COMBUSTIBLE DUST

SAFETY WORKSHOP
Navigating the Combustible Dust Explosion & Fire Risk Mitigation Journey

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Lewellyn Technology
Jason Reason

• Education & Certifications
  – B.S. Industrial Hygiene – Purdue University
  – MBA – University of Indianapolis
  – CIH, CSP, CHMM

• Experience
  – 12.5 years as OSHA Compliance Officer
  – Performed over 50 combustible dust inspections
  – Assisted Federal OSHA & State Plan OSHAs on numerous combustible dust inspections and issues
  – Instructor for OSHA Combustible Dust Course at OTI
Jason Reason

- NFPA Technical Committees
  - Chair of Committee for Wood & Cellulosic Materials (NFPA 664)
  - Principle Member of Committee for Handling & Conveying of Dusts, Vapors and Gases (NFPA 91, 654 & 655)
  - Principle Member of Committee for Fundamentals of Combustible Dusts (NFPA 652)
  - Principle Member of Flash Fire Protective Garment Committee (NFPA 2112 & 2113)
  - Member of Correlating Committee for Combustible Dusts (Over all NFPA combustible dust committees)
Overview

• Hazard Identification
  – Dust Explosion History
  – Definition & Description of Combustible Dusts
  – Hazards Associated with Combustible Dusts
  – Combustible Dust Testing
  – Combustible Dust Standards

• Hazard Assessment
  – Dust Hazard Analysis (DHA)
Overview

• Hazard Mitigation and Prevention
  – Engineering Controls
    • Explosion Protection Systems
    • Electrical Area Classification
  – Administrative Controls
    • Housekeeping
    • Cleaning Methods
A HUGE Problem

• Between 1982 and 2007, there were 281 dust fires and explosions
• Between 2009 and 2013, there were 57 dust fire and explosions
Paarl Print Factory
(South Africa)
FM Global Loss Data by Industry

- Woodworking: 39%
- Food: 16%
- Metals: 8%
- Chemical/Pharmaceutical: 7%
- Paper/Pulp: 4%
- Utility: 3%
- Rubber: 3%
- Plastics: 3%

Combustible Dust Safety
FM Global Loss Data by Dust Group

- Wood: 42%
- Food: 15%
- Chemical: 10%
- Metal: 9%
- Coal: 8%
- Plastic/Rubber/Resin: 8%
- Paper: 5%
- Various: 2%

Combustible Dust Safety
Key Factors Contributing to Incidents

- Dust collectors were inadequately designed or maintained to minimize explosions (> 40% of incidents)
- Process changes were made without adequately reviewing them for the introduction of new potential hazards
- Outside parties inspecting the facilities failed to identify dust explosion hazards:
  - Government enforcement
  - Insurance underwriters
  - Health and safety professionals
Combustible Dust Inspections (Federal OSHA)

October 1, 2007 – March 31, 2015

- Unprogrammed: 1,594
- Fatality/Catastrophe: 42
- Complaint: 937
- Referral: 486
- Monitoring: 3
- Variance: 1
- Follow-Up: 97
- Unprogrammed Related: 28
- Programmed: 1,393
- Program Planned: 1,372
- Program Related: 21
Number of OSHA Citations

- Non-Serious: 4,169
- Serious: 16,774
- Willful: 400
- Repeat: 459
- Failure to Abate: 8

Combustible Dust Safety

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Current Penalties Under The NEP

![Bar graph showing total penalties for different types of violations.]

- **Other-than-Serious**: $843,674.55
- **Serious**: $20,113,955.53
- **Willful**: $13,827,861.00
- **Repeat**: $2,836,011.00
- **Failure to Abate**: $114,290.00

**Total Penalty**
Types of Industries Inspected by OSHA

- Woodworking: 24%
- Food Products: 16%
- Plastics & Rubber: 10%
- Paper Manufacturing: 10%
- Chemical Manufacturing: 8%
- Furniture & Fixtures: 7%
- Primary Metals: 6%
- Equipment Manufacturing: 5%
- Other: 14%
How Do Combustible Dust Fires and Explosions Occur?
Combustible Dust

- A finely divided combustible particulate solid that presents a flash fire hazard or explosion hazard when suspended in air or the process-specific oxidizing medium over a range of concentrations.

