# Making Sense of Combustible Dust DHAs versus a PHA

An ioMosaic White Paper

## Introduction

Process Hazard Analyses (PHAs) have been conducted for decades across the chemical processing industries. First conceived at ICI in the 1960s, the PHA process has been continually refined to identify, understand, and mitigate risk. Today, hazard analysis has now solidified its place in combustible dust hazard management. When applied specifically to combustible dust handling environments, this systematic review is known as a Dust Hazard Analysis (DHA).

For all industrial operations, the fundamental premise of any hazard evaluation remains identical: identifying hazards, understanding causes/consequences, identifying adequate safeguards and assessing the risks associated with each hazard.

However, a critical question arises for safety professionals, particularly those in the chemical industry sectors: How is a traditional PHA truly different from particulate solids or dust-focused DHA?

In dust-handling facilities, the primary hazard—combustible particulate solids—is already well-known. Hidden, complex chemical reaction hazards rarely surface during a particulate solids' evaluation. Instead, the challenge lies in managing a solid material that naturally migrates, settles, and disperses.

The regulatory landscape reached a historic milestone with the publication of NFPA 660 (2025), the unified Standard for Combustible Dusts and Particulate Solids. NFPA 660 consolidates all legacy industry-specific standards into a single, comprehensive framework and defines DHA as:

> *"A systematic review to identify and evaluate the potential fire, flash fire, or explosion hazards associated with the presence of one or more combustible particulate solids in a process or facility." (NFPA 660, 2025)*

This paper will outline the most current dust hazard analysis requirements, to best complete those requirements to meet regulations, as well as internal obligations to maintain a safe work environment.

## Criticality of Risk Assessment and Ranking

While NFPA 660 provides clear compliance mandates and includes an example DHA template within its annexes (NFPA 660, Annex B-Dust Hazards Analysis-B.4 Sample DHA, NFPA, Annex H-Checklist for Dust Hazard Analysis-Example for an Existing Facility), the standard example suffers from a severe practical limitation: it focuses strictly on whether a hazard exists or not (a binary yes/no assessment). The example does not progress to provide an example of risk ranking.

By ignoring risk probability and consequence severity, a facility utilizing the basic NFPA 660 example is often left paralyzed by data. The output is a flat, unprioritized list of deficiencies or gaps in design. Plant managers are left with no answer to the most vital questions: "What are the highest risks?" “How do I prioritize?”. "Where do we focus our critical engineering resources and budget to prevent a major fire, or worse an explosion?"

By embedding a traditional PHA risk-ranking framework directly into a standard dust hazard analysis utilizing the checklist methodology, facilities transform a flat compliance exercise into an actionable, risk-prioritized capital expenditure roadmap for proper design. This approach is critical for effective capital budgeting and is also in line with the proven best practice methodologies outlined in CCPS publication “Guidelines for Hazard Evaluation Procedures”.

## Key Differences Between a DHA and PHA

OSHA does not have a specific, standalone regulation that explicitly mandates a Dust Hazard Analysis (DHA), unlike a PHA that is directly mandated by both OSHA and EPA in specific regulatory requirements. A DHA is required by the National Fire Protection Association (under NFPA 660, previously NFPA 652), which is a consensus industry standard not a regulation mandated by Congress. Therefore, OSHA cannot directly cite a facility for simply "not having a DHA". Instead, OSHA enforces combustible dust safety through its National Emphasis Program (NEP – CPL 03-00-008)) and issues citations under Section 5(a)(1) of the OSH Act (the General Duty Clause) or other applicable regulations such as emergency response, housekeeping and electrical standards. When a facility fails to identify and mitigate explosive dust risks OSHA lists the "failure to conduct a Dust Hazard Analysis" as a specific, formal deficiency within a broader General Duty Clause citation. Recent major federal enforcement actions and inspection data highlight this pattern.

One such example is from a wood dust explosion that occurred in July 2025. In OSHA's Feb 10, 2026, news release OSHA communicated Horizon Biofuels was cited for multiple violations totaling over $147,542. Many of these serious or willful violations were directly related to lack of safeguards or actions that would have prevented the event if a dust hazard analysis had been conducted.

Another, more direct example, of how OSHA is citing the lack of a DHA is from citation 15787.015/01001 dated 7/18/2022 at Spring Valley Millwork, Inc. This citation stated, "f) Facility-Wide - The employer failed to conduct a Dust Hazard Analysis (DHA) to identify and document the equipment and areas of the facility where dust fire and explosion hazards exist, on or about February 16, 2022."

There are also differences between DHA and PHA, on how the analysis is conducted. One such difference is how a DHA typically divides a manufacturing facility or process into nodes that are reflective of individual material handling components (i.e. mill, blender, dust collector,) while a PHA utilizes nodes that are much smaller in scope such as a pipe segment, a recirculation line, a reactor. Another key difference is a DHA must also include a hazard assessment of the entire building structure and the potential for a secondary dust explosion. PHAs typically assume steady state which means the hazard is inside a pipe or vessel or tank, while a DHA must also assess fugitive dust accumulations external to the equipment in rafters or building members or on floors.

PHAs use a variety of methodologies that have a process that assists with surfacing unknown hazards such as the HAZOP or "what if" techniques. In particulate solids or dust operations the hazards are already well known, therefore a prescriptive methodology is more appropriate such as the “Check list” methodology.  Other methodologies are still appropriate for unique operations.

## The Unified Standard: NFPA 660

NFPA 660 completely replaced all previous standalone dust standards (including NFPA 652, 654, 61, 484, 655, and 664). The new NFPA 660 standard serves as both the general fundamental baseline and the specific industry-chapter guide for chemical, agricultural, metal, and wood dust processing.

Under NFPA 660, the requirements for a comprehensive DHA are explicitly mandated and retroactive to all operations with a dust hazard. Requirements under NFPA 660 include:

- Existing Processes: Complete and maintain a valid DHA for all existing processes handling combustible particulate solids.
- Management of Change (MOC): Complete a DHA prior to any material modifications or process changes.
- Scope or Boundary: Evaluate the fire, deflagration, and explosion hazards of each part of the process equipment and each building compartment/room.
- Operational Control: Identify safe operating ranges and verify existing safeguards.
- Actionable Plan: Recommend additional safeguards as necessary, accompanied by a documented plan for implementation

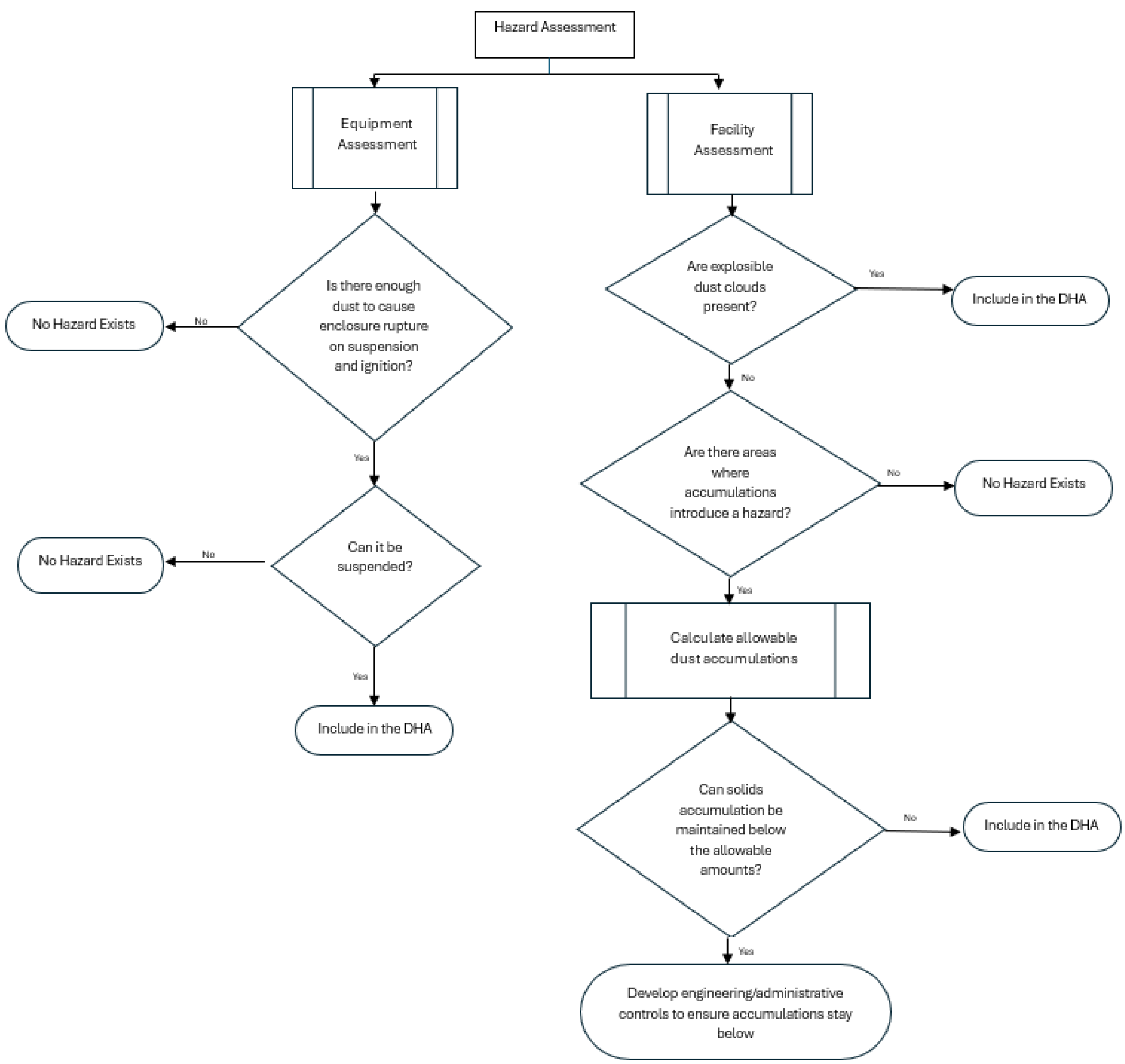
Qualifications: The DHA must be led by a qualified person and re-evaluated and updated every five (5) years.

## Study Boundary

The first step in any hazard analysis is defining the scope. This requires a clear understanding of the types of hazards evaluated, the physical process equipment, and the building zones that contain them.

A multi-step approach simplifies this boundary definition, ensuring that valuable engineering resources are spent appropriately on high-hazard areas. See Figure 1 below. Each piece of equipment and facility room must be mapped according to its unique characteristics.

Figure 1: Combustible Dust Hazard Assessment Flow




Source: ioMosaic Corporation

The first step in the analysis is gathering physical characteristics of each individual particulate solid that is being handled (one can use a "worst case" representative sample if multi-purpose equipment is being analyzed"). One cannot assume material is combustible or not combustible without data. Physical data must be obtained. If data is not available in literature, physical characterization data must be obtained via testing. It is not practical to conduct a good risk assessment without understanding key characteristics of the solids being handled. Characteristics are unique between solids; therefore, they are critical to obtain and understand. One must be able to answer, "Is my particulate solid explosible?". This can be concluded from a low cost "Go-No Go" test. If tested as non-explosible dust, that one piece of data can save an organization hundreds of thousands of dollars. In contrast if the particulate has a low minimum ignition energy (<30 mJ), this single characteristic has significant impact on the dust hazard analysis, in particular the likelihood of ignition and required safeguards for the design. Hence characterization of the particulate solids is not only required by NFPA 660 and OSHA's NEP but also has significant impact on the resulting hazard analysis and risk assessment.

## Determining Allowable Accumulations

To evaluate hazard areas external to process equipment, plant engineers must calculate allowable dust accumulations and compare them against the worst-case physical dust levels present in the area. NFPA 660 establishes validated methodologies to determine these boundaries:

- The Layer Depth Criterion: Relies on a baseline accumulation depth (historically 1/32” or adjusted for materials with a bulk density less than 75 lb/ft$^3$). Generally, a hazard is deemed to exist where the total area exceeding this layer depth covers more than 5% of the room footprint area.
- Mass Method A: A simplified mass-balance equation that utilizes generalized assumptions regarding typical dust characteristics and standard building structural strength to establish a maximum safe mass threshold.
- Mass Method B: A highly accurate, engineering-grade calculation that factors in measured facility design variables and precise laboratory dust characteristics (such as Deflagration Index Kst, Max Explosion Pressure Pmax, Enclosure Strength Pes, and Dynamic Load Factor DLF).

To optimize accuracy, facilities may default to utilizing the most detailed equation (Mass Method B) for which verified dust testing and structural data are available. Interior process compartments containing dust loads higher than these calculated thresholds must be targeted for advanced engineering protections evaluated through the risk-ranked PHA process.  For a general easy engineering assumption, one can use the “Can I write my name in the accumulated solids, and my name is discernable?” method, which is the most time efficient method.

The flowchart in Figure 1, taken from the ioMosaic Corporation whitepaper, shows how this process can be executed. Using the left side of the chart, each *piece of equipment* can be assessed according to the applicable criteria. Using the right side of the chart, each *process area* can be assessed according to the applicable criteria. Working through the steps in the chart results in a list of hazardous equipment and process areas to include in the DHA.  The potential dust characteristics and facility information that might be needed are provided in the boxes.

**Dust Characteristics**

$K_{St}$ – Deflagration index
$P_{max}$ – Max explosion pressure
$(dP/dt)_{max}$ – Max pressure rise rate
$C_W$ – Worst-case dust concentration

**Facility Information**

$A_f$ – lesser of floor area or 2000 m$^2$
H – lesser of ceiling height or 12 m
$\rho$ – probability of flame impingement
$P_{es}$ – Enclosure strength
DLF – Dynamic Load Factor

## Implementation of the multi-step flowchart

For process equipment, this is straightforward. Does enough combustible dust exist to introduce an explosion with rupture of equipment if suspended and ignited? Is a means of suspending the dust present? If the answer to both is yes, the equipment presents a dust explosion hazard and should be included in the DHA.

The second step is to determine if explosible dust clouds exist external to equipment. Do dust clouds of hazardous concentration exist? If the answer is yes, the area is a dust flash fire and explosion hazard.

The third step is to determine if external dust accumulations can reach hazardous levels. Are there areas where dust accumulation makes the underlying colors or a same written in the solids indiscernible? If the answer is yes, determine allowable accumulations for flash fire and explosion hazards using the provided equations. This is further described in the section below.

The final step is to decide if the areas with potential hazardous accumulation levels can be maintained below the allowable threshold levels. Engineering and administrative controls can be implemented to ensure that accumulation levels do not go above the acceptable threshold. Engineering controls include preventive maintenance of equipment to prevent leaks, enclosing equipment, and dust collection systems. Administrative controls, such as housekeeping, are generally less costly but also less reliable.

Where accumulations are allowed to reach levels above the allowable accumulation, these portions of the facility can pose flash fire and/or explosion hazards and should be included in the DHA.

During conduct of the DHA, each piece of equipment and process area with dust explosion or flash fire hazards should be evaluated to make sure they comply with the specific requirements outlined in the applicable NFPA standards. DHAs will evaluate existing controls and develop recommendations for additional protections as appropriate.

## The Solution: The Risk-Ranked Checklist DHA Methodology

For well-understood, standard industrial unit operations handling particulate solids, a checklist methodology analysis hybridized with a traditional PHA risk-ranking matrix is the most effective approach. This approach satisfies the legal requirements of NFPA 660 while correcting the flaws of the binary NFPA annex example.

Instead of simple 'Yes/No' answers, each checklist item assessing an equipment component or building compartment is evaluated through a quantitative Probability × Severity matrix. Many organizations already have a well-defined corporate standard for a risk matrix. Utilizing an organization's existing risk matrix enables prioritization of hazards across multiple sites, as well as actions from PHAs, or other applications, such as prioritizing incident investigation actions. An example Risk Matrix is below in Figure 2:

Figure 2: Example 4 x 4 Risk Matrix (RPL = Risk Priority Level)

| Likelihood Level | Consequences (Level 1) Minor | Consequences (Level 2) Serious | Consequences (Level 3) High/Flash Fire | Consequences (Level 4) Catastrophic/Explosion |
|---|---|---|---|---|
| Very Frequent (Level 4) >1/yr | Medium Risk (RPL C) | HIGH RISK (RPL B) | CRITICAL (RPL A) | CRITICAL (RPL A) |
| Frequent (Level 3) >1/yr to $10^{-1}$/yr | Low Risk (RPL D) | Medium Risk (RPL C) | HIGH RISK (RPL B) | CRITICAL (RPL A) |
| Possible (Level 2) >$10^{-1}$/yr to $10^{-2}$ | Low Risk (RPL D) | Low Risk (RPL D) | Medium Risk (RPL C) | HIGH RISK (RPL B) |
| Unlikely (Level 1) >$10^{-2}$/yr to $10^{-3}$ | Low Risk (RPL D) | Low Risk (RPL D) | Low Risk (RPL D) | Medium Risk (RPL C) |

## Why is the adoption of the CCPS approach for hazard and risk analysis advantageous over the example provided in NFPA 660?

1. Defensible Capital Allocation: A Risk Priority Level (RPL) allows corporate management to instantly group deficiencies. Capital budgeting can be cleanly funneled into mitigating the highest risk items first, rather than treating a dusty light fixture with the same urgency as an unvented dust collector.
2. Accounting for Secondary Explosion Risks: Traditional chemical PHAs rarely focus on overhead structural dust. The Checklist DHA methodology ensures items associated with a facility that could introduce a secondary dust explosion hazard are assessed and risk ranked. The approach takes into consideration the severe consequence potential for an accumulation of solids outside of equipment. This scenario represents a catastrophic building collapse hazard via a secondary explosion.
3. Probability of Occurrence: It evaluates the likelihood of an ignition source based on the mechanical reality of the specific component (e.g., presence of tramp metal, bearing overheating, or lack of electrical grounding), or the minimum ignition energy of the particulates rather than assuming ignition is always equally possible. This enables an engineer to make a risk-based decision on safeguards required, versus the prescriptive option. Both are acceptable based on NFPA 660.

## PHA Process

The basic PHA process is outlined in many standard references including the *CCPS Guidelines for Hazard Evaluation Procedures* (Center for Chemical Process Safety, 2008). Application of the process to combustible dust operations was described in detail in an earlier article by ioMosaic Corporation (Perry, 2009). In this article, the authors describe the use of a checklist approach DHA that is still valid today. The use of other hazard identification techniques (e.g., Hazard and Operability (HAZOP) study) can be relied on for unique operations if needed.

## Wrapping Up

Dust Hazard Analyses are resource-intensive investments with far reaching impacts and benefits. With the right approach, valuable resources can be conserved, regulatory requirements can be met, and most importantly – risk can be reduced. By adopting a risk-ranked DHA checklist approach, facilities achieve a simpler, more legally defensible, and cost-effective solution for proper design of particulate solids handling operations.

Combining the DHA requirements of the standards with the established best practice PHA methodology, implementation will be simpler, consistent, and the process renewable. This process is summarized as follows:

1. Characterize the particulate solids
2. Leverage knowledge on characteristics of the material as well as accumulation amounts external to equipment to establish definitive scope and boundaries of hazardous operations.
3. Use the dust hazard assessment approach to establish precise study boundaries.
4. Use a qualified person for the analysis.
5. Risk analyze the equipment and buildings using established PHA techniques
6. Document the risk ranked findings into an active corporate capital budgeting roadmap, ensuring the highest risks are abated first.
7. Update the DHA every five years or when there is a change in the process or facility

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