Plant Issues in an NFPA 652 Dust Hazard Analysis

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Objectives

- Compliance Standards and Codes
- Combustible Dust Properties and Hazards
- Dust Hazard Analysis:
  - Process Safety Information
  - Assessments:
    - Plant Equipment,
    - Process Facility and Rooms,
    - Programs, and
    - Dust Hazard Analysis.
- When Should Dust Testing Begin?
- Performance Based Design
- Summary and Next Steps

Relevant Standards Applicable to Combustible Dust

- Canadian Dust Laws
  - Canada Occupational Health and Safety Regulation (SOR/86-304) [6% workforce]
    - Applies to all equipment ignition sources in any area that might contain combustible dust, in a sufficient quantity to be a fire or explosion risk, and
    - Requires the workplace and surrounding areas within reach of an ignition source, to be "substantially free of combustible dust."
  - Provincial Regulations:
    - Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland and Labrador, Northwest Territories and Nunavut, Nova Scotia, Ontario, Prince Edward Island, Quebec, Saskatchewan, and the Yukon. [94% workforce].
- US Occupational Safety and Health Administration (OSHA)
  - OSHA General Duty Clause,
  - National Emphasis Program CL-03-00-008 (Reissued),
  - Hazard Communication Standard 29 CFR 1910.1200, and
  - Recognized and Generally Accepted Good Engineering Practices (RAGAGEP).

National Fire Protection Association (NFPA) Standards

NFPA #	Title
68	Venting of Deflagrations
69	Explosion Protection Systems
70	National Electric Code Electrical classification: Class I, II, and III; Divisions 1 or 2
77	Recommended Practice on Static Electricity
91	Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids
499	Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Location for Electrical Installations in Chemical Process Areas

NFPA 652 Standard
The Fundamentals of Combustible Dust

NFPA 652

Defines a Dust Hazard Analysis

NFPA 68, 69, 70 etc.

Engineering Controls: Deflagration Venting, Explosion Prevention Systems, and the National Electrical Code

NFPA 61
Agricultural
&
Food

NFPA 484
Metal dusts
Zinc, Metal Catalysts, Shot Blas Fines, etc.

NFPA 664
Wood
Processing

NFPA 654
Combustible Dust
Raw Materials
Isolated Intermediates
Final Bulk Powder Blends

ASTM

Testing
Protocols

Commonly Measured Properties of Combustible Dusts

Property	Definition	ASTM Test Method	Application
K_{St}	Dust deflagration index	ASTM E1226	Measures the relative explosion severity compared to other dusts
P_{max}	Maximum explosion overpressure generated in the test chamber	ASTM E1226	Used to design enclosures and predict the severity of the consequence
$(dP/dt)_{max}$	Maximum rate of pressure rise	ASTM E1226	Predicts the violence of an explosion. Used to calculate K_{st}
MIE	Minimum ignition energy	ASTM E2019	Predicts the ease and likelihood of ignition of a dispersed dust cloud
MEC	Minimum explosible concentration	ASTM E1515	Measures the minimum amount of dust, dispersed in air, required to spread an explosion Analogous to the lower flammability limit (LFL) for gas/air mixtures
LOC	Limiting oxygen concentration	ASTM E2931	Determines the least amount of oxygen required for explosion propagation through the dust cloud
ECT	Electrostatic charging tendency	No ASTM standard	Predicts the likelihood of the material to develop and discharge sufficient static electricity to ignite a dispersed dust cloud
BD	Bulk Density	ASTM D1895	The bulk density is also determine with the MEC test

