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Conducting Process Hazard Analyses for Dust-Handling Operations

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Use this checklist-based technique of process hazard analysis (PHA) to identify and assess potential dust hazards and to evaluate safeguards that can mitigate risks.

Techniques for managing the risks associated with dust explosions continue to evolve. The most recent trend is the use of a formal process hazard analysis (PHA) to identify hazards and ways to reduce and/or eliminate them. PHAs use structured brainstorming techniques to pinpoint weaknesses in the design and operation of facilities that could lead to accidents; most PHAs include evaluations of the risks associated with the hazards identified.

Process hazard analysis is a universally accepted technique. For more than a decade, U.S. Occupational Safety and Health Administration (OSHA) Process Safety Management (PSM) and U.S. Environmental Protection Agency (EPA) Risk Management Plan (RMP) regulations have required PHAs for processes that handle highly hazardous chemicals (HHCs), such as flammable liquids, chlorine, ethylene oxide.* Recent standards, such as the National Fire Protection Association's (NFPA) Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids (NFPA 654) *(1)*, now require that PHAs be conducted for processes handling powders and bulk solids that present a fire or explosion hazard.

Much guidance is available on the steps involved in conducting PHAs. For instance, Ref. 2 discusses the general subject of hazard-analysis and provides a guide to various hazard analysis techniques. This article explains the critical steps in applying PHA to dust-handling operations: compiling process safety information (PSI); establishing a PHA team; preparing a PHA checklist; conducting the PHA, including identifying the method of explosion protection; and following up on any recommendations generated by the PHA team.

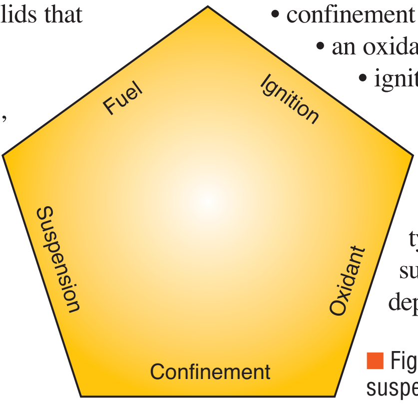
Dust explosion basics

The catastrophic potential of dust hazards can be significant — three of the four deadliest incidents that have occurred since the U.S. Chemical Safety and Hazard Investigation Board (CSB; www.csb.gov) was created in 1998 have been dust explosions.

Many dusts are combustible, and if these dusts are suspended in air, they become a potential explosion hazard. This is illustrated by the dust explosion pentagon (Figure 1), which depicts the five elements necessary for a dust explosion to occur:

- ignitable dust, which serves as fuel
- dispersion/suspension of the dust into a cloud at a sufficient concentration
- confinement
- an oxidant (usually air)
- ignition.

When ignited, a dust cloud produces a fireball eight to ten times larger than the original cloud. If the dust cloud is ignited within a confined area, the pressure will typically rise to 8–10 times the original pressure. The time required to reach that pressure depends on the characteristics of the dust *(3)*.



■ Figure 1. A dust explosion requires fuel, suspension, confinement, an oxidant, and ignition.

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* The complete list of HHCs can be found at www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9761

Typically, a dust explosion takes a few hundred milliseconds.

Secondary explosions can be just as catastrophic (or more so) than the primary dust explosion. A secondary explosion occurs when the blast wave emanating from ruptured equipment lifts the accumulated dust into suspension, which is then ignited by the flame from the primary explosion The resulting devastation and casualties are consequences of both the burning and the structural damage to the building.

Table 1 outlines the damage caused by an overpressure wave. For example, an overpressure of only 2–4 psi within a building can collapse non-reinforced cinderblock walls.

Dust explosion hazards are not unique to large-scale bulk-handling operations. Reference 2 provides details on several incidents that involved smaller facilities. The standard on static electricity hazards published by the European Committee for Electrochemical Standardization *(4)* addresses the potential for ignition of a dust cloud from a static discharge in equipment larger than 2 m^3, and in even smaller equipment where there is a high rate of charge input, such as in micronizing devices.

Many industries deal with dusts that are also wet with an organic solvent, and the resulting hybrid mixture of combustible dust and flammable vapor elevates the hazard level. Equipment of any size containing a hybrid mixture could be a high hazard due to the increased explosibility hazard.