Plastic Dust
- 99% 420 μm
- $K_{st} = 340$ b.m/s

Corn Starch Dust
- 100% 420 μm
- $K_{st} = 144$ b.m/s
Combustible Particulate Solid

• Any solid material composed of distinct particles or pieces, regardless of size, shape, or chemical composition that, when processed, stored, or handled in the facility, has the potential to produce a combustible dust

• Includes dusts, fibers, fines, chips, chunks, flakes, or mixtures of these
Dust Explosion Pentagon

Confinement  Fuel  Dispersion

Ignition  Oxygen
Sources of Ignition

- Hot Surfaces
- Flame or glowing ember
- Electrically produced sparks
- Sparks from metal to metal contact
- Static electricity
Combustible Dust Hazards

- **Flash Fire**
  - Fire that spreads by means of a flame front rapidly through a diffuse fuel **without the production of damaging pressure**

- **Deflagration**
  - Propagation of a combustion zone at a velocity that is **less than the speed of sound in the unreacted medium**

- **Explosion**
  - Bursting or rupturing of an enclosure or a container due to the development of internal pressure from a deflagration
The “Typical” Explosion Event

Initial Internal Deflagration

Process Equipment

Time, msec.

0 25 50 75 100 125 150 175 200 225 250 300 325
The “Typical” Explosion Event

Initial Internal Deflagration

Shock Wave

Process Equipment

Time, msec.
The “Typical” Explosion Event

Initial Internal Deflagration

Elastic Rebound Shock Waves

Process Equipment

Time, msec.

0 25 50 75 100 125 150 175 200 225 250 300 325
The “Typical” Explosion Event

- Initial Internal Deflagration
- Dust clouds caused by Elastic Rebound
- Process Equipment

Time, msec.: 0 25 50 75 100 125 150 175 200 225 250 300 325
The “Typical” Explosion Event

Containment Failure from Initial Deflagration

Dust Clouds Caused by Elastic Rebound

Process Equipment

Time, msec.
0 25 50 75 100 125 150 175 200 225 250 300 325
The “Typical” Explosion Event

Dust Clouds Caused by Elastic Rebound

Process Equipment

Secondary Deflagration Initiated

Time, msec.

0  25  50  75  100  125  150  175  200  225  250  300  325
The “Typical” Explosion Event

Process Equipment

Secondary Deflagration Propagates through Interior

Time, msec.

0 25 50 75 100 125 150 175 200 225 250 300 325
The “Typical” Explosion Event

Process Equipment

Secondary Deflagration Vents from Structure

Time, msec.
The “Typical” Explosion Event

Secondary Deflagration Causes Collapse and Residual Fires

Time, msec.

0  25  50  75  100  125  150  175  200  225  250  300  325
Make-Up (Return) Air System
Spark/Ember Infrared Detectors
Combustible Dust Standards
Relevant OSHA Standards for Combustible Dust

- 1910.22 Housekeeping
- 1910.36 Design and Construction for Exit Routes
- 1910.37 Safeguards and Features for Exit Routes
- 1910.38 Emergency Action Plans
- 1910.39 Fire Prevention Plans
- 1910.94 Ventilation
- 1910.119 Process Safety Management
- 1910.132 Personal Protective Equipment
- 1910.145 Specifications for Accident Prevention Signs and Tags
- 1910.146 Permit-Required Confined Spaces
- 1910.157 Fire Extinguishers
- 1910.165 Employee Alarm Systems
- 1910.176 Material Handling
- 1910.178 Powered Industrial Trucks
- 1910.252 Hot Work (General Requirements)
- 1910.261 Pulp, Paper, and Paperboard Mills
- 1910.272 Grain Handling Facilities
- 1910.307 Hazardous Locations
- 1910.1200 HazCom
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<tr>
<th>Industry or Commodity-Specific NFPA Standards</th>
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<td><strong>Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities</strong></td>
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<td><strong>Standard for Combustible Metals</strong></td>
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<tr>
<td><strong>Standard for the Prevention of Fires and Dust Explosions in Wood Processing and Woodworking Facilities</strong></td>
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<tr>
<td><strong>Standard for the Prevention of Fires and Dust Explosions from Manufacturing, Processing and Handling of Combustible Particular Solids</strong></td>
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Standard on Fundamentals of Combustible Dusts (NFPA 652-2016)

