5 Steps to Safely Handle Combustible Dust

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Overview: 5 Steps for Combustible Dust
10,000 ft View

Identify | Evaluate | Protect
---|---|---
Manage | Audit

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Introduction to Combustible Dust

- What is Combustible Dust (CD)?
- What is a Combustible Dust Explosion?
- Key Terms
- Key Players
- Why does Combustible Dust explode?

Characteristics of CD
Combustible Dust—What is It?

- Fine material that can catch fire when mixed with air.
- Typically a process material (flour, plastic, API powder/dust) or
- Generated as a by-product of manufacturing (waste/fugitive dust)

NFPA 654 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.
What is a Dust Explosion

- A dust explosion occurs when a fine, combustible dust is suspended in air and ignited.
- This causes a very rapid burning of the fuel (dust).
- This rapid burning releases gaseous products and heat that cause additional nearby particles to ignite rise and pressure to rise.
- The resulting force of the pressure wave and extreme Explosion. The bursting or rupture of an enclosure or container due to the development of internal pressure from a deflagration. [69, 2014]

Dust explosions can be categorized as either

Primary or Secondary
Definitions  Explosion Types

○ Primary
  - occurs when a dust suspension within a container, room or piece of equipment is ignited and explodes

○ Secondary
  - occurs when dust accumulated on floors or other surfaces is lifted into the air and ignited by the primary explosion
Where Do Primary Dust Explosions Occur?

- Dust collectors
- Transfer points in enclosed conveyors or bucket elevators
- Elevator legs
- Holding bins (Enclosures)
- Electrical equipment
Where Do Secondary Dust Explosions Occur?

- Anywhere dust can accumulate in the workplace
  - On top of equipment
  - On top of pipes
  - In hidden spaces
  - In the rafters
  - On floors, walls, ceilings
The “Typical” Primary Explosion Event

- Initial Internal Deflagration
- Process Equipment

Time, msec.

Proprietary property of Fauske & Associates, LLC
The “Typical” Primary Explosion Event

Initial Internal Deflagration

Process Equipment

SHOCK WAVE

Time, msec.

0 25 50 75 100 125 150 175 200 225 250 300 325
If Inadequate Housekeeping
Secondary Explosion will Ignite

- Initial Internal Deflagration
- Process Equipment
- Elastic Rebound Shock Waves

Time, msec.
If Inadequate Housekeeping Secondary Explosion will Ignite

Containment Failure from Initial Deflagration

DUST CLOUDS CAUSED BY ELASTIC REBOUND

Process Equipment
Secondary Explosion

- Secondary Deflagration Initiated
- DUST CLOUDS CAUSED BY PLASTIC REBOUND
- Process Equipment
Secondary Explosion

Secondary Deflagration Propagates Through Interior

Process Equipment

Time, msec.

0 25 50 75 100 125 150 175 200 225 250 300 325
Secondary Explosion

Secondary Deflagration Vents from Structure

Process Equipment

Time, msec.
The “Typical” Explosion Event (continued)

Secondary Deflagration Causes Collapse and Residual Fires
Clarification

- **Deflagration**
  - Subsonic combustion that spreads by heating the next layer of cold material and igniting it. Most "fire" found in daily life, from flames to explosions, is technically a deflagration.

- **Detonation**
  - Propagation of a flame or combustion zone through a fuel/air mixture at a velocity greater than the speed of sound in the un-reacted medium (NFPA 69)
  - Only under very unique circumstances will a dust deflagration accelerate to a detonation
  - Produce very devastating damage
  - Hard to quench/stop once started
  - Prevention is usually the key
Some Dusts are Not Combustible

Certain materials will not form combustible dust, including:

Cement,
Gypsum,
Limestone,
Sand And
Table Salt.
Workers and supervisors are the first line of defense:

Recognizing unsafe conditions

Taking preventative action, and/or

Alerting management
Why does Combustible Dust explode?

- Characteristics of Combustible Dust
  - Particle size and shape
  - Particle size Distribution
  - Chemical properties of dust
  - Moisture content
  - Cloud dispersion
Particle Size & Shape

TIME TO SETTLE 5 FEET BY UNIT DENSITY SPHERES

0.5 μm 1.0 μm 3.0 μm
41 hrs 12 hrs 1.5 hrs

10.0 μm
8.2 min
5.8 sec

100 μm

Source: NIOSH
So why does particle size or shape matter?

- Flake particles have a large surface area that can be in contact with an oxidizer when compared with a spherical particle.

- Granular particles often have sharp edges that can ignite more easily than the smooth, round edges of an atomized powder.
Today’s Math...Let’s go figure..