Gather process safety information

OSHA and EPA spell out what PSI is required prior to conducting a PHA on a process handling HHCs. However, an equivalent standard for dust does not exist.

A CRITICAL NEED

One year ago, on Feb. 7, 2008, a catastrophic dust explosion and fire at the Imperial Sugar Refinery in Port Wentworth, GA, killed 14 employees and injured 40 others. During a Senate hearing in July 2008, John Bresland, chairman and CEO of the U.S. Chemical Safety and Hazard Investigation Board (CSB), testified that a 2006 CSB study *(5)* identified 281 dust fires and explosions that killed 119 and injured 718 workers in the U.S. between 1980 and 2005. Since that study was released, the news media have reported approximately 80 additional dust fires and explosions.

Furthermore, the CSB report stated that if many of the facilities that had dust explosions had followed good engineering practices, such as those in National Fire Protection Association (NFPA) standards, the incidents would have been prevented or significantly mitigated. This indicates that the information needed to prevent this type of incident is available but is not being used by industry.

“The urgency for action is greater than ever,” Bresland urged in his testimony.

In response to these incidents and calls by several labor unions for the U.S. Occupational Safety and Health Administration (OSHA) to issue an emergency standard, on Mar. 4, 2008 the Worker Protection Against Combustible Dust Explosions and Fires Act (H.R. 5522) was introduced into the U.S. House of Representatives. The bill was passed by a vote of 247–165 and is awaiting Senate approval. In its current form, the bill requires OSHA to issue an interim emergency standard within 90 days, and a final rule based on NFP and other recognized industry standards within 18 months.

The bill applies to the handling of combustible particulate solids and their dusts, including manufacturing, processing, blending, conveying and repackaging (it does not apply to grain handling). It directs employers to implement improved housekeeping methods, engineering controls such as building design and explosion protection, and worker training, as well as provide a written combustible-dust safety program.

The bill also suggests revisions to OSHA’s hazard communication standard to ensure that the review of potential on-the-job hazards includes combustible dusts. The CSB recommended that OSHA further amend the hazard communication standard to require the inclusion of hazards and physical properties of combustible dusts on Material Safety Data Sheets (MSDSs).

In response to another CSB recommendation, OSHA has implemented the national emphasis program (NEP) targeting industries at risk for dust explosions *(12)*. Between Nov. 1, 2007, and June 30, 2008, OSHA had completed 326 inspections and issued 1,187 violations, 65% of which (746) were designated as serious. Among the violations:

- baghouse dust collectors at several facilities were located inside a building without proper explosion-protection systems, such as explosion venting or explosion-suppression systems
- deflagration-isolation systems were not provided to prevent the propagation of deflagration from dust collectors to other parts of the plant
- rooms with excessive dust accumulations were not equipped with explosion relief venting distributed over the buildings’ exterior walls and roofs
- horizontal surfaces, such as beams, ledges and elevated screw conveyors, were not minimized to prevent the accumulation of dust on surfaces
- at several facilities, air from a dust collector was recycled through ductwork back into the work area
- legs of bucket elevators were not equipped with explosion relief venting
- explosion vents on bucket elevators were directed into work areas and not vented to a safe, outside location away from platforms, means of egress, or other potentially occupied areas
- equipment (such as grinders and shakers) was not maintained to ensure that it was dust-tight, which allowed combustible dust to leak into the surrounding area
- pulverizers were not provided with explosion venting or deflagration-suppression systems.

All of these violations could have easily been prevented and addressed if a PHA had been conducted using the checklist methodology. Each of the requirements can be easily tracked to recognized and generally accepted good engineering practices (RAGAGEPs).

Readers who doubt the potential for dust hazard catastrophes might want to review the CSB’s investigations of the following incidents at its website, www.csb.gov:

- Imperial Sugar Refinery explosion, Feb. 7, 2008
- CTA Acoustics dust explosion, Feb. 20, 2003
- West Pharmaceuticals dust explosion, Jan. 29, 2003.

Table 1. Structural damage is a function of overpressure.

Overpressure, psi*	Biological Damage	Structural Damage
70	99% Probability of fatality	Total structural damage
50	50% Probability of fatality	Total structural damage
35	1% Probability of fatality	Total structural damage
15	Lung damage	Severe structural damage
7–8		Shearing and flexure of unreinforced, 8–12-in.-thick brick wall panels
5	Eardrum rupture	Shattering of unreinforced, 8–12-in.-thick concrete wall panels
2–4		Shattering of unreinforced cinderblock walls; 50% destruction of brick buildings; distortion of steel-frame buildings; rupture of light industrial buildings
1–2		Failure of wood siding, corrugated steel, and aluminum panels; shattering of asbestos siding
0.5–1		Shattering of glass windows

*The total overpressure may be achieved by reflection of an incident wave of about half the stated value.