• Effective Date September 7, 2015
• Coexists with other NFPA industry specific standards
• Simplifies OSHA compliance and enforcement
• Provides the basic principles of and requirements for identifying and managing the fire and explosion hazards of combustible dusts and particulate solids
Retroactivity of NFPA Standards

• Where specified, provisions of the standards are retroactive
• For major replacement or renovation of existing facilities, all provisions of standards apply
• Where AHJ determines that the existing situation presents an unacceptable degree of risk, AHJ shall be permitted to apply retroactively **ANY** portions of standards deemed appropriate.
2015 International Fire Code (IFC)

• 2204.1 – The fire code official is authorized to enforce applicable provisions of the codes and standards listed in Table 2204.1 to prevent and control dust explosions.
  – NFPA 61
  – NFPA 69
  – NFPA 484
  – NFPA 654
  – NFPA 655
  – NFPA 664
Uniform Fire Code (NFPA 1-2015)

• Equipment, processes, and operations that involve the manufacture, processing, blending, repackaging, or handling of combustible particulate solids or combustible dusts regardless of concentration or particle size shall be installed and maintained in accordance with this chapter and the following standards as applicable:
  – NFPA 61-2013
  – NFPA 68-2013
  – NFPA 69-2014
  – NFPA 484-2015
  – NFPA 654-2013
  – NFPA 664-2012
The “Magic” Formula

1. Identify Your Hazard
2. Define the Scope of the Hazard in Your Process
3. Identify Controls
4. Identify Resources
5. Commissioning & Documentation
6. Sustain Performance
Step 1: Identify Your Hazard
Developing A Sampling Strategy

• Do you have every dust tested?
• What about if you have multiple dusts that may and may not mix?
• Do you test the dust buildup on surfaces, floor areas, or both?
• Do you test “as received” or prepared by sizing?
• Do you test at different stages of a process or at one location?
Hierarchy of Combustible Dust Testing

Importance of Test(s)

Specificity of Hazard

$K_{st}$, $P_{max}$, Particle Size

MEC, MIE, MIT, LIT

LOC, Charge Relaxation, Resistivity, Chargeability

Combustible Dust Safety
Step 2: Define the Scope of the Hazard in Your Process
Dust Hazard Analysis (DHA)

- Systematic review to identify and evaluate the potential fire, flash fire, and explosion hazards associated with the presence of one or more combustible particulate solids in a process or facility
- Determine the consequences of what could go wrong and to determine what safeguards could be implemented to prevent or mitigate those consequences
- Does not need to comply with the PHA requirements contained in OSHA’s PSM Standard
DHA Methodology

• Identifies and evaluates the process or facility areas to determine if fire, flash fire, and explosion hazards exist

• Where such a hazard exists, identify and evaluate specific fire and deflagration scenarios:
  a. Identification of safe operating ranges
  b. Identification of the safeguards that are in place to manage fire, deflagration, and explosion events
  c. Recommendation of additional safeguards where warranted, including a plan for implementation
DHA Methodology

What’s Normal?

What Can Go Wrong?

How Bad is Bad?

What Protection Currently Exists?

What Additional Protection is Needed?
DHA General Requirements

• The owner/operator of a facility where materials that have been determined to be combustible or explosible are present in an enclosure shall be responsible to ensure a DHA is completed
• Requirement applied retroactively
• Must be performed by a qualified person
• Absence of previous incidents cannot be used as the basis for not performing a DHA
Timeline to Complete DHAs

- For existing processes and facility compartments that are undergoing material modification, the owner/operator shall complete DHAs as part of the project.
- For existing processes and facility compartments that are not undergoing material modification, the owner/operator shall schedule and complete DHAs of existing processes and facility compartments within a 3-year period from the effective date of the standard.
Step 3: Identify Controls
Identify Controls to Minimize Hazards

• Use Information from DHA & Applicable Content from Consensus Standards to:
  – Develop a Basis of Design (BOD)
    • Overall process
    • Individual aspects of the process
  – Include in BOD
    • Facility design concepts
    • Equipment design concepts
    • Electrical classification concepts (NFPA 499)
    • Explosion & Fire Protection/Prevention (NFPA 68, 69)
    • Administrative Controls/Processes
Risk Mitigation Controls

Engineering
- Venting & Suppression
- Explosion Isolation
- Electrical Area Classification

Administrative
- Housekeeping
EXAMPLES OF ENGINEERING CONTROLS
# Explosion Protection Systems (Section 8.9.3.2 of NFPA 652-2016)

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<th>Active</th>
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<td>• Deflagration Venting</td>
<td>• Oxidant Concentration Reduction</td>
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<td>• Deflagration Suppression Systems</td>
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<td>• Dilution with a Noncombustible Dust</td>
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<td>Arresting Device</td>
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**Passive**

- Deflagration Venting
- Deflagration Pressure Containment
- Deflagration Venting Through a Listed Dust Retention and Flame-Arresting Device

**Active**

- Oxidant Concentration Reduction
- Deflagration Suppression Systems
- Dilution with a Noncombustible Dust
Explosions by Type of Process Equipment

- Dust Collector: 53%
- Pulverizer/Mils: 4%
- Conveyor/Elevator: 4%
- Dryer/Oven: 4%
- Silo/Bin: 4%
- Sander: 15%
- Electrostatic Precipitator: 7%
- Grinder: 7%
Suppression vs. Venting

- Equipment indoors & vent duct not practical
- Not enough vent area on equipment
- High $K_{st}$ or hybrid dust
- No safe place to vent
- Toxic dusts cannot be discharged to atmosphere via a vent
- Flame propagation through interconnection suppression on equipment - isolation suppression controlled by same controls
EXAMPLES OF ADMINISTRATIVE CONTROLS
The Truth About Housekeeping

• Good housekeeping alone **WILL NOT** prevent a fire or explosion, as well as injuries or fatalities

• Large dust accumulations are a secondary explosion hazard

• Cleaning methods associated with housekeeping can actually introduce significant hazards
HOW MUCH DUST IS TOO MUCH DUST???
Housekeeping Memorandum

• Issued on April 21, 2015
• Provides guidance in calculating the levels of dust accumulations that may be allowed at workplaces for combustible dusts with bulk densities less than 75 lb/ft$^3$
• Supplements the dust accumulation guidance provided in several sections of NEP, including IX.E.3.c and d; IX.E.8; and IX.E.9.c and d
• Very low bulk density materials, such as tissue paper dust, may not create a deflagration hazard even at an accumulation level of ¼ inch, covering over five percent of the floor area or 1000 ft$^2$, whichever is less
• https://www.osha.gov/dep/enforcement/Combustible_Dusts_04212015.html
Poor Housekeeping Can Affect

- Electrical Classification
- Emergency Egress Requirements
- Selection of Powered Industrial Trucks
- Use of Flame-Resistant Clothing
Step 4: Identify Resources to Execute Your Plan
Resources

Internal
- Operations
- EHS
- Engineering
- Maintenance
- QA
- Procurement

External
- Consulting Firms
- Regulatory Authorities
- Insurance Reps
- NFPA
- US Chemical Safety Board
Step 5: Commissioning & Documentation
Document EVERYTHING

• Dust Testing Data
• PHA (Review Every 5 Years)
• Basis of Design
  – Facility
  – Explosion Protection
  – Administrative Controls
• Commissioning Documents
  – Explosion Suppression & Isolation Systems
• Training Records
• Names & Qualifications of Resources Used
Step 6: Sustain Performance
Environmental Implications

- Loss of Building Containment
- Soil & Groundwater Contamination
- Emissions from Combustion By-Products
- Disturbance of Asbestos Containing Materials
- Permitting for Dust Collectors
- “Firing Element” for Chemical Suppression
  - Tier II Reporting

By-Products of Fighting Fires
Hazard Recognition

Testing

Dust Hazard Analysis

Engineering Controls

Administrative Controls

Hazard Mitigation
Questions???

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