



FOCUS ARTICLE

Establishing a Housekeeping Program for Combustible Dusts

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The importance of having good housekeeping in facilities, where combustible dust is handled/processed, cannot be overstated. The Chemical Safety Board and other agencies who have investigated serious dust explosions over the last 30 years have found a number of common casual factors for these incidents. Among them, lack of adequate housekeeping programs designed to maintain accumulations of combustible dusts to acceptable levels to prevent flash fire or explosion hazards within these facilities. Where combustible dust accumulations are allowed to exceed these levels, the plant becomes at risk for secondary dust explosions.

A secondary dust explosion occurs when dust accumulating on elevated surfaces or floors becomes suspended and ignited by some primary event. Dust accumulating on elevated surfaces is most at risk. The blast wave from the secondary explosion can cause accumulated dust, in other areas, to become suspended in air which may generate additional explosion events. Depending upon the extent of the dust deposits, even a weak primary explosion may cause one or more very powerful secondary dust explosions. An example of this occurred at CTA Acoustics, in Corbin, KY, on February 20, 2003. In this catastrophic event, which claimed the lives of seven workers, injured 37 more and destroyed the manufacturing facility, secondary dust explosions occurred over 300 feet away from the primary event.

Plant management must be committed to controlling accumulations of combustible dusts in their facilities in order to protect employees and property against secondary flash fires and explosions. Design and implementation of a rigorous housekeeping program will ensure that combustible dust accumulations are effectively managed. This article will focus on the relevant NFPA requirements for housekeeping and important strategies that can be used to determine what levels of dust accumulations put the facility at risk for flash fires and explosions and what can be done to manage this risk.

Relevant Regulatory and NFPA Requirements

OSHA Requirements

OSHA's housekeeping standard (29 CFR Part 1910.22), requires that all places of employment, passageways, storerooms, service rooms be kept clean and orderly and in a sanitary fashion. This standard also requires the floor of every work room to be maintained in a clean and, so far as possible, dried condition. This standard is very subjective in nature and thus, subject to interpretation by the various compliance safety and health officers.

NFPA Requirements

There are five **NFPA** consensus standards that govern combustible dusts. Each of the standards addresses housekeeping in some fashion.

NFPA 61 "Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities"

This standard requires that dust on floors, structural members and other surfaces be removed, concurrently with operations. Each facility must develop and implement a written housekeeping program that establishes the frequency and methods to best reduce accumulations of fugitive dust. Annex A of the standard refers the reader to NFPA 654 for guidance on housekeeping.

NFPA 484 "Standard for Combustible Metals"

The standard takes a very conservative approach with regard to housekeeping. The prescriptive requirement is that fugitive dust must not be allowed to accumulate to a level that obscures the color of the surface beneath it; however, it is permissible to establish, in a building or room, an alternative dust accumulation threshold for the commencement of housekeeping, based on a documented hazard assessment acceptable to the authority having jurisdiction (AHJ). The standard requires a documented housekeeping program to be established. This program must include procedures for unscheduled housekeeping of unplanned or accidental spillage of combustible metal dusts. No guidance is provided with regard to the levels of dust accumulations that could present a flash **fire** or **explosion** hazard within the plant.

NFPA 654 "Standard for the Prevention of Fires and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids"

NFPA 654 is the most comprehensive of all of the combustible dust standards and provides a significant amount of detail with regard to establishing a housekeeping program. There are four principal

methods that can be used to determine whether or not a flash fire or explosion hazard exists. All four methods are considered to be equivalent in nature. The housekeeping program should be structured to avoid dust accumulation levels that could put the plant at risk with regard to flash fires and explosions.

The Layer Depth Criterion Method establishes an upper limit for combustible dust accumulation based on the bulk density of the dust. The layer depth, LD, is calculated by multiplying the previous benchmark accumulation level (NFPA 654, 2006 Edition) of 1/32 in. by 75 lb/ft³, (assuming a dust with a bulk density of 75 lb/ft³ as a reference), and dividing this number by the bulk density of the dust of interest (ρ_{dust}), to establish a new maximum allowable accumulation thickness or layer depth criterion.

$$> \text{EQ 1 - LD} = (1/32) * 75 / \rho_{\text{dust}}$$

Dust accumulations reaching the maximum allowable thickness (LD) must not cover an area that is more than 5 percent of the room area. Additionally, the total volume of dust accumulations in the room (including dust accumulating on overhead surfaces) cannot exceed the layer depth criterion (LD) multiplied by 5 percent of this area. For rooms with areas over 20,000 ft², the maximum allowable accumulation levels and total dust volumes must be based on an area of 1000 ft². As a practical example of how this method is applied, assume a room with an area of 1000 ft², where a dust having a bulk density of 37.5 lb/ft³ has accumulated. The layer depth criterion is calculated to be 1/16 in. The total dust accumulation in this room must not exceed 1/16 in. over an area of 50 ft². Additionally, the total volume of dust in this room must not exceed (1/16 in.)/12 in./ft*50 ft² = 0.26 ft³ or 9.8 pounds.