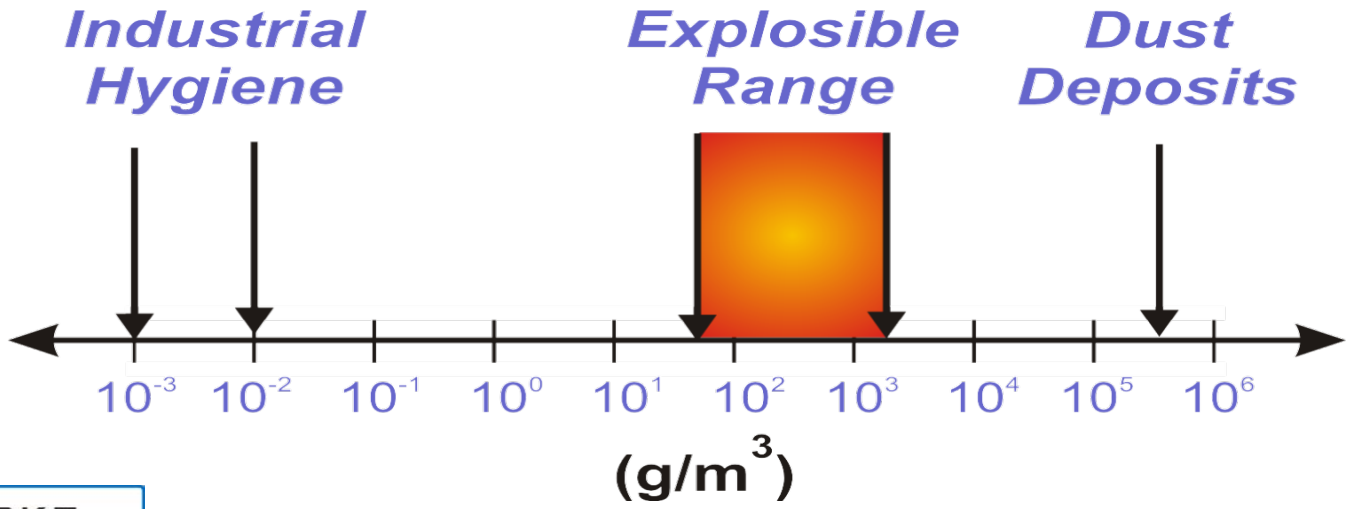
Minimum Ignition Energy (MIE) ASTM E2019

- Powder Fines/Fibers: sugar (confectionary) 10 mJ, flour 300 mJ, paper dust (fibers) 300 mJ, aluminum 50 mJ, and magnesium 40 mJ.
- Static discharge from human body can be 20-30 mJ.

MIE (mJ)	Recommended Precaution per BS 5958
500	Low sensitivity to ignition; ground equipment below this level
100	Consider grounding equipment below this level
25	The majority of ignition incidents occur below this level
10	High sensitivity to ignition. Consider inerting and restrictions on the use of high resistivity non-conductors below this level
1	Extremely sensitive to ignition at this level. Handling operations should be such that they minimize the possibility of suspending the powder in air; dissipate or discourage open charging operations. Inerting necessary with bonding & grounding.

Minimum Explosible Concentration

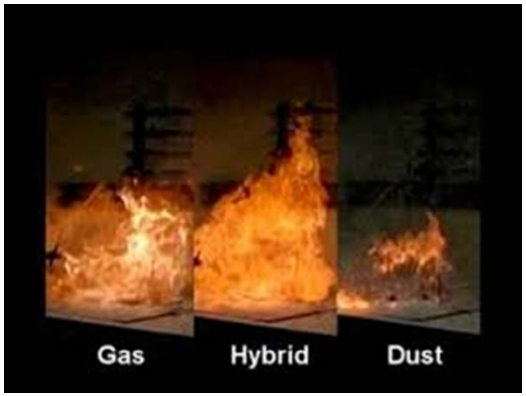
- Industrial hygiene levels are generally lower than explosible range.
- Dust deposits are above explosible range, but gravity will cause them to fall out of suspension onto a surface.
- MEC concentrations achievable if dust is present in large quantities.
- Housekeeping is critical; dust remediation is more efficient.



Bulk Density (BD) Layer Depth (LD)

- BD of accumulated powder outside of the process equipment on floor, rafters, electrical boxes, ductwork, at all levels of the process.
- The layer depth (LD) criterion method is based on the concept that "a dust flash fire or dust explosion hazard area exists when the dust layer thickness measured external to process equipment exceeds the quantity determined."
- The baseline layer depth criterion is 1/32"(0.8 mm) for materials with a bulk density (BD) of 75 lb/ft^3 (1,200 kg/m^3).
- The layer depth criterion may be calculated according to the following equation:
- $$\text{LD (in.)} = \frac{(1/32")(75\ \text{lb/ft}^3)}{\text{BD}}$$

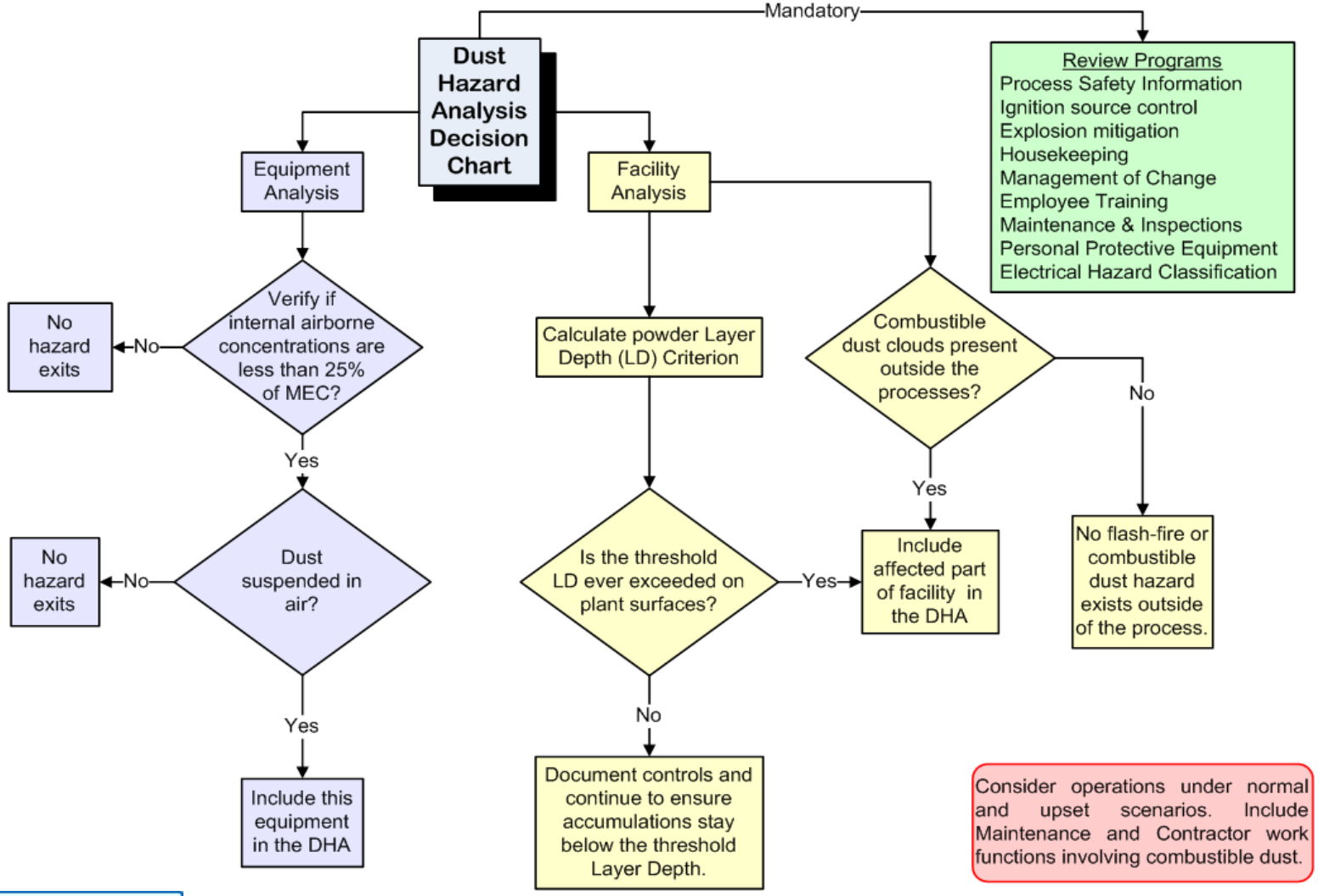
Dust Hazard Analysis (DHA)



Risk Reduction:

- **Identify hazards,**
- **Evaluate safeguards, and**
- **Implement DHA recommendations.**

Dust Hazard Analysis Decision Chart



Dust Hazard Analysis (DHA) Overview

- National Fire Protection Association (NFPA) 652 Defined Concept.
- Prescriptive approach:
  - Identify potential of dust or powder fires, flash fires, and explosions in a process or facility, and
  - Goal is to have a safer process, propagation-free facility, and reduced overall risk.
- Three stage methodology:
  1. Review all process safety information (e.g., dust test reports),
  2. Assessment of all the process equipment, engineering controls and administrative practices, and
  3. Understand the risk for a deflagration (subsonic speed) and the potential for propagation between linked equipment and the rooms of the facility.
- Personal Protective Equipment (PPE)
  - Flame-resistant safeguards; not IH issues.
- Focuses on combustible dust in the entire facility, which distinguishes if from a PHA.
- Recommendations:
  - Management consideration, and
  - Implement in a prioritized strategy.
- Alternative:
  - Performance-Based design option (Detailed Engineering Study)

Dust Hazard Analysis Preparation

- Team:
  - NFPA 652 recommends a “qualified” person to lead the DHA,
  - Involvement from Operations, Maintenance, and EHS, and
  - Other representatives as needed to meet applicable requirements.
- Process Safety Information
- Equipment Information:
  - Process descriptions, plot plans, and P&IDs, as needed
  - Equipment list for each process area
  - Previous incidents
  - Explosion protection, isolation, and discharge methods
  - And other specific equipment information
- Facility Information:
  - Housekeeping, fire protection, ignition control, Maintenance inspection and PM programs, electrical classification, etc.
- Agenda:
  - Identify all issues to be assessed to prevent any inadvertent omissions.

Step 1
Inventory and Hazards of all Process Dust

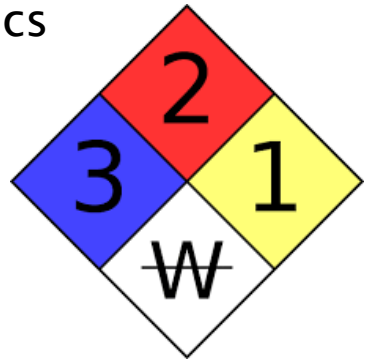
- All dust/powder:
  - Raw materials,
  - Intermediates and byproducts,
  - Final bulk products,
  - Recycled waste materials,
  - Solid hazardous waste,
  - Surface dust (floor, equipment, rafters, interstitial spaces, etc.), and
  - Calculate Layer Depth (LD) criterion.
- Review the Process Safety Information (PSI) to ensure the test data is valid, identify any gaps and understand a material's explosion severity/ignition sensitivity, limiting oxygen concentration, etc., including electrostatic properties, as needed (e.g., discharge rate, Flexible Intermediate Bulk Containers, etc.
  - Representative process samples (primary event), and
  - Representative surface samples (secondary event).

Additional Process Safety Information Resources
Transport of Dangerous Goods

- Class 4 Classification Testing
  - Division 4.1, Flammable Solids,
  - Division 4.2, Self-Heating Substances, and
  - Division 4.3, Dangerous When Wet Material.
- Class 5 Classification Testing,
  - Division 5.1, Oxidizing Solids.
- Impact and Friction Sensitivity Testing.
- Self Accelerating Decomposition Temperate (SADT).

Additional Process Safety Information Resources
Flammability Hazards

- Not all combustible dusts are free of flammable vapors or gases.
- NFPA "Fire Protection Guide to Hazardous Materials":
  - Flash Point,(FP
  - Autoignition Temperature (AIT)
  - Flammability Limits (Lower and Upper Flammable Limits), boiling point, fire extinguisher types, sprinkler or chemical foam types, and
- NFPA 704: Standard System for the Identification of the Hazards of Materials for Emergency Response
  - Health, Flammability, Reactivity, and Special
- Customized Testing: ΔT, ΔP, or specialized references:
  - Sustained Burning/Combustibility (Fire Point)
  - Flash and Spontaneous Ignition Temperature of Plastics
  - Temperature Limits of Flammability (LTFL)
  - Limiting Oxygen Concentration (LOC)
  - Minimum Ignition Energy (MIE)
  - Explosion Severity (P_{MAX}, K_G)



Step 2
Equipment Analysis

- Identify all unit operations and equipment,
- Understand if there is sufficient material in each vessel to reach its minimum explosive concentration (MEC) in air,
- Assess if the dust can become suspended in the equipment in and in what atmosphere, e.g., nitrogen, air, pressure swing absorption nitrogen, etc.,
- Determine the capability for process dust control under normal and adverse operations,
- Dust collectors: Verify isolation technology to prevent propagation back to the process, vessel overpressurization protection, exhaust to a safe area, and vent sizing calculations,
- Identify the use of ignition controls, e.g., hot work permit, bonding & grounding, etc.,
- Assess the Management of Change procedure other than like for like changes,
- Evaluate effectiveness of Maintenance equipment inspections and PM programs. Use reliability approach to maintenance; not a “run to break” one, and
- Consider the potential for flammable vapors or gases to migrate into process equipment containing combustible dust.

Step 3
Potential for Propagation within the Facility

- This is probably, the most critical step.
- Evaluate the explosion or fire risk between the process building or the rooms of the structure, which is a workplace.
- Critical factors to consider involve:
  - Accumulation of fugitive dust/powder and housekeeping practices
  - Closure of all fire doors,
  - Ceiling and wall blow-out prevention engineering controls,
  - Fire protection,
  - Safe exhaust of overpressurization devices, and
  - Other engineering and administrative controls, e.g. Management of Change, operator training, and so forth.
- Accumulated surface dust outside the process can result in secondary explosions, that can be catastrophic in terms of human injury/death, capital loss and business interruptions.

Dust Hazard Analysis Organization

- Collect all background information prior to the DHA,
- Develop an agenda,
- Ensure critical personnel are scheduled and available,
- Define the scope of the assessment,
- All information should be readily available for DHA,
- Logically organize the plant tours, and
- Be flexible, as plant conditions and administrative issues can change; always have a Plan B ready.

Dust Hazard Analysis Coordination

- Opening meeting.
- On-site equipment and facility tour.
- Evaluation of all combustible dust programs.
- Interviews with affected personnel to validate programs.
- Closing meeting:
  - Present observations and findings,
  - Review preliminary recommendations, and
  - Discussion with affected personnel.
- Issue draft report.
- Team review of draft.
- Revise and issue final report:
  - Client proceeds to implement the prioritized action plan with deadlines, responsible person, status, and updates to affected groups. Retain DHA report for the Authority Having Jurisdiction.
- Repeat the DHA every three years or if needed by an MOC review.

When Should You Test?

- Until verified; assume all dusts are combustible.
- Early Development (Kilo-Lab and Pilot Plant):
  - Develop a strategic procedure based on equipment, risk, handling, housekeeping, and other safeguards to prevent a dust incident,
  - Material instability/reactivity: Chemical Thermodynamic and Energy Release Evaluation (CHETAH) or equivalent, thermal stability screening test, observed oxidation, etc. MIE info is critical for milling ops, or use Nitrogen as a pad gas, and
  - Perform developmental scale-up under nitrogen, or at less than LOC. Consider (PSA units) as pure nitrogen costs can be significant.
- Approaching full-scale processing levels, potentially using air:
  - Conduct appropriate testing on representative process samples of raw materials, isolated intermediates, and bulk powder blends:
    - OSHA Suite Tests: combustible content, PSD, moisture, K_{St}, dP/dt_{max}, P_{max}, MIE_{Cloud}, MEC_{Cloud}, MIT_{Cloud}, and
    - Electrostatic: volume resistivity, charge relaxation time, & powder chargeability on different materials of construction.

Performance Based Design
Detailed Engineering Studies

- Maximum Allowable Working Pressure (MAWP) calculations using finite analysis, wall thickness data, and other techniques.
  - Useful for legacy equipment, etc.
- Blast and thrust calculations for exhaust vents robustness.
  - Ensure exhaust vent from a burst rupture disc, remains intact after an explosion.
- Desktop Review of Proposed Explosion Protection Strategy.
  - Useful to have subject matter expert review projects at an early stage.
- Performing a Management of Change procedure.
  - Ensure all hazards are identified at the design stage.
- Develop Engineering Drawings.
  - Typically used to support a concept or model
  - Electrical Engineering Classification and Plot Plans.

Summary

- Reviewed:
  - Compliance Standards and Codes, and
  - Combustible Process Safety Information.
- Dust Hazard Analysis
  - Overview,
  - Detailed information of critical issues, and
  - Aware of DHA requirements.
- Next step is to conduct your DHA to assess hazards, evaluate safeguards, and make recommendation for a safer process to reduce the risk of injury/death, and business interruptions.

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Questions?