A cube with the length of every side is 2cm
Area of face: $2 \times 2 = 4 \text{ cm}^2$
Cube has six faces,
Surface area of cube is $4 \text{ cm}^2 \times 6 = 24 \text{ cm}^2$

Area of 1 face       $1 \text{ cm} \times 1 \text{ cm} = 1 \text{ cm}^2$
Area of 1 cube       $1 \text{ cm}^2 \times 6 \text{ faces} = 6 \text{ cm}^2$
Total surface Area   $6 \text{ cm}^2 \times 8 \text{ cubes} = 48 \text{ cm}^2$
Increase of Surface Area

Repeat Hundreds of Times
Particle Size Distribution

Particle Size

<table>
<thead>
<tr>
<th>Material</th>
<th>Moisture Content (wt.%)</th>
<th>Mean Particle Size (μm)</th>
<th>( K_{St} ) (bar m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saw Dust</td>
<td>3.5</td>
<td>34</td>
<td>185 ± 12%</td>
</tr>
</tbody>
</table>

Diameter at 10%: 6.99 μm
Diameter at 50%: 31.67 μm
Diameter at 95%: 72.46 μm
Mean diameter: 34.20 μm

Histogram

Cumulative values / %
Average Size of Un-sieved Sample: 700.7µm

- Sieved at 1000µm
- Sieved at 75µm
- Sieved at 250µm
- Sieved at 425µm

- <425 microns>250 microns
- <250 microns>75 microns
- <1000 microns>425 microns
- >1000 microns
Optimum cloud density
- Sufficient distance between particles
- Access to oxygen around particles

Fire
- Rapid oxidation process
- \( 2C + O_2 \rightarrow 2CO \)

Minimum Ignition Energy
Chemical Properties

- Materials may be a mixture of two or more substances

- Coal contains volatile components and variable quantities of incombustible ash

- Incombustible matter in the form of inert solid material, and non-flammable volatile components tends to reduce the flammability of the dust by chemical inhibition

- Particulate may contain solvents from previous processes

- Metal dusts may be contaminated with oxide
The speed of a chemical reaction is affected by:
- Temperature
- Concentration
- Particle size and shape

It can be calculated by measuring changes in reactants/products.
Combustion Rate Increase

Combustion Rate Increases with Increasing Subdivision

Slow Combustion

Fast Combustion

Deflagration/Explosion
Combustion Rate

Size Distribution Affects Rate

Content Affects Rate
Thermodynamics

- Amount of heat liberated during combustion
- Different types of dust generate various levels of heat
- This also can be calculated
<table>
<thead>
<tr>
<th>Substance</th>
<th>Oxidation product(s)</th>
<th>KJ/mole O₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca</td>
<td>CaO</td>
<td>1270</td>
</tr>
<tr>
<td>Mg</td>
<td>MgO</td>
<td>1240</td>
</tr>
<tr>
<td>Al</td>
<td>Al₂O₃</td>
<td>1100</td>
</tr>
<tr>
<td>Si</td>
<td>SiO₂</td>
<td>830</td>
</tr>
<tr>
<td>Cr</td>
<td>Cr₂O₃</td>
<td>750</td>
</tr>
<tr>
<td>Zn</td>
<td>ZnO</td>
<td>700</td>
</tr>
<tr>
<td>Fe</td>
<td>Fe₂O₃</td>
<td>530</td>
</tr>
<tr>
<td>Cu</td>
<td>CuO</td>
<td>300</td>
</tr>
<tr>
<td>Sucrose</td>
<td>CO₂ and H₂O</td>
<td>470</td>
</tr>
<tr>
<td>Starch</td>
<td>CO₂ and H₂O</td>
<td>470</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>CO₂ and H₂O</td>
<td>390</td>
</tr>
<tr>
<td>Carbon</td>
<td>CO₂</td>
<td>400</td>
</tr>
<tr>
<td>Coal</td>
<td>CO₂ and H₂O</td>
<td>400</td>
</tr>
<tr>
<td>Sulphur</td>
<td>SO₂</td>
<td>300</td>
</tr>
</tbody>
</table>
Moisture Content

- Moisture tends to reduce the flammability of the dust both by chemical inhibition and by the cooling effect of the particles.

- High concentrations of moisture in the dust may also impede the formation of a dust cloud.

- Moisture may increase “clumping” of particulate
Ease of Dispersion

- Individual density of dust particles
- Diameters
- Shapes
- Cohesive properties with respect to each other
- Adhesive properties with respect to supporting surfaces
External Factors of Dispersion

- Structure/intensity of aerodynamic disturbances
- Location of dust loading
- Geometry of surfaces

Dust Build-up on Pipes

Dust on vertical surface and conduit
Dust Build Up on Overhead Surfaces
Conditions Needed for a Fire

Three elements needed for a fire.