> **Mass Method A** – A dust flash fire or dust explosion **hazard area** is judged to exist when the total accumulated dust external to the equipment exceeds the quantities determined from Equations 2 and 3. The threshold dust mass establishing a building or room as a dust explosion hazard area, $M_{\text{basic-exp}}$, is determined by the following equation:

$$\text{Eq. 2 } M_{\text{basic-exp}} = 0.004 * A_{\text{floor}} * H \text{ kilograms}$$

The threshold dust mass establishing a building or room as a dust flash-fire hazard area, $M_{\text{basic-fire}}$, is determined by the following equation:

$$\text{Eq. 3 } M_{\text{basic-fire}} = 0.02 * A_{\text{floor}} \text{ kilograms}$$

Where:

$M_{\text{basic-exp}}$ is threshold mass (kg) based on building damage criterion.

$M_{\text{basic-fire}}$ is threshold mass (kg) based on personnel fire exposure criterion.

A_{floor} is lesser of enclosure floor area (m²) or 2000 m².

H is lesser of enclosure ceiling height (m) or 12 m. These equations do not require measurement of any physical or combustibility properties for application and tend to lead to a more conservative outcome.

- > **Mass Method B** - This is a rather complicated method of determining whether or not a flash fire or explosion hazard exists within a particular area. There are separate equations that are used to determine the threshold dust mass that establishes the hazard. These equations require inputs of several parameters, some of which may be difficult to establish or estimate. These parameters include the strength of the building, worst case dust concentrations with regard to burning rates, dust entrainment factors and probability of flame impingement on a person. The reader is referred to NFPA 654 for more information with regard to this method.
- > **Risk Evaluation Method** - A documented risk evaluation acceptable to the authority having jurisdiction (AHJ) is permitted to be conducted to determine whether or where a **dust explosion** hazard or dust flash fire hazard exists. This method is intended to focus on material properties and inherent design features of the equipment and the facility necessary to determine the extent of the hazard areas. Typically, use of this method, will require specialist expertise with extensive knowledge of combustible dusts and the associated fire and explosion hazards. In addition, appropriate **test data** will be required with regard to the particular dust being generated. The method can offer significant advantages over the other three methods described here, for example where:
 - the bulk density of dust is low.
 - hygroscopic dusts are being handled/generated.
 - the ignition sensitivity properties of dusts are low.
 - the nature of the solid particulate makes the formation of fine dust clouds difficult.

NFPA 655 “Standard for Prevention of Sulfur Fires and Explosions”

The sulfur dust standard provides criteria to determine whether or not a flash fire or explosion hazard exists inside the plant. The criteria is very similar to that of NFPA 654. Operators are required to establish housekeeping frequencies to ensure that accumulated dust levels do not exceed threshold dust accumulation values as dictated by the standard. A planned inspection process is also required to evaluate dust accumulation rates and the housekeeping frequencies required to maintain dust accumulations to acceptable levels.

NFPA 664 “Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities”

This standard requires that a documented housekeeping inspection program be developed and maintained. Annex A of the standard provides some details regarding the content of the program. Typical housekeeping routines, as a minimum, should include daily, or per shift, cleanup of personal work areas, walkways, emergency escape routes and access ways to the fire protection equipment, weekly cleanup of floors throughout the facility and weekly to semiannual cleanup of dust accumulations on horizontal surfaces and on structural members. As a rule of thumb, the standard suggests that wood dust accumulations do not exceed 1/8 of an inch in depth.

Goals of an Effective Housekeeping Program

The goal of any effective housekeeping program should be to maintain dust accumulation levels below those at which flash fire or explosion hazards will exist in the plant, if the accumulated dust were to become airborne. Development and effective implementation of such a plan, including the inspection component, should ensure that the goals are achieved. For metal dusts, where the hazards of flash fire and explosion may be greater, when compared to other dusts, due to inherently high adiabatic flame temperatures, the housekeeping program must be tailored around maintaining fugitive dust accumulations below levels that obscure the color of the underlying surfaces. Alternatively, NFPA 484 allows for establishment of a dust accumulation threshold for the initiation of housekeeping that is based on a documented hazard assessment. For other dusts, the Layer Depth Criterion or Mass Method A can be used to determine the threshold limits of dust accumulations to manage the risk of dust flash fire and explosion. If these methods prove to be impractical or problematical to implement, then management should consider a risk based evaluation. Implementation of an effective housekeeping program can significantly reduce the risk of having a major industrial dust flash fire or explosion incident.

Key Elements of the Housekeeping Program

The housekeeping plan should include the following:

1. The cleanup frequency to ensure that accumulated dust on walls, floors, and horizontal surfaces on equipment, ducts, pipes, hoods, ledges, beams and above suspended ceilings and other concealed surfaces, such as the interior of electrical enclosures, do not exceed the established levels.
2. A planned inspection process to evaluate dust accumulation rates and the housekeeping frequencies required to maintain dust accumulations below the established levels.
3. Specific requirements establishing time to clean up local spills or short term accumulations. Table 1, excerpted from Annexes A of NFPA 484 and NFPA 654, provides guidelines with regard to these times.

Table 1 - Unscheduled Housekeeping Guidelines

Unscheduled Housekeeping		
Accumulation on the Worst Single Square Meter of Surface	Longest Time to Complete Unscheduled Local Cleaning of Floor-Accessible Areas	Longest Time to Complete Unscheduled Local Cleaning of Areas
> 1 to 2 times threshold dust mass/accumulation	8 hours	24 hours
> 2 to 4 times threshold dust mass/accumulation	4 hours	12 hours
> 4 times threshold dust mass/accumulation	1 hour	3 hours

Summary

Development and implementation of an effective housekeeping program is not only required by NFPA standards but is absolutely essential in order to manage the risk of secondary dust explosions, which have often proven to be more devastating in terms of loss of life, injuries, and facility damage. This article provides some practical guidance with regard to establishing housekeeping programs. For metal dusts, the program must be designed to prevent accumulations of dust from developing to levels that will prevent determination of the underlying surface colors of the floor, equipment, etc. unless an alternative maximum allowable dust accumulation level is established, based on a documented hazard assessment acceptable to the AHJ. For other dusts, the NFPA 654 strategies for determining whether or not a flash fire or explosion hazard exists can be used to determine when clean-up activities are warranted. Three methodologies are discussed in this regard. The Layer Depth Criterion method and Mass Method A are relatively easy to implement but, in some cases, the threshold dust

accumulation or mass levels that dictate cleanup may prove to be impractical, in terms of control. In these cases, the Risk Evaluation Method may offer a workable solution. Conduct of a risk evaluation may necessitate the services of an expert and will require explosibility and ignitability data with regard to the particular dust(s) being generated. A planned inspection process is also essential to evaluate dust accumulation rates and to establish housekeeping frequencies required to prevent dust accumulations from exceeding the acceptable levels. A well-designed housekeeping program will also include cleanup frequencies designed to ensure that dust levels do not exceed hazardous accumulation levels and will include timetables for cleanup of unscheduled spills.

References

Investigation Report, Combustible Dust Hazard Study, US Chemical Safety and Hazard Investigation Board, Report No. 2006-H-1, November 2006.

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Steven J. Luzik, PE, CFEI is a Senior Process Safety Specialist at DEKRA Process Safety with over 30 years experience in the area of fire and explosion hazards including gas/vapor explosions, dust explosions and fire and explosion protection strategies. He graduated from the University of Notre Dame with a BS degree in Chemical Engineering. He is a registered Professional Engineer in the State of Pennsylvania and a Certified Fire and Explosion Investigator (CFEI) with the National Association of Fire Investigators (NAFI). As a former Mine Safety and Health Administration [MSHA] manager and technical specialist, he has investigated a multitude of incidents involving flammable vapors, gases and dusts that have included surface and underground mining facilities and industrial facilities where fires and explosions have occurred. He has conducted dust explosion hazard assessment at several coal-fired power plants.



He also has served as a moderator of a flammability and dust explosibility laboratory, processing requests from MSHA and other Federal agencies for testing to determine the flammability and explosibility properties of solids, liquids, dusts and vapors. In this capacity, he has been called upon to provide expert testimony on the explosibility hazards associated with the manufacturing, processing and handling of these materials. He is a member of the American Society for testing and Materials (ASTM) E-27 Committee on Hazardous Properties of Chemicals, the National Association of Fire Investigators (NAFI) and the National Fire Protection Association (NFPA). He has authored numerous publications in the areas of fire and explosion prevention, protection and investigation.

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