooling pump curve should exhibit the characteristic of stable continuously rising head from the rated capacity to the shutoff (preferably 10% head rise from the rated to the shutoff).

Typically, a VSI system's footprint is less than 75% of that of a comparable LCI system. In addition, it usually weighs less than 70% of a comparable LCI system.

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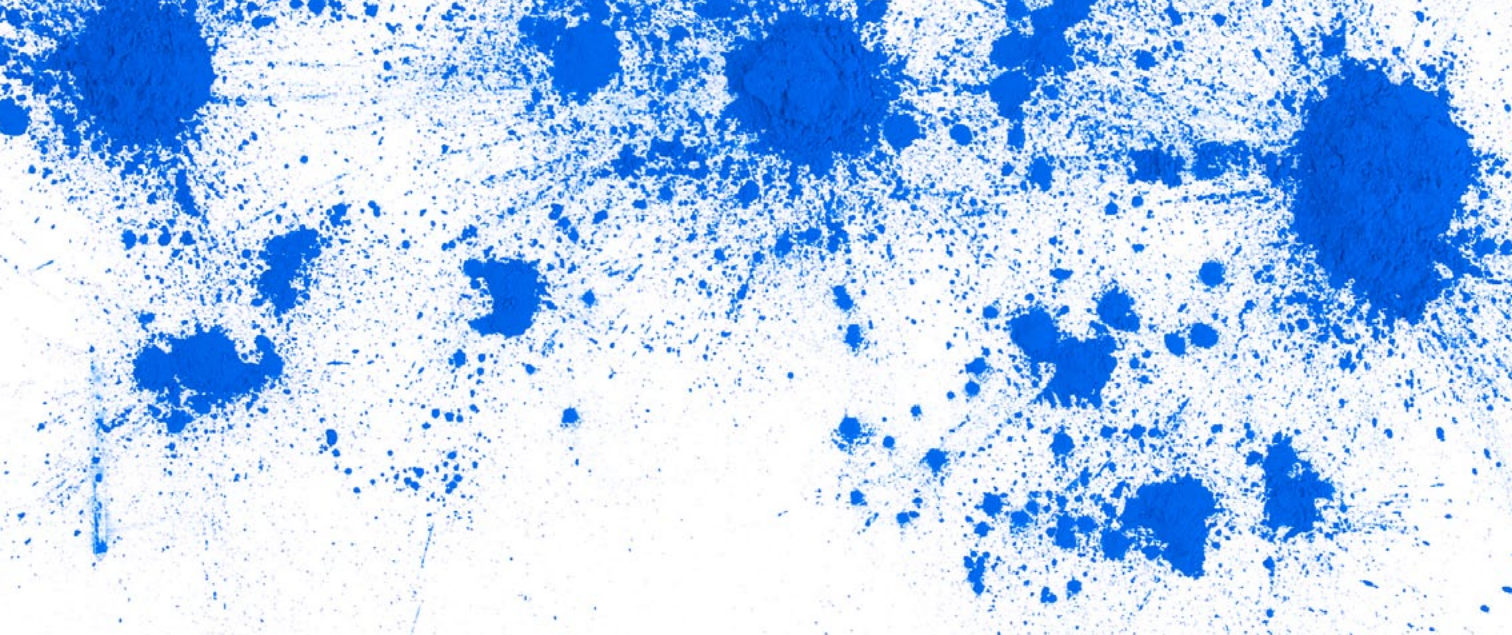

Bob for Accurate Measurements

Cable-based sensors help simplify inventory managment

By Jenny Nielson Christensen, BinMaster Level Controls

WHETHER REFERRED to as weight and cable, plumb bob, cable-based, or yo-yo-type sensor, the principle of its operation is simple. The device works as an automated tape measure that repeatedly takes measurements from the top of the silo at a consistent location. This eliminates the need to climb silos to take manual measurements. When a measurement is taken, the sensor releases a cable with a weighted sensor probe — often referred to as a plumb bob — that stops and retracts when the probe comes into contact with material. The "brains" of the sensor convert the distance data to a measurement that can be displayed as either the height of the material or the distance to the material, referred to as headroom. The sensor takes redundant measurements, when the sensor probe is both descending and retracting, to confirm that every measurement is precise. When minimal contact with the vessel's material is acceptable, a weight and cable-based sensor is a very economical and accurate continuous level measurement solution.

Cable-based sensors are designed for single-point level measurements taken periodically throughout the day. Level measurements can be programmed to take place at predetermined time intervals or initiated as needed from a console at ground level or from a PC, depending upon the type of communication devices used. High-temperature and explosion-proof options make cable-based sensors suitable for most challenging applications. Their versatility makes them well-suited for the chemical industry where ongoing inventory management and remote reporting is required for multiple small and large vessels containing a wide array of materials.

Figure 1. Weight and cable-based or bob-style sensors are an ideal level measurement solution for chemical processors as they work in virtually any material regardless of particle size or bulk density.

POWDERS, GRANULES AND SOLIDS

Weight and cable-based or bob-style sensors (Figure 1) are an ideal level measurement solution for chemical processors as they work in virtually any material regardless of particle size or bulk density. Immune to most material characteristics, they perform equally well whether the silo contains light, fluffy powders; plastic pellets; fine to coarse granules; or heavy, dense lump materials. "Bobs" are a proven technology that have been in existence for decades. These trouble-free, long-lasting devices require no calibration, even if the material in the silo changes. These sensors will perform reliably and are not affected by dust, humidity, temperature, dielectric constant or fumes that may be present in the vessel. The stainless steel probe at the end of the cable makes minimal contact with the material in the silo, so there's very little risk of contamination.

A BAND OF "BOBBERS"

Due to their versatility in many types of materials in vessels of any construction, height or diameter, a network of multiple weight and cable sensors can meet the challenge of just about any silo measurement need in the facility. For example, if multiple silos containing different types of processing, packaging or waste materials need to be monitored, the sensor can be adapted to the needs of each particular silo. A bob-style sensor can be used in large silos up to 180-ft tall, but also are often used in smaller, active process silos under 40-ft tall.

While a stainless steel weight is commonly used with the sensor, a round stainless steel sphere float is an alternative for silos containing light powders, slurries or liquids. A hollow, inverted stainless steel cone can be used in liquids or light powders or solids with a bulk density of at least 3 lb/ft^3. An economical choice that's often used in light or dense powders or liquids is a digestible bottle that fits through a rotary valve or screw conveyor and filled with paraffin wax or alternative compatible material.

Figure 2. For the best accuracy, the sensor should be mounted on the roof of the silo about 1/6 of the way in from the outer perimeter.