Oxygen
Fuel
Ignition source
Add Dispersion

The Fire Triangle
From Fire to Deflagration…
(continued)
One more is needed for a deflagration.
Deflagration elements plus one more are needed for an explosion.
Prevent One Element – No Explosion!

1. Minimize fuel
2. Control for potential ignition sources
3. Control for potential mechanisms of dispersion
4. Remove the confinement
5. Remove the oxygen
Dust Accumulation Prevention

- 3 Keys to Preventing Dust Accumulation:
  - Preventive Maintenance, Repair, & Housekeeping
  1. Implement Preventive Maintenance Program
  2. Implement housekeeping plan
  3. Implement hazardous dust inspection, and audit

Most fatalities, injuries and property damage caused by secondary explosions.
5 Steps for Combustible Dust

- Identify
- Evaluate
- Protect
- Manage
- Audit
Checklist 1: Identify

- Got Dust? or Got Powder?
- Where is it?
  - On floor
  - On equipment
  - On rafters
  - On ducting/water lines
  - Be Comprehensive
- How did it get there?
  - Spills
  - Equipment Leak
  - Duct leaks
- Why did it stay there?

What kind?
- Wood
- Food or Grain
- Metal
- Sulfur
- Plastic
- Chemical / Pharma

What NFPA Standard

What needs to change
Sampling Strategy

Consider from receipt of raw materials to end product packaging
- Where are Dust deposits?
- Where is Dust in a cloud?

Enclosed equipment
- Hoppers, bins, dryers

Locations where properties of the material could change
- Size reduction
- Change in moisture content
- Chemical exposure

Test material with finest particle size
- Baghouse or dust collector
- Elevated horizontal surfaces

Source: Hughes Environmental
Sampling Strategy
from where

Is the dust/powder a waste or a product?

- If waste, your focus may be only on the dust collectors

If product, you may have to focus on
  - size reduction
  - compaction
  - conveying
  - mixing
  - drying and
dust collectors, just to name a few
Sampling Strategy
Test for what?

FIRE PROTECTION

- Explosion Severity Kst, Pmax
- Minimum Ignition Energy MIE
- Minimum exploisible concentration (MEC)
  - Limiting oxygen concentration (LOC)
  - Layer Ignition Test (LIT)
  - Electrical Properties Tests (3)

Combustibility Testing

- Explosibility classification screening test ASTM E 1226

Do you have combustible dust?
- Yes
  - Hazard Analysis Test
- No
  - Don’t know

- No
  - Explosibility classification screening test ASTM E 1226

- Yes
  - Explosibility classification screening test ASTM E 1226
Characterize the Fire Potential of a “Material”

Combustibility for powders and dusts:


or

Other equivalent fire exposure test methods

a.k.a. the Orange Book
Characterize the Explosion Potential of a “Material”

- Explosion severity – violence of the explosion
  - $K_{St}$ – Dust deflagration index
  - $P_{\text{max}}$ – Maximum overpressure
  - $(dP/dt)_{\text{max}}$ – Maximum rate of pressure rise

- Ignition sensitivity – ease of ignition
  - MIE – Minimum ignition energy
  - MEC – Minimum explosible concentration
Definitions

- \( (dP/dt)_{\text{max}} \) Maximum rate of pressure rise
  
  Predicts the violence of an explosion. Used to calculate \( K_s \)

- \( P_{\text{max}} \) Maximum Explosion Pressure
  
  Predicts the violence of an explosion. Used to calculate \( K_s \)

- MEC, Minimum Explosion Concentration
  
  The minimum concentration of a combustible dust suspended in air, measured in mass per unit volume, that will support a deflagration

- MIE, Minimum Ignition Energy
  
  The minimum amount of energy released at a point in a combustible mixture that causes flame propagation away from the point, under specified test conditions.
Definitions

○ $K_{St}$, **Deflagration** index
Value indicated by the use of variable, K as a measure of explosion severity.

○ **LIT**, **Layer Ignition Temperature**
Minimum temperature a dust should attain to ignite on a heated surface

○ **LOC**, **Limiting Oxygen Concentration**
Determines the least amount of oxygen required for explosion propagation through the dust cloud

○ **ECT** **Electrostatic Charging Tendency**
Predicts the likelihood of the material to develop and discharge sufficient static electricity to ignite a dispersed dust cloud
20-L Siwek Test Chamber

1. Pressure gauge
2. Solenoid valve
3. Dust storage chