FOCUS ARTICLE

Effective Management of Combustible Dust Hazards: The Role of an Effective Mechanical Integrity Program

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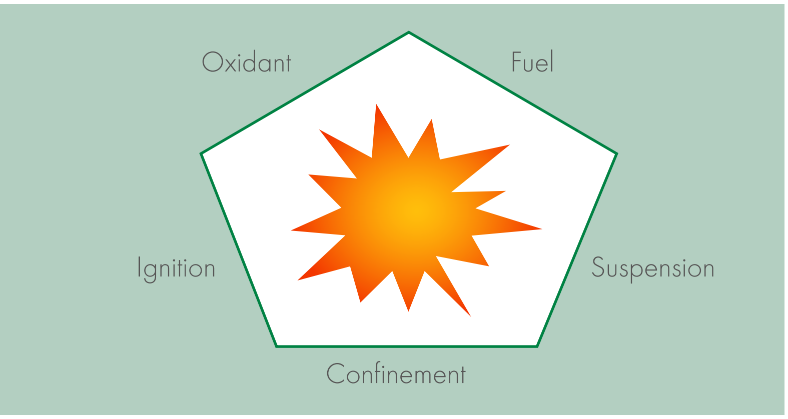
Managing combustible dust fire and explosion hazards can be a challenging task because it requires not only a detailed understanding of the fuel/combustible material (the dust), but also an understanding of the process equipment, operating conditions, maintenance practices, engineering and administrative controls currently in place, process-design strategies, hazards-analysis methods, and the site's safety culture. It is not unusual to find facility management with a good understanding of the process but a limited understanding of the hazards posed by the combustible dust.

Most organic solids are capable of burning. Burning of combustible dust requires all three elements of the familiar fire triangle to be present together and at the same time: fuel, heat, and oxygen. The heat can be supplied by any appropriate source of energy and the concentrations of fuel and oxygen must be sufficient to support combustion.

On the other hand, if a sufficiently large concentration of combustible dust is suspended and ignited in an enclosed space, the resulting combustion would develop pressure that can cause injuries and fatalities and damage or destroy equipment and buildings. The elements of dust suspension and combustion confinement are commonly added to the fire triangle to depict the "Dust Explosion Pentagon" (Figure 1). If any one element of the pentagon is missing, an explosion would not occur. In the absence of confinement, a "flash fire" or fireball can be a consequence of suspended-dust combustion, resulting in a hazard to people and potential property damage.

The purpose of this article is to outline an effective approach to addressing combustible dust hazards by implementation of a proactive and robust mechanical integrity program.

Figure 1 Dust Explosion Pentagon



Mechanical Integrity

Generally speaking, a mechanical integrity (MI) program is intended to manage the maintenance of all of the processing equipment of a facility, to ensure that it is operating safely and within its intended parameters. It should be apparent that if equipment or systems are operated outside their safe operating limits, the potential for equipment failure is much more likely.

At minimum, MI includes the inspection, testing, and preventive maintenance (ITPM) of "safety-critical" equipment, where an equipment failure or malfunction could result in a combustible dust fire or explosion. A more comprehensive approach to MI would include all of the process equipment that could contain combustible dust during normal and/or abnormal conditions, along with combustion-preventing instrumentation and alarm/interlock systems. Equipment in the scope of the MI program should be maintained "fit for service" for its entire lifecycle, from procurement and receiving to installation, maintenance, and decommissioning.

Three brief examples may serve to demonstrate the importance of mechanical integrity to the control of combustible-dust hazards:

1. A well-known ignition source for combustible dust is overheated bearings. Depending on the specific service, an anti-friction bearing design may be required. The bearings must be maintained per manufacturer recommendations, with proper lubrication and cleaned at a frequency that would prevent a hazardous build-up of dust. Alternatively, the design should provide for bearings that are outside the dusty environment.

   An effective MI program for this example would include temperature-monitoring of the bearings, either by manual or automated means to ensure that the bearing temperature remains at a safe margin below the Layer Minimum Ignition Temperature (LMIT) of the powder. LMIT is typically determined by a laboratory test according to ASTM E2021. If an automated monitoring system is utilized, then maintenance of this system with a high degree of reliability is needed.