MOUNTING FOR THE BEST ACCURACY

For the best accuracy, the sensor should be mounted on the roof of the silo about 1/6 of the way in from the outer perimeter (Figure 2). When used in free-flowing material, this ideal sensor placement location accounts for the angle of repose on a center-filled vessel. When a vessel is being filled, the material forms a "cone up" in which material is higher at the center and lower near the sides of the vessel. If you draw a horizontal line at the point the sensor probe comes into contact with the material surface (1/6), there's a peak at the center of the vessel and voids at the sides. If you take the material in the peak and fill in the voids, it will flatten out the angle of repose (Figure 3).

The same is true when the vessel is being emptied and material is lower in the center and higher on the side forming a "cone down." Mounting the sensor 1/6th from the outer perimeter is proven academically to calculate the most accurate level reading for a vessel. Properly mounted on a center-fill, center-discharge bin, bob-style sensors will consistently provide 5% to 7% accuracy.

EASILY ACCESSIBLE DATA

Cable-based sensor networks can be integrated utilizing a wide variety of communication options dependent upon how you want to access and use the data. The most cost-effective and popular option is to mount a control console at ground level. A single console can be mounted at each bin, or more advanced consoles can report data from more than 100 bins at a single console. Consoles are easily programmed with silo size information and each silo is assigned a vessel number. Browsing through a pushbutton menu, the user can access information such as distance to product (headroom), height of product and percentage full (Figure 4).

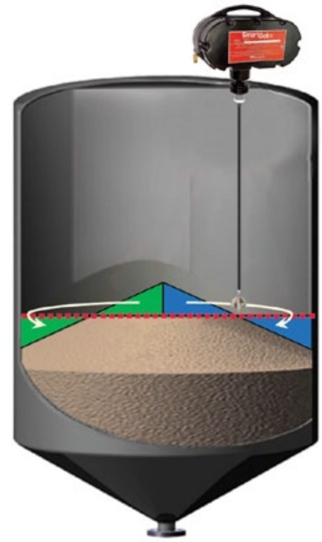

Figure 3. A properly located sensor probe will come in contact with the material surface at a point where there's a peak at the center of the vessel and voids at the sides. If you take the material in the peak and fill in the voids, it will flatten out the angle of repose.

If the preference is to have level-measurement data sent to a personal computer, several companies offer

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Windows-based software to report detailed data for multiple vessels simultaneously and generate a visual that shows silo levels as a percentage full (Figure 5). Silos can be named by location and labeled by their contents. Alarms or alerts can be generated when a silo reaches a predetermined high or low level. Other communication options include the ability to send an automated email when bins reach an alert level. The measurement data can be stored on the computer and used to generate historical reports. LAN configurations are also possible to share a common measurement database with multiple users on a local area network.

Internet-based monitoring solutions are also available that enable 24/7 access to bin data from any device with an Internet connection, and also allow for managing multiple sites from any remote location.

For facilities that prefer an analog output to a PLC for monitoring bin level measurement data, some models of cable-based sensors offer an integrated 4–20-mA output. In this type of configuration, the sensor is installed on top of the silo and the measurement data is sent directly to a PLC, eliminating the need for either a console or software.

Figure 4. A control console mounted at ground level enables users to access information such as distance to product (headroom), height of product and percentage full.

MEASURING SUBMERSED SOLIDS

Sometimes chemical facilities encounter unique challenges, such as the need to measure submersed solids under water. A submersed solids sensor option is a proven solution when the requirement is to measure the level of solid material below a liquid surface, such as in brine interface applications (Figure 6). The weighted probe drops through

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the liquid and makes contact with solid material settled at the bottom of a tank, such as for measuring the level of sediment under water. This sensor is an excellent alternative to relying on sight tubes and can be used in any application where solid material needs to be measured under liquid.

ACCOUNTING FOR COMPACTION OR IRREGULAR VESSEL SHAPE

Many powdered materials will have a greater bulk density at the bottom of the tank than near the top, due to the weight of material compressing downward as the vessel is filled. By entering the weight of the material at different heights in the bin, a strapping table can account for the compaction of material in the vessel. By adding valuable weight-to-distance data into a table, the estimate of material in the bin can be tailored to exactly how material behaves in a particular vessel. Strapping tables are also a useful tool when measuring the contents of cone-bottomed bins, because they can take into account the amount of material in a tapered cone. Strapping table data also allows for more accuracy in measuring irregular tanks, such as a cylindrical tank installed on its side.

Many new, innovative level measurement technologies are available for measuring powders and solids, but if you are looking for a proven, long-lasting, reliable and hassle-free solution, a cable-based sensor ensures simplicity and repeatability. This robust inventory management system can be networked using wired or wireless communications for up to a hundred vessels using just one license of software or one integrated console, making it an economical and uncomplicated choice.

Advances in software and Internet-based solutions allow users to initiate a measurement from a remote location and provide real-time inventory data from anywhere there's an Internet connection. Cable-based sensor networks cost less and present few headaches compared to other technologies, while providing a wealth of data for effective inventory management. ●

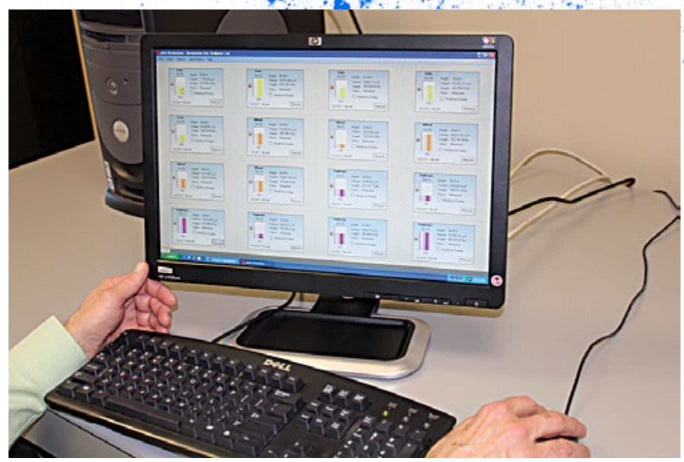
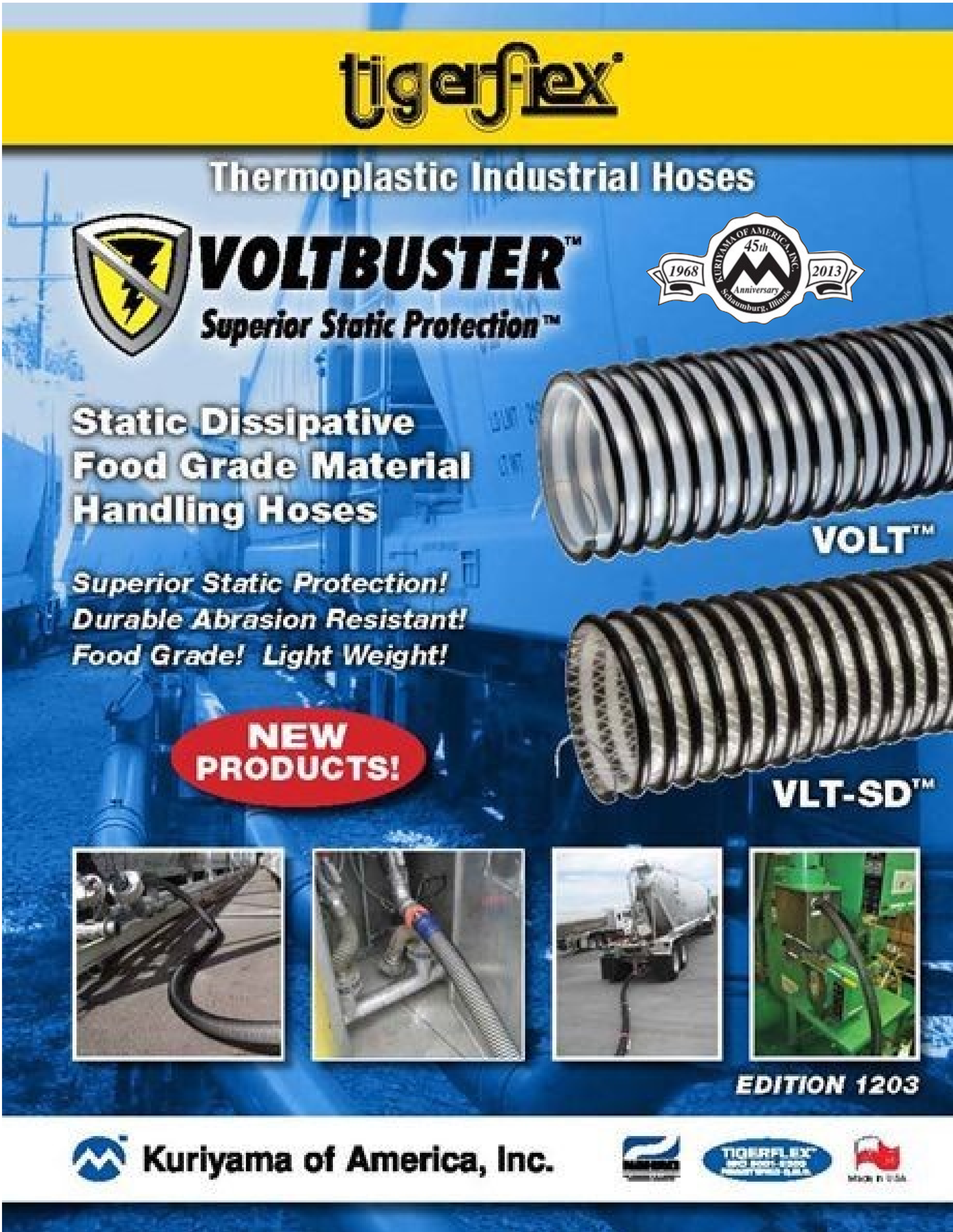


Figure 5. Windows-based software reports detailed data for multiple vessels simultaneously and generates a visual that shows silo levels as a percentage full.

Figure 6. A submersed solids sensor can measure the level of solid material below a liquid surface, such as in brine interface applications.

JENNY NIELSON CHRISTENSEN, MBA, is director of marketing for BinMaster Level Controls. She can be reached at jchristensen@binmaster.com.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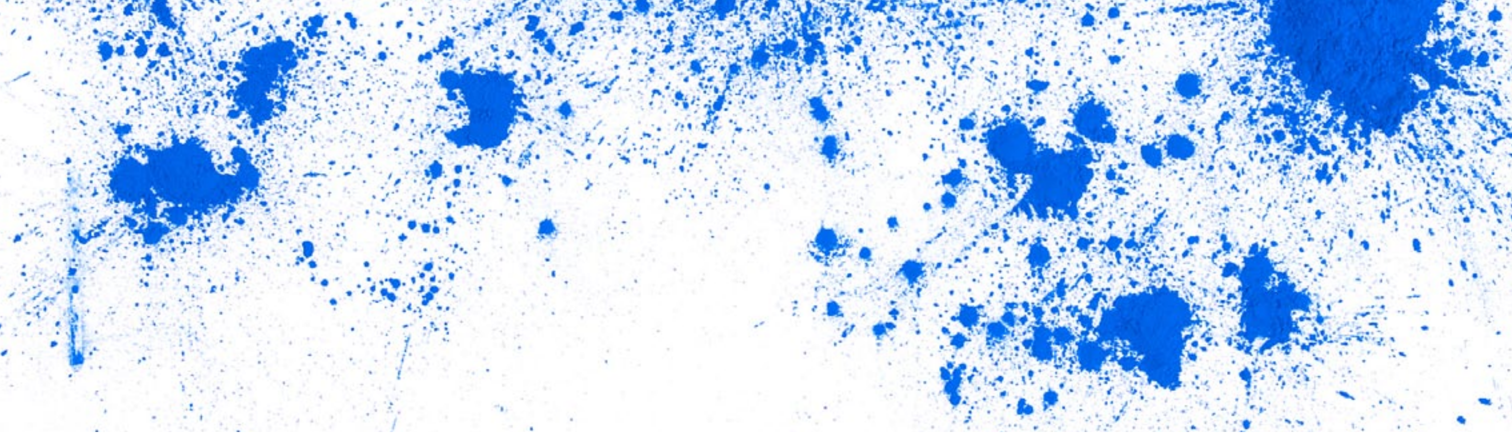

Does Moisture Affect Powder Flowability?

A shear cell instrument and relative humidity tests can determine a powder's flow behavior

By Robert McGregor, Brookfield Engineering Laboratories, Inc.

COMMON SENSE suggests that powders may have greater difficulty flowing in vertical discharge out of bins as the moisture content increases. This is true if the moisture acts more as a binder than as a lubricant. Changes in relative humidity can cause the moisture content in a vessel containing powder to fluctuate. These fluctuations may explain why the powder discharges reasonably well one day and less so the next. The final consideration is how long the powder sits in the vessel before flow is initiated. Gestation time in the bin can be a determining factor, along with humidity, for flowability.

How do you predict beforehand whether this type of problem will affect your operation? Traditional measurement methods for flowability, such as the Flodex Cup or the Angle of Repose test, don't provide sufficient accuracy to detect subtle changes that could relate to moisture content. The Shear Cell shown in Figure 1 is an instrument which gives a more comprehensive assessment of the powder's flow behavior and can, in fact, discern differences in powder "failure strength" as a function of relative humidity.

Figure 2 shows the test apparatus that constitutes a shear cell. The powder is placed in an annular chamber or cell called a "trough" which is positioned on the instrument. A lid with vanes

Figure 1: This powder flow tester from Brookfield can access a powder's flow behavior and can discern differences in powder "failure strength" as a function of relative humidity.

Figure 2: Powder is placed in an annular chamber or cell called a "trough" which is positioned on the shear cell instrument.

that create small pockets shown in Figure 3 descends on the sample and applies a consolidating pressure. The powder trapped in the vane pockets is sheared against the powder in the trough and a measurement of the sliding friction between particles is established. This friction value quantifies the "failure strength" of the powder, i.e. the amount of force that is required to cause the particles to move when sliding against each other.

Test measurements are made at increasing consolidating pressures. Figure 4 illustrates how the data is displayed with consolidating stress or pressure on the x-axis and powder "failure strength" on the y-axis. The resulting curve is called a Flow Function. Industry has agreed to define regions of flow behavior, ranging from "Free Flowing" along the x-axis to "Non Flowing" along the y-axis. In this example, the powder exhibits "Cohesive" flow behavior

Figure 3: A lid with vanes creates small pockets that descend on the powder sample and applies a consolidating pressure.

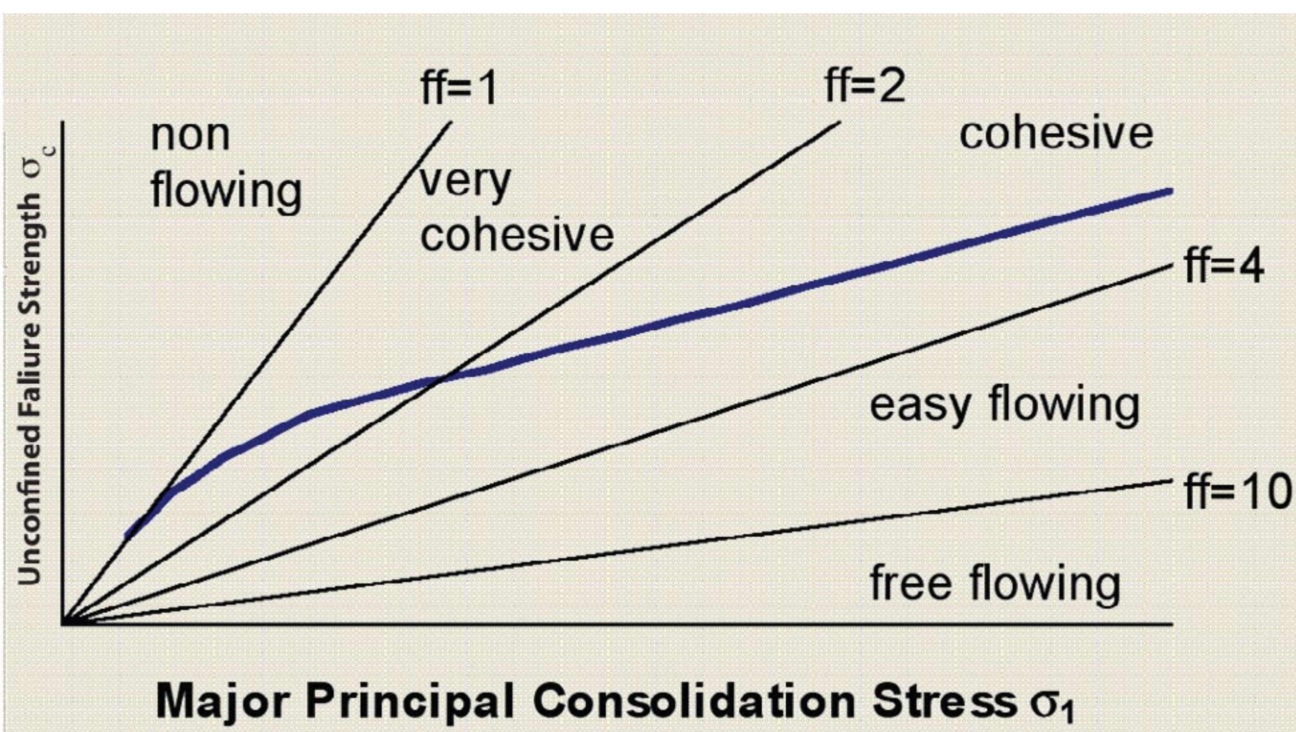

Figure 4: Data is displayed with consolidating stress on the x-axis and powder "failure strength" on the y-axis. The resulting curve is called a Flow Function.

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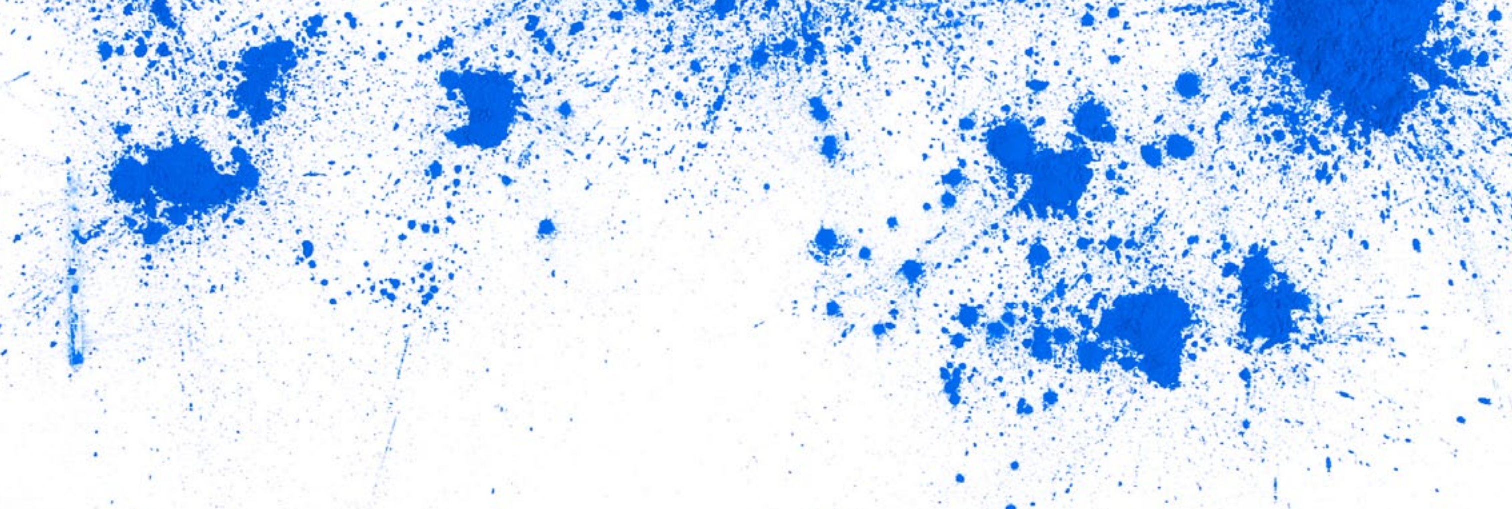


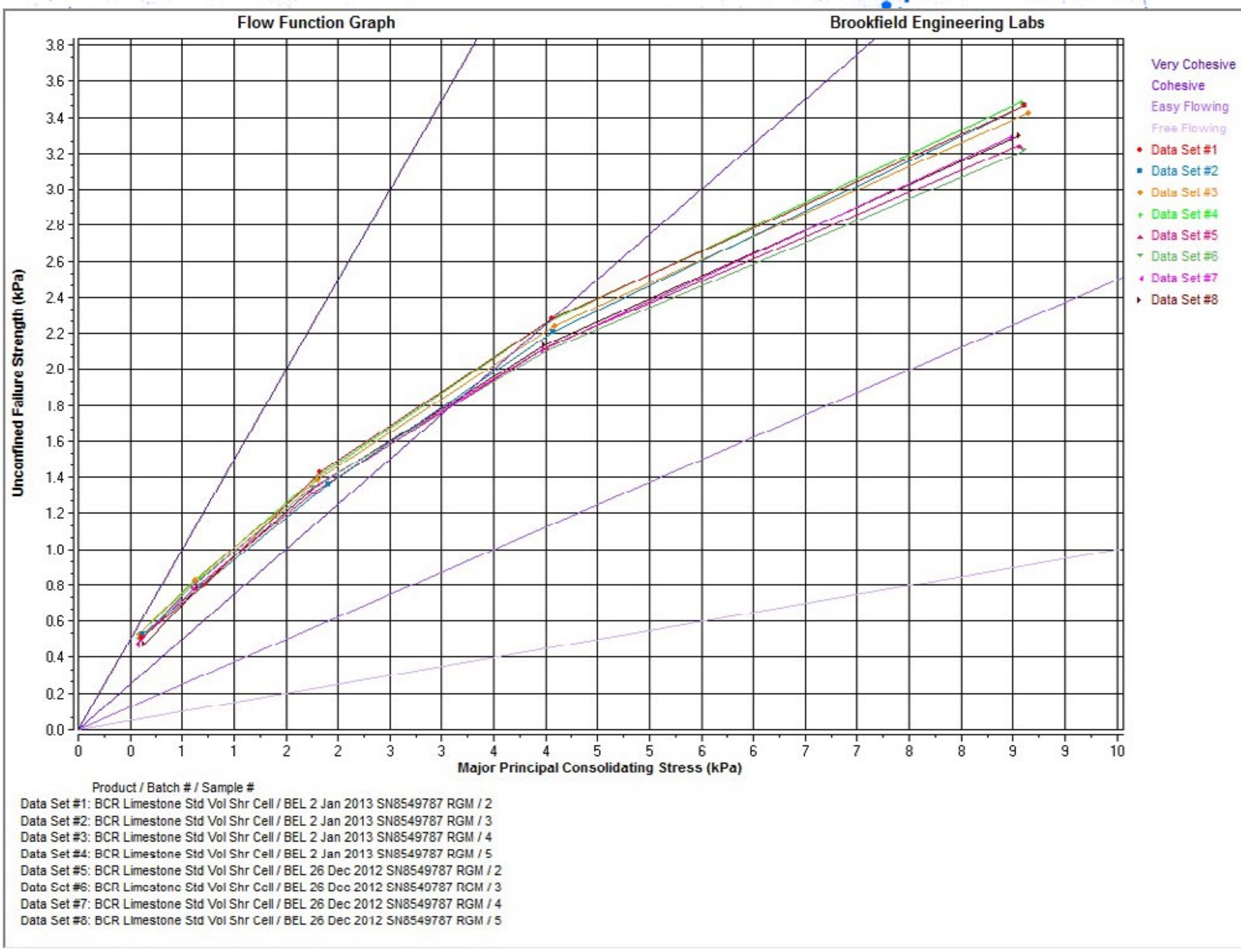
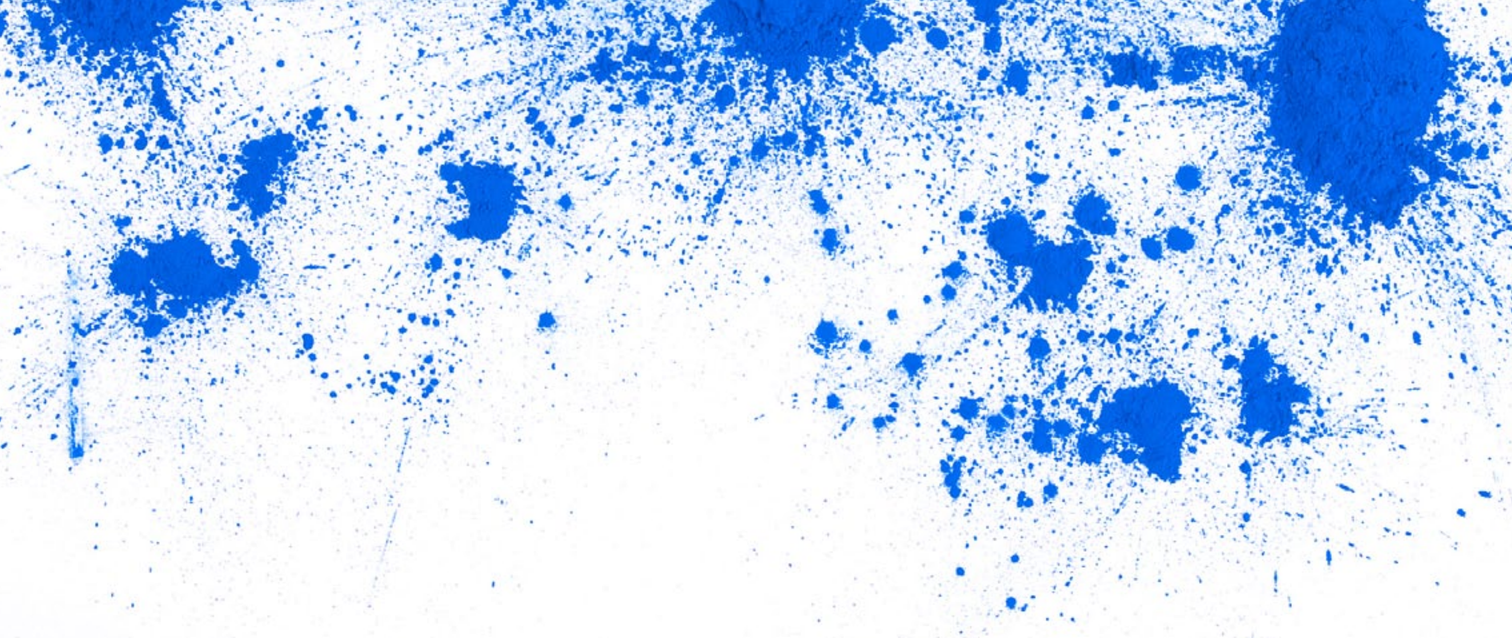


Figure 5: Data shows limestone flows with somewhat greater difficulty when relative humidity increases.

at high consolidating stress and "Very Cohesive" flow behavior at low consolidating stress.

Temperature and relative humidity (RH) are two additional parameters that are measured by the instrument during the Flow Function test. To measure the effect of moisture on powder flowability, a certified BCR limestone powder procured from the European Commission was conditioned before the test in a controlled environment. Temperature was held constant at 73°F while RH was maintained below 20% before and during four separate tests, then at 40% during four more tests. Figure 5 shows the Flow Functions for both groups of tests; data sets #1 through #4 are for 20% RH and data sets #5 through #8 are for 40% RH. Increasing RH caused the Flow Function to shift upwards, which means the limestone powder gained strength and flowed with somewhat greater difficulty.



The following table summarizes the average values for consolidating stress (pressure) applied to the limestone sample and the corresponding failure strengths. All data values are stress measurements and the units are Kilo Pascal (kPa).

Consolidating Stress	.311	.610	1.21	2.42	4.85
Failure Strength at 20% RH	.480	.795	1.33	2.12	3.26
Failure Strength at 40% RH	.526	.819	1.39	2.25	3.46

Note that changes in failure strength are on the order of 5% to 10%. The greatest difference in flow behavior appears to occur at the lower consolidating pressures. This is analogous to the situation where the fill level of powder in the bin has reduced significantly.

Conclusions from the above discussion are as follows. Moisture can affect powder flow behavior. Conventional tools used to predict flowability aren't useful for this purpose. The Shear Cell is a proven instrument that can detect small changes in flowability and should be used for this type of analysis. Repeating the Flow Function test using a time delay at each consolidating stress will give additional information on the consequence of allowing the powder to remain static in the bin for a defined time interval. This will show how moisture can affect the long term ability of the powder to initiate flow when the discharge gate is finally opened. The test results may cause appropriate concern for potential stoppages that will likely occur on the production floor.

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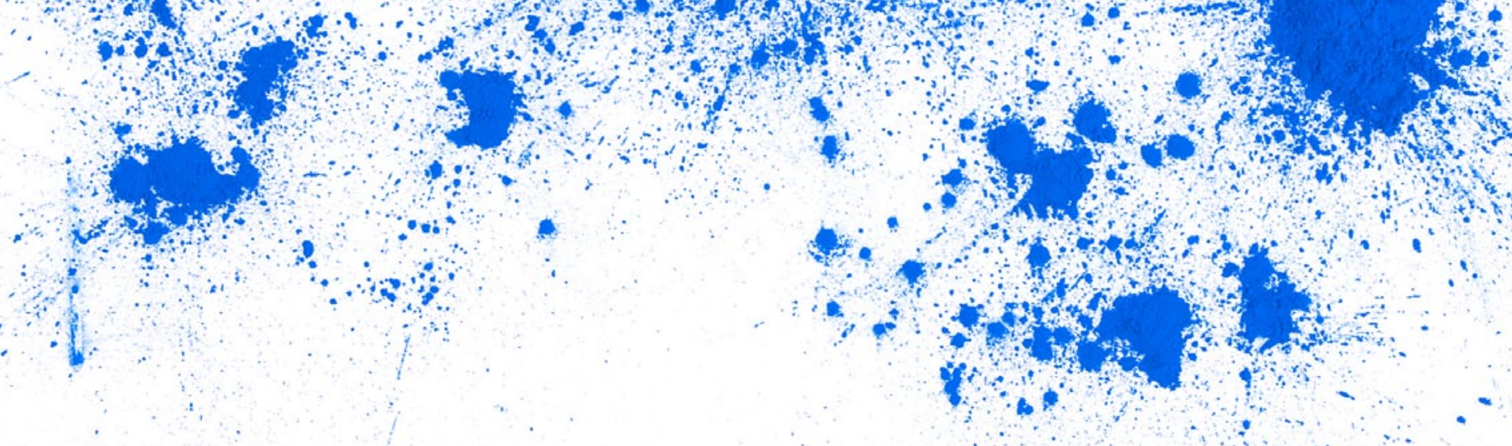

Mitigate Explosions with Indoor Flameless Venting

Modern technology can eliminate the risk of damage and reduce maintenance costs

By Dr. Gerd Ph. Mayer, Rembe, Inc.

THE HISTORY of catastrophic industrial explosions is a long and truly horrible one. In 1921, a silo containing 4,500 tons of ammonium sulphate and ammonium nitrate exploded at BASF in Germany; 561 workers were killed. The explosion was so massive it was felt 300 miles away and left a crater more than 70-ft. deep. In 1971, a flower mill exploded in Germany and resulted in the death of 17 workers. In 1984, an explosion in Bhopal, India immediately killed 2,259 people. In 2001, 31 people died in a dust explosion in Toulouse, France. [1]

In the U.S., too, there have been many explosions. In 2008, 14 died and 60 were injured at an Imperial Sugar plant. At Hoeganaes Corporation in 2011, 5 died in 3 separate incidents in less than 5 months. Six were killed and 38 injured at West Pharmaceutical in 2003. All of these incidents were caused by combustible dust or gas-related explosions. [1]

According to the Occupational Safety and Health Administration (OSHA) and the U.S. Department of Labor (DOL), at least 350 explosions caused by combustible dust killed 130 workers and injured more than 800 since 1980. A number of statistics are available from insurers and others that show the property damage caused by an explosion could range anywhere from an average of $400,000 to $1.6 million in loss per explosion incident [2]. Destroyed buildings and the huge loss of production as well as the cost of reinvesting in new production equipment can run into the billions of dollars. The average downtime after an explosion can be estimated to be at least several months, that is, long enough for customers to find another supplier. [3]

Figure 1. A flameless vent installed in a manufacturing facility is an economical and safe means of eliminating the risk of damage and fatality from dust explosions.

The explosion at Imperial Sugar in Georgia in 2008 is the watershed "catastrophic" event, which resulted in a re-issuance of the National Fire Protection Association (NFPA) standards and implementation of a National Emphasis Program with strict enforcement by OSHA. More than 30,000 companies have been made aware of combustible dust hazards and the need for strict compliance with NFPA standards. [4]

Some random measures have been undertaken over the years to curtail risks in production. Smoking is no longer allowed in any production facility and welding has to be done with special precaution taken, special permission/permitting and strict direction. Even cell phones are banned in some production facilities.

But to achieve a truly safe production facility, a modern explosion protection solution must consist of

- prevention of explosive atmospheres;
- avoidance of the ignition of explosive atmospheres; and
- mitigation of the effects of an explosion to an acceptable level.

There's much literature about the first two prongs [5], so we will focus on the third prong for purposes of this article.

MITIGATION OF EXPLOSION EFFECTS

The most commonly used method for deflagration prevention in the U.S. is chemical suppression and, in fact, for many years, chemical suppression was the only method used to protect indoor enclosures from the risk of combustible dust explosions where venting to the outside wasn't an option. With chemical suppression, bottles of an extinguishing agent under pressure of 80 Barg are installed in an enclosure or duct. These bottles are triggered by devices such as spark detectors or pressure sensors. In the event a spark or increase in pressure is detected, the suppression bottles quickly release their agent and extinguish the flame, thereby stopping propagation.

TABLE 1. EFFECT OF VENT DISCHARGE DUCT SIZE ON SAFE DEFLAGRATION PRESSURE

Discharge duct length, m	P_{red}, barg
0	0.2
2	0.4
3	0.5
4	0.6

Calculations based on: Vessel volume = 8 m^3; P_{stat} = 0.1 barg; K_{st} value = 139 bar-m/s; P_{max} = 9 barg; Vent relief area = 0.44 m^2

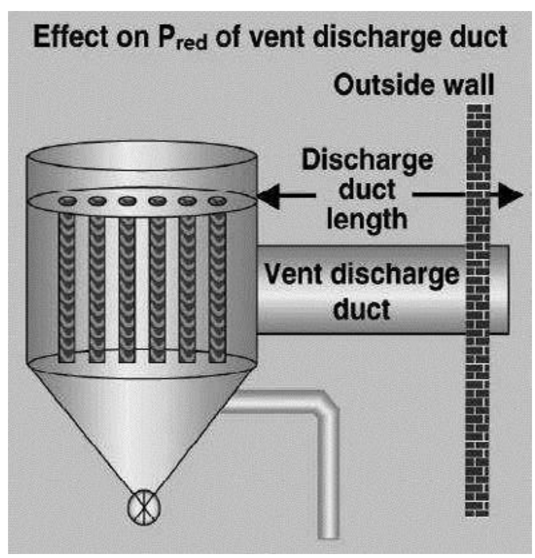

Figure 2. This table and graph show the effect of vent size on safe deflagration pressure; even a 10-ft length won't hold an explosion due to back pressure. *Source: Ralph Foiles, To Vent or Not to Vent, Chemical Engineering, 2004*

One drawback to chemical suppression is false triggering of the system due to sudden but small changes of pressure in real world manufacturing processes. False triggering can contaminate the process being protected by suppression and then has to be cleaned. The suppression bottles must be refilled or replaced and the system must be recertified by authorized personnel. Thus, a facility will suffer from downtime and real expenditures due to false triggering. [6]

In addition, in small enclosures, chemical suppression reaction time might not be fast enough to reduce the pressure build-up inside an enclosure below the enclosure's design pressure. Bursting of the enclosure or deformation could result.

Lastly, suppression systems require quarterly maintenance per NFPA 69 by authorized personnel (which is quite often the vendor's personnel) and create high maintenance costs for the lifetime of production.

For products or dusts with very high Kst values, suppression systems are still the only choice for explosion prevention for enclosures located indoors that can't be vented to the outside. For the vast majority of applications, however, indoor flameless venting systems are the best solution.

THE NEED FOR SAFE INDOOR VENTING

Today, there are options for safely venting indoor enclosures. Explosion vents or panels are the least expensive method of venting an enclosure so long as that enclosure can be safely ducted to the outside. After an event, the vent must be replaced.

NFPA 68 describes the calculation of the vent area necessary to safely vent the deflagration, based on Kst value and Pmax, the maximum explosion pressure and the Pred, or reduced design pressure, of the enclosure.

Figure 3. The Q-Rohr-3 flameless venting system from Rembe has an ATEX system certificate and can be installed indoors to safely vent an explosion.

Many dust collectors are installed indoors, located close to the source of dust, and away from outside walls. Any duct between the dust

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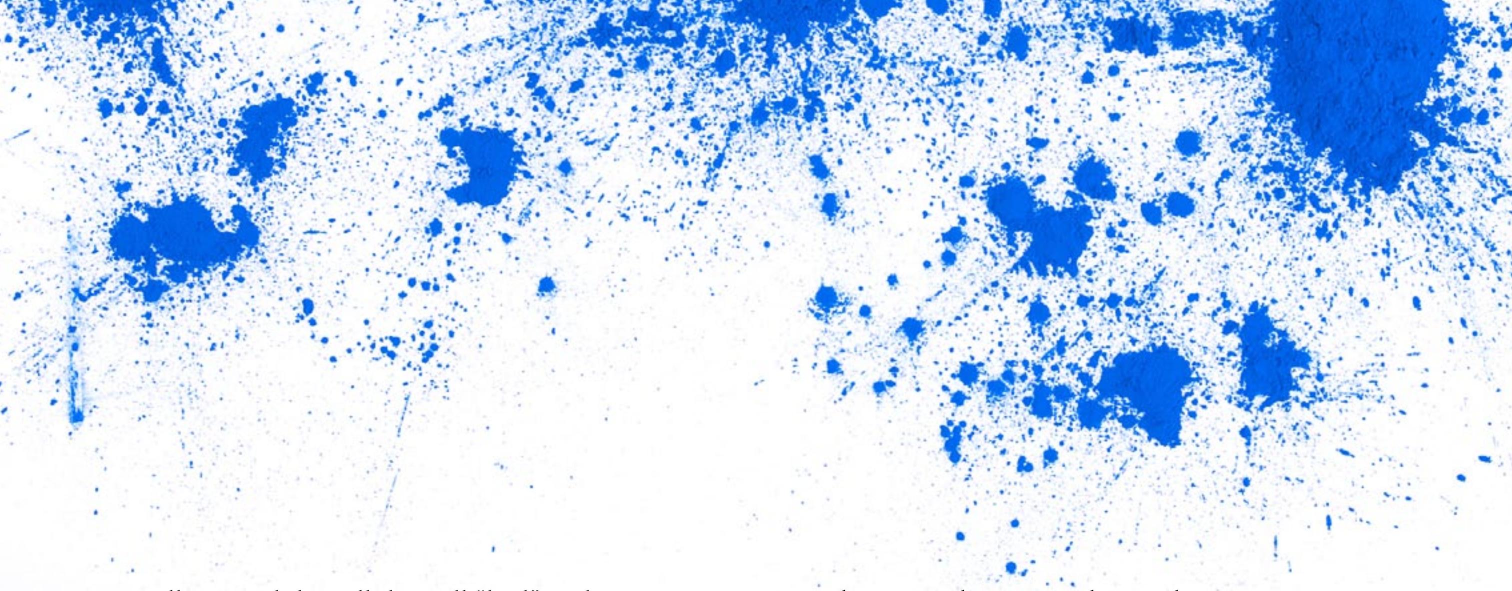

collector and the wall that will "lead" explosion pressure to the outside will cause a back pressure. This has a huge impact on the strength of the dust collector. [7]

There are many dust collectors installed with a very low Pred, either because they've been designed without taking into consideration the potential of an explosion, or they've weakened after many years of use. The average Pred of rectangular dust collectors today is less than 0.3 Barg. For dust properties shown in Figure 2 — a standard combination in many food processes — even a length of 10 feet wouldn't hold an explosion due to back pressure.