A primary reference for most organizations is a material safety data sheet (MSDS). However, MSDSs are not reliable for identifying the hazard potential of a dust — 41% of the MSDSs reviewed by the CSB did not include a dust explosion warning for materials that form combustible dusts *(5)*.

Various references address the characterization of dust hazards. Two key publications are the Center for Chemical Process Safety's "Guidelines for Safe Handling of Powders and Bulk Solids" *(3)* and "Dust Explosions in the Process Industries" by R. K. Eckhoff *(6)*. These resources provide a thorough overview of dust characteristics and hazards.

Each dust has unique physical and chemical characteristics that impact its level of hazard. Physical characteristics include size, shape, and moisture content, among others. Chemical characteristics include flammability, explosibility, susceptibility to thermal degradation, susceptibility to ignition, instability, and chemical reactivity. A good understanding of these properties is essential to understanding the hazards and ultimately the risks associated with the dust being handled.

The first step in assessing hazards is to review the published literature. In some cases, particularly when one is seeking chemical reactivity data relative to known functional groups, property and hazard test data that are directly applicable to the materials in question are already available.

Although literature data can give a general indication of a potential hazard, many dust characteristics affecting combustibility are a function of process-specific conditions. To ensure that the PSI is representative of the dust in the process being analyzed, most dusts must be characterized based on testing of an actual sample from the process. Depending on the type of process and the explosion prevention measures that may be employed, multiple tests may be necessary. Physical properties such as particle size and moisture content are typically known; other data will be based on testing results. A dust-characterization testing plan typically includes many of the tests listed in Table 2.

A key chemical characteristic is minimum ignition energy (MIE). Many dusts ignite well below 25 milliJoule (mJ), which indicates that static generation is a potential ignition source. To further understand static hazard potential, it is important to know the dust's resistivity. Some dusts are much less conductive than others and thus will be more likely to retain a charge on the dust particle.

Another key chemical characteristic is the explosion severity potential. Explosion severity can be obtained by testing for P_{max}, the maximum explosion pressure in a closed vessel. To determine the time to reach P_{max}, one needs to obtain the rate of pressure rise, $(dP/dt)_{max}$. The shorter the time to achieve maximum pressure in a dust explosion, the greater the potential for a total loss of the facility. This is because the faster the maximum pressure is reached, the less likely sprinklers and other safeguards will be effective.

Because the maximum rate of pressure rise is volume-dependent, it is commonly converted into K_{St}, which is independent of volume (V):

$$K_{St} = (dP/dt)_{max} \times V^{1/3} \qquad (1)$$

Dusts are placed into explosion hazard classes (St 0, St 1, St 2 or St 3) based on their K_{St} values, as shown in Table 3.

Particle size and moisture content influence these characteristics. P_{max} and K_{St} increase, and MIE generally decreases, with decreasing particle size and moisture content *(6)*.

The cost of testing is often offset by savings on engineering controls, particularly if the data are appropriately factored into the risk ranking during the PHA. If data are not available to characterize a dust prior to a PHA, a high hazard level must be assumed. This will result in an overly conservative and more costly approach.

Establish a PHA team

Once PSI is developed, the PHA team should be formed. A team leader with formal training in the checklist methodology of process hazard analysis should be selected. The team should also include one or more members who are

Table 2. Typical tests for dust characterization.

Dust Characteristic (PSI)	Test Symbol	Units	When the Test is Conducted
1. Particle size and particle size distibution	d	μm	To determine the size and size distribution of a sample. All four generic hazards (toxicity, combustibility, reactivity and instability) generally increase with decreasing particle size. Some ASTM dust-characterization test procedures specify a particle size of 95% <75 μm. Some organizations request "as received" testing to characterize the uniqueness of a sample.
2. Water content of a powder	WC	wt.%	To determine the moisture content of a given sample. Some ASTM dust-characterization test procedures specify a moisture content. Some organizations request "as received" testing to characterize a sample's uniqueness.
3. Maximum explosion pressure	P_{max}	barg	To determine whether a dust is combustible and the degree of explosion hazard. One test determines P_{max}, $(dP/dt)_{max}$, and K_{st}.
4. Maximum rate of pressure rise and deflagration index	dP/dt, K_{st}	bar-m/s	Used as input in explosion-protection system design. This is typically one of the first tests recommended to determine whether dust is explosive and the degree of explosion hazard. One test determines P_{max}, $(dP/dt)_{max}$, and K_{st}.
5. Minimum ignition energy	MIE	mJ	To determine the energy required for ignition. MIE <100 mJ indicates a potential for ignition from static discharges from personnel; MIE <25 mJ indicates a potential for ignition from static discharges during bulking of powders. If MIE <30 mJ, resistivity testing and charge relaxation testing is typically required.
6. Surface resistivity and volume resistivity	γ_s, γ_v	ohm-cm	To assess electrostatic hazard. Resistivity $>10^9$ Ω-cm poses a hazard.
7. Electrostatic decay and dielectric constant	$k'(\varepsilon_T)$, τ	s	To determine if an electrostatic hazard from powder exists. Data on dielectric constant with charge relaxation time is needed if MIE < 30 mJ.
8. Minimum autoignition temperature of a dust cloud	$\text{MAIT}_{\text{dust cloud}}$	°C	To assess a dust's sensitivity to hot surfaces, such as dryers, bearings, and other mechanical parts.
9. Limiting oxygen concentration	LOC	vol.%	To determine the lowest concentration of oxygen that will propagate a flame. LOC is needed if inerting is the basis of safety for explosion prevention.
10. Minimum explosive concentration	MEC	g/m^3 or vol.%	To determine the minimum concentration of dust in air that will propagate a flame. MEC is required if dilution is the basis of safety for explosion prevention.
11. Minimum ignition temperature of a dust layer (smoldering temperature)	ST	°C	To determine whether a dust is sensitive to hot surfaces. ST is typically lower than MAIT.
12. Autoignition temperature of a dust deposit	AIT	°C	To determine whether a dust is sensitive to hot surfaces. AIT is typically lower than MAIT.
13. Thermal stability	DSC	cal/g	To screen for self-reactivity hazards.

Note: Additional testing may be recommended if the product has potential for chemical reactivity hazards or spontaneous ignition.

familiar with the engineering design (including common safeguards associated with the operation being analyzed), operation and maintenance of the unit, as well as someone familiar with dust explosion or other potential hazards that may be anticipated based on the dust characterization results. Providing a scribe to support the team leader will make the PHA process much more efficient.

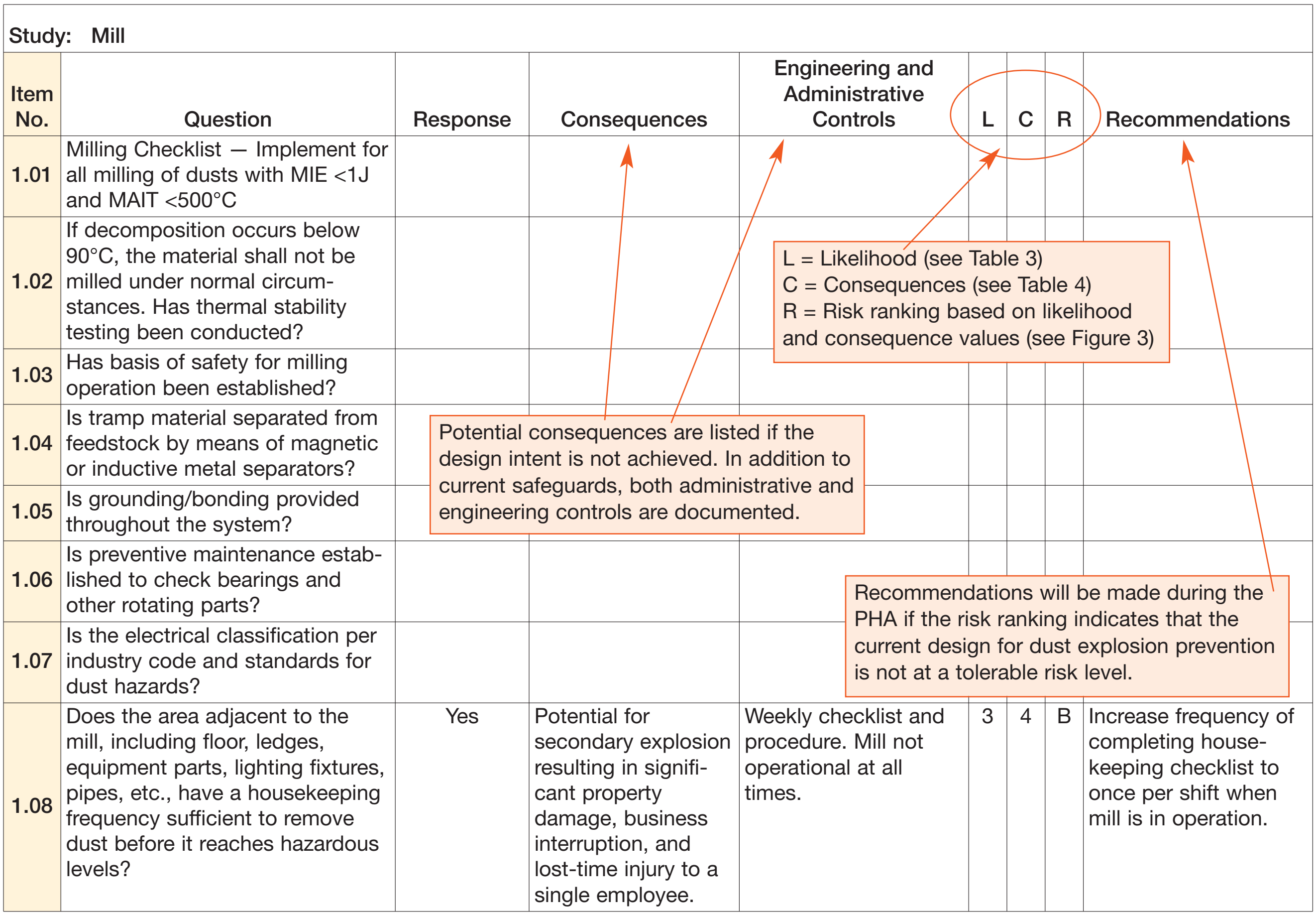
Table 3. Dust hazards are classified based on the maximum rate of pressure rise, K_{St}.

K_{St}, bar-m/s	Dust Explosion Class	Description
0	St 0	No explosion
0–200	St 1	Weak explosion
200–300	St 2	Strong explosion
>300	St 3	Very strong explosion

Develop the PHA checklist

Of the various hazard-analysis techniques, the checklist methodology is a logical choice for dust-handling operations. Checklists guide the identification of hazards and gaps in safeguards that may be missed utilizing other methodologies. They help ensure that a process is designed in accordance with codes and standards, and promote consistency in the choice of safeguards across multiple units. Checklists that incorporate current industry standards and regulations can also aid in regulatory compliance.

Checklists are particularly well-suited for use in organizations with limited knowledge of the safeguards for dust haz-



Study: Mill

Item No.	Question	Response	Consequences	Engineering and Administrative Controls	L	C	R	Recommendations
1.01	Milling Checklist — Implement for all milling of dusts with MIE <1J and MAIT <500°C							
1.02	If decomposition occurs below 90°C, the material shall not be milled under normal circumstances. Has thermal stability testing been conducted?							
1.03	Has basis of safety for milling operation been established?							
1.04	Is tramp material separated from feedstock by means of magnetic or inductive metal separators?							
1.05	Is grounding/bonding provided throughout the system?							
1.06	Is preventive maintenance established to check bearings and other rotating parts?							
1.07	Is the electrical classification per industry code and standards for dust hazards?							
1.08	Does the area adjacent to the mill, including floor, ledges, equipment parts, lighting fixtures, pipes, etc., have a housekeeping frequency sufficient to remove dust before it reaches hazardous levels?	Yes	Potential for secondary explosion resulting in significant property damage, business interruption, and lost-time injury to a single employee.	Weekly checklist and procedure. Mill not operational at all times.	3	4	B	Increase frequency of completing housekeeping checklist to once per shift when mill is in operation.

L = Likelihood (see Table 3)
C = Consequences (see Table 4)
R = Risk ranking based on likelihood and consequence values (see Figure 3)

Potential consequences are listed if the design intent is not achieved. In addition to current safeguards, both administrative and engineering controls are documented.

Recommendations will be made during the PHA if the risk ranking indicates that the current design for dust explosion prevention is not at a tolerable risk level.

Figure 2a. A checklist facilitates the review of safeguards for a dust-handling operation and documentation of the PHA.

Table 4. A consequence table should be prepared in advance of the PHA.

Consequence Severity Rating	Onsite	Offsite	Operability
Level 4 Very High	Multiple worker fatalities	Public disability or fatality Multimedia event	Over $1 million equipment damage Over 1 month downtime Over 30 days of production scrap
Level 3 High	Worker disability or fatality Environmental release exceeding permit limits or reportable quantities	Public injury (hospitalization) Significant environmental damage	$100,000 to $1 million equipment damage 1 week to 1 month downtime 3–30 days of production scrap
Level 2 Medium	Worker injuries (lost time); Onsite chemical spill	Minor public injury (first aid) Moderate environmental damage	Up to $100,000 equipment damage Up to 1 week downtime Up to 3 days of production scrap
Level 1 Low	Recordable injury or multiple minor injuries	No public injury No offsite environmental issues	No significant loss

ards. In addition, the knowledge base matures as lessons are learned — ideally, the checklists are treated as dynamic documents that are updated periodically, such as after incident investigations and when codes and standards change.

For most dust-handling operations, checklists can be easily developed, although it takes time and resources to ensure that all recognized and generally accepted good engineering practices (RAGAGEPs) are included. Several resources, including Refs. 3 and 7 and several NFPA standards, outline appropriate safeguards for common dust operations, such as dryers, mills, granulators, storage (silos, bins), etc. The safeguards are typically prescriptive in nature, and can easily be converted into checklists for use in the PHA. Figure 2 is a portion of an example checklist developed from consensus standards using the HAZOPtimizer software, which can be downloaded free from www.iomosaic.com. Item No. 1.08 of Figure 2a demonstrates the use of the checklist for a mill, and Figure 2b illustrates typical questions for a dust

Study: Dust Collector

Item No.	Question
2.01	Cyclone Separators
2.02	Is venting and/or suppression provided for the cyclone collector?
2.03	If the material is toxic, is suppression protection provided or is the cyclone designed for P_{max}?
2.04	Are inspection ports installed if the dust can self-decompose, is highly reactive, or has a propensity for caking on walls?
2.05	If inspection ports are required, have means for removing deposits been provided (*e.g.,* water or solvent spray nozzles)?
2.06	Electrostatic Precipitators
2.07	Is automatic sprinkler (AS) protection of 0.25 gpm/ft^2 provided inside the ESP oil bath reservoirs?
2.08	Is AS provided inside the ESP if it is collecting a combustible material?
2.09	Is AS provided over ESP oil seals and oil settling tanks, reservoirs and piping?
2.10	Is an interlock provided to automatically de-energize the ESP upon actuation of the AS or automatic water-spray system?
2.11	For ESPs and ducts serving 2 or more pieces of equipment: Is a sprinkler head provided inside each duct penetration at the roof and all floors, with the temperature rating of the heads 50°F higher than the temperature of the gas in the duct?

Study: Portable Container Filling / Intermediate Bulk Container Charging

Item No.	Question
3.01	Is it possible to inert the IBC with nitrogen before filling begins so the potential for ignition from static spark is minimized?
3.02	Have precautions been made to prevent or minimize emissions of fines to the surrounding area?
3.03	Has operator personal protective equipment (PPE) been specified to prevent personnel exposure?
3.04	Are metal rings on fiber drums bonded or grounded, or are the conveyor or platform on which the drums rest bonded or grounded?
3.05	Is the filling machine provided with good ventilation to control and minimize emissions of fines?
3.06	Are samplers containing metal and plastic parts that are inserted into a stream of flowing solids bonded and is the sampler grounded?
3.07	Has the appropriate class of IBC been selected for dispensing materials into combustible atmospheres?

Study: Manway Charging of Solids

Item No.	Question
4.01	Has the alternative of a closed charging system been considered?
4.02	Has validation that the vessel has a nonflammable atmosphere (<25% LEL) prior to charging occurred?
4.03	Has the vessel been purged to 2% below LOC, or 60% of LOC if LOC <5%?
4.04	Has testing to validate the appropriate balance and flowrate of inert gas during charging of solids been conducted?
4.05	If continuous oxygen monitoring is not present, have maximum charge volumes between testing been established?
4.06	Has local ventilation at the manway been provided and tested to ensure proper balance?
4.07	Do operating procedures include a step to close the main vent line during charging of solids if charging to an empty vessel?
4.08	If charging flammable liquids to a vessel, has consideration been given to changing the charging order (solids first)?

■ Figure 2b. Typical checklist questions for dust-handling operations.

collector, container filling/charging, and manway charging.

It is important that any PHA is properly documented *(7)*. Documentation typically includes the hazard, safeguards in place, the potential likelihood of the hazard occurring, and consequences. This documentation should also include any risk evaluation completed as part of the PHA, as discussed in the next section. The headings in Figure 2a facilitate documentation of this information.

Prepare a risk matrix

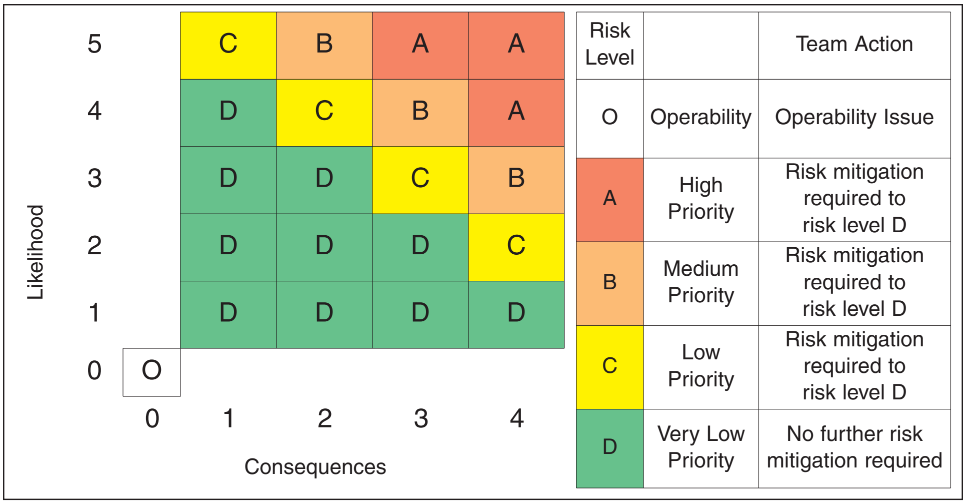
Most companies find it useful to evaluate the risk of an identified hazard during a PHA. To do this, before conducting the PHA, the organization should define likelihood and consequence levels, typically in semi-quantitative terms, based on its internal standards for tolerable risk, such as those provided in Tables 4 and 5. These likelihood and consequences values are then used to prepare a risk matrix. Risk matrixes vary among organizations; a typical risk matrix is shown in Figure 3. Many publications (*e.g.,* Refs. 8 and 9) explain how to develop a risk matrix.

Table 5. A likelihood table should be prepared in advance of the PHA.

Likelihood Range	Event Frequency	Description
Level 5	$>10^{-1}$/yr	Is likely to occur once or more in 10 years
Level 4	$>10^{-2}$/yr	Is likely to occur once in 100 years (once during the life of the process); May have occurred in another company-owned plant
Level 3	$>10^{-3}$/yr	Is likely to occur once in 1,000 years (once in the life of 10 processes); May have occurred in another company-owned plant or the studied industry
Level 2	$>10^{-4}$/yr	Extremely unlikely to occur (once in the life of 100 processes); May have occurred in another industry
Level 1	$<10^{-4}$/yr	Extremely unlikely to occur (once in the life of 1,000 processes); Has never occurred

Conducting the PHA

The PHA team leader should ensure that the team members understand the hazards of dusts as well as which safeguards within a checklist should be applied to each dust haz-



Likelihood					
5		C	B	A	A
4		D	C	B	A
3		D	D	C	B
2		D	D	D	C
1		D	D	D	D
0	O				
	0	1	2	3	4

Consequences

Risk Level		Team Action
O	Operability	Operability Issue
A	High Priority	Risk mitigation required to risk level D
B	Medium Priority	Risk mitigation required to risk level D
C	Low Priority	Risk mitigation required to risk level D
D	Very Low Priority	No further risk mitigation required

Figure 3. A risk matrix is a cost-effective tool for identifying appropriate measures for mitigating risks.

ard level, so that the checklists can be applied appropriately.

A checklist PHA typically starts with documenting the checklist questions and responses (Figure 2a). Any deviation from the design intent revealed by the answer to a checklist question should be analyzed. This is done by identifying potential consequences (assuming the design safeguard is not present), the likelihood of an event, and safeguards active at the time of the analysis, and then risk-ranking the scenario to assess whether additional mitigation should be recommended.

Any risk ranking that does not meet the company's tolerable-risk criteria should be accompanied by recommendations for mitigation measures that will lower the risk to an acceptable level. The risk rankings based on the likelihood and consequence values in columns L and C in Figure 2a can then form the basis for prioritizing identified hazards for follow-up.

Depending on the complexity of the operation, it may be necessary to supplement the checklist methodology with a what-if, hazard and operability (HAZOP), or other hazard-analysis technique *(2)* to ensure any non-routine or unique hazards are addressed.

Explosion protection for equipment

Explosion protection may involve either prevention or mitigation of a hazard. According to NFPA 654 *(1)*, the design of explosion protection for process equipment should incorporate one or more of the following methods of protection:

- oxygen exclusion (or reduction)
- deflagration venting
- deflagration containment
- deflagration suppression
- dilution to render the dust noncombustible.

The PHA team should identify which of these methods have been selected, and this should be documented in the final PHA report.

If oxygen exclusion is selected as the method of protection, ISA Standard 84.00.01, Functional Safety Application of Safety Instrumented Systems for Process Industry Sector *(10)*, requires a more-quantitative PHA methodology (*e.g.*, fault-tree analysis or layer of protection analysis) to supplement the checklist PHA. If the method of protection is reduction of the oxidant concentration, ISA 84.00.01 requires the installation of oxygen monitoring. This ISA standard is well-known in industries covered by OSHA's PSM and EPA's RMP regulations. Details of safety instrument systems were discussed recently in Ref. 11.

Oxygen exclusion is critical for materials with a low MIE (<25 mJ) and is a preferred method of protection, unless the process can be made inherently safer by material substitution. Oxygen exclusion is a proactive safeguard, as it targets prevention rather than mitigation. Completely eliminating ignition sources is almost impossible. However, if oxygen is not present, an explosion will not occur even if an ignition source is present (assuming the material itself is not an oxidizer).

Another fundamental prevention method is to supplement the explosion protection with stringent control of potential ignition sources. This can be achieved by evaluating the hot-work management system, providing properly classified and maintained electrical equipment, controlling open flames and smoking, and ensuring appropriate bonding/grounding of conductive components.

Each prevention method should be considered during a PHA of the dust hazard. The number and type of prevention method(s) should be selected based on the level of the hazard, ease of application to the process, and many other variables. For example, oxygen exclusion for a small mill processing a material with a high MIE (>100 mJ) may not be an effective use of funds because the likelihood of ignition via static is fairly low, but if the same small mill is used to process a low-MIE and high-resistivity material, oxygen exclusion may be justified because the likelihood of ignition from static is much higher.

Follow up after the PHA

The current edition of NFPA 654 imposes the same PHA filing and maintenance requirements that OSHA and EPA mandate for PSM- and RMP-covered processes — that is, the PHA results must be documented and maintained for the life of the process. In addition, the PHA must be reviewed and updated at least once every five years. NFPA 654 also requires dust-handling operations to adopt the same management of change (MOC) approach that OSHA and EPA require for HHC-handling facilities — *i.e.*, the establishment and implementation of written procedures to manage changes to process materials, technology, equipment, procedures and facilities. Note that NFPA has made this new requirement for an MOC system retroactive, applicable to existing dust operations that were active prior to the standard's publication in 2006.

Closing thoughts

Compliance with standards and codes can help facilities that handle dusts reduce their risk levels. Many of the techniques commonly used for proper management of HHCs can be adopted for the management of combustible dusts.

Companies should identify their dust-handling processes; prioritize the risks; conduct testing to characterize dust hazards; and conduct PHAs on each process, starting with the processes with the highest risks. (These will often be processes with dust collectors, as this is the type of equipment most often involved in incidents.)

The PHA process is a proven technique for identification and assessment of potential hazards. Companies should not wait for an incident, or for OSHA to take a more-aggressive stance on dust hazard management or for H.R. 5522 to pass. With OSHA's new national emphasis program on dust handling *(12)* and current political pressures, the wait may not be very long. **CEP**

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