2. Poorly maintained equipment in combustible dust service may leak or spill powder to the floor and onto equipment surfaces in the work area. In addition to the obvious hazard of providing fuel in the form of a combustible dust layer, there is an additional hazard if a dust layer forms on equipment that can develop temperatures that could cause ignition of the accumulated powder.

   For this example, the containment of dust within equipment will depend on frequent inspections or audits to detect incipient failures that could lead to leakage or spills. Also, it is important for the equipment that could be exposed to combustible dust accumulation to operate with a surface temperature well below the Layer Minimum Ignition Temperature (LMIT) of the powder according to ASTM E2021. In this case, in addition to LMIT, it is proposed to also determine the Minimum Ignition Temperature of the dust cloud according to ASTM E1491 for the powder of interest.

3. For some processes, a basis of safety for protection of personnel, facility, and the community from explosive rupture of equipment is by explosion relief venting, explosion suppression, or explosion containment by a pressure vessel that is rated for the maximum explosion pressure that would develop during a deflagration of combustible dust. The design of any explosion protection measure (venting, suppression, or containment) requires appropriate data on the severity of the dust cloud explosion (Maximum Explosion Pressure and Kst). This data is obtained by performing a laboratory test on a representative dust sample in accordance with ASTM E1226. The MI program should include periodic inspection of explosion vents, quarterly tests of explosion-suppression systems, and periodic checks of vessel integrity according to Recognized And Generally Accepted Good Engineering Practice (RAGAGEP), such as API 510 and API 570, and FM Global Data Sheet 7-43 [1, 2, and 3]. Inspections and non-destructive tests should be performed by personnel with appropriate training and experience.

Mechanical Integrity program requirements and housekeeping requirements can be found in National Fire Protection Association (NFPA) 652 [4] and in industry/material specific standards such as NFPA 654 [5], NFPA 61 [6], and NFPA 484 [7].

A recent development in ensuring mechanical integrity involves "risk-based inspections' and the equipment-maintenance actions that follow the inspections. As stated by the pertinent FM Global document [8]: Risk-Based Inspection (RBI) is a methodology that is used to prioritize inspections, and it was based on the premise that the most effective use of inspection activity and to minimize costs is to focus first on those facilities, systems, or equipment that present the highest risk. However, it is possible for RBI to reduce inspection costs but at the expense of larger loss exposures and higher likelihoods of occurrence. This happens when an analysis under-states or fails to fully quantify an exposure, uses inappropriate data and methods for measuring consequences, makes incorrect assumptions when establishing likelihoods, or uses an inappropriate rating scheme. RBI is a comprehensive program requiring long-term commitment from senior management to implement and support.

Summary

A sound mechanical integrity program is an essential component of effective combustible dust fire and explosion hazard control. Using appropriate process information, material (powder/dust) data, and industry standards, a site-specific mechanical integrity management system can be designed and implemented to address these hazards efficiently and effectively with the resources available.

References

1. American Petroleum Institute, "Pressure Vessel Inspection Code: In-Service Inspection, Rating, Repair and Alteration", API 510, 10th edition (2014).
2. American Petroleum Institute, "Piping Inspection Code: In-Service Inspection, Rating, Repair and Alteration", API 570, 4th edition (2016).
3. FM Global, "Loss Prevention in Chemical Plants", Property Loss Prevention Data Sheet 7-43, Paragraphs 3.1.1.3, 3.1.2.6, 3.1.2.6.4, and 3.1.3.1.6 (2015).
4. National Fire Protection Association, "Standard on the Fundamentals of Combustible Dust", NFPA 652, Paragraphs 7.3.4.2.1, 8.4, 9.4.2, and A.8.4.2 to A.8.4.7.1 (2016).
5. National Fire Protection Association, "Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids", NFPA 654, Paragraphs 5.2.4, Chapter 8, Paragraphs 12.1.2, A.6.5.2 to A.8.2.1.3, A.8.2.2.5, and Annex D (2017).
6. National Fire Protection Association, "Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities", NFPA 61, Paragraphs 8.4 and A.8.4.2.2, and Figure F.3 (2017).
7. National Fire Protection Association, "Standard for Combustible Dusts", NFPA 484, Paragraphs 6.2.1.2, Chapter 7, and Paragraphs A.7.2 to A.7.8 (2015).
8. FM Global, "Risk-Based Inspections", Property Loss Data Sheet 9-0, paragraphs 2.2.1.4 and 2.2.2, and Appendix C.3 (2014).

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