Many experts, OSHA inspectors and publication editorials have, over the years, recommended that a dust collector be installed outdoors to avoid the catastrophic results of a combustible dust explosion. In fact, this is simply wrong and not practical. This "solution" would cost industry a fortune to relocate dust collectors and install more powerful blowers and fans and result in a tremendous increase in energy costs.

Simply placing a dust collector or other enclosure outdoors doesn't necessarily reduce the risk of property damage or people being injured or killed. If an event occurs, the length of the flame can be more than 100 ft and care must be taken to ensure that an explosion vent/panel doesn't face the direction of a neighboring building, a driveway, or other area where people or vehicles could be located. And, for some production, dust collectors must be installed inside. This is true, for example, of sugar-based products. Changes in temperature and humidity would block filter elements. In such cases, and in many others, indoor flameless venting is the best option.

FLAMELESS VENTING TECHNOLOGY

An explosion can be vented safely indoors, as well as outdoors, with quenching systems like the REMBE Q-Rohr-3 flameless venting system.[8] Invented in the 1990s in Europe by REMBE GmbH, flameless venting technology consists of a cage, wrapped with a specially developed mesh material. The bottom of the cage is hermetically sealed with a round burst panel.

Once a deflagration starts, the increasing pressure causes the rupture disc to burst. Flame and dust shoot into the cylindrical body of the Q-Rohr. Because the mesh material provides a very large surface area, the heat is dissipated. Dust particles can't pass through the mesh material and are also kept inside the cylinder.

The increase of pressure *outside* of the Q-Rohr is negligible when an event occurs and the rupture disc bursts. There's no pressure wave so no dust will become airborne and create the potential for a secondary explosion.

Some flameless venting systems, like the Q-Rohr-3, have an ATEX system certificate and can be installed indoors to safely vent an explosion; these systems also are in accordance with NFPA regulations and are Factory Mutual approved.

In addition, these passive systems don't need any other device (such as a spark detector or sensor) to be triggered — the explosion pressure will activate the system. Unlike other prevention systems, such as suppression systems, flameless venting systems don't require quarterly maintenance. The

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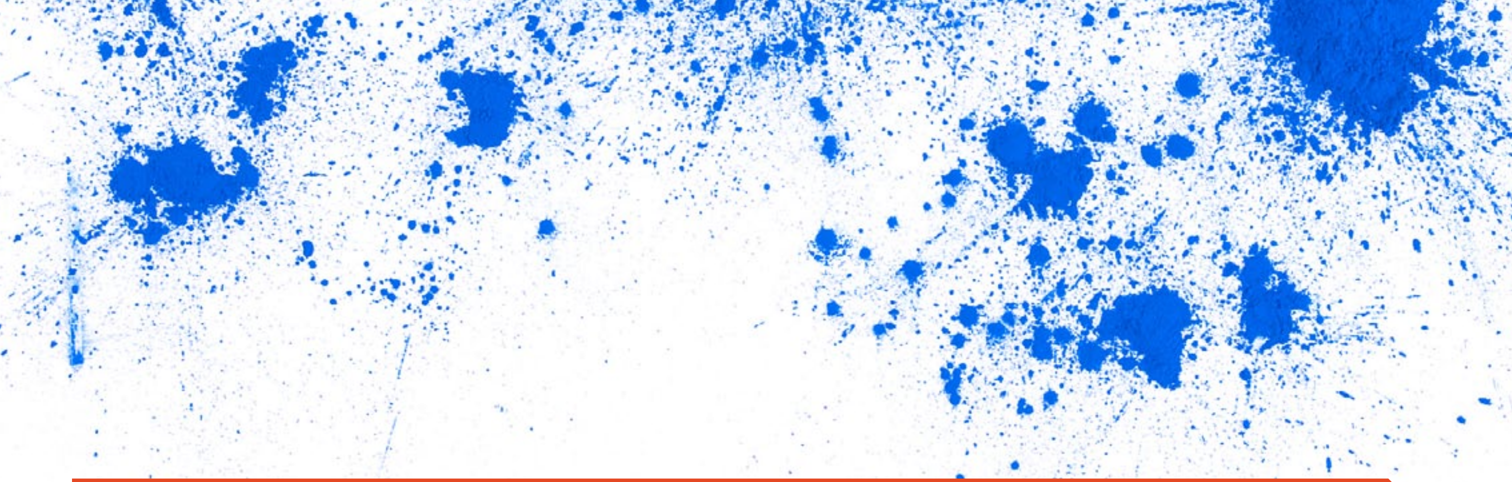
"Explosion Protection System Selection," pg. 19-24, Chemical Processing Powder eHandbook, www.chemicalprocessing.com/assets/wp_downloads/pdf/CP1205_Powder_eHandbook2.pdf (May 2012).



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burst panel of the flameless vent is specifically equipped with burst sensors. Once an explosion occurs, the signal is activated to shut down the entire process.

Just as a point of information, in accordance with NFPA 654, an enclosure — in many cases a dust collector — also must be isolated to prevent flame propagation into adjacent enclosures causing secondary explosions. [9]

For companies having converted from suppression systems to flameless venting, the cost savings are enormous. The average downtime after an explosion is suppressed can be more than three days due to the need to clean the entire production line to eliminate the suppression agent. Compare this with a system protected with a flameless vent: the downtime is significantly reduced to just the time it takes to replace the panel and rinse the vent. [3]

BENEFITS EXTEND BEYOND SAFETY

In the past 10 years, indoor venting has become more popular in North America, not only because of its effectiveness in eliminating the risk of damage and fatality, but also for economic reasons. Dust collectors don't have to be relocated or placed outside and downtime caused by false triggering doesn't occur with passive indoor venting systems. Maintenance costs are dramatically reduced. If an event occurs, replacing the indoor venting system disc is fairly easy and production is able to resume within a short period of time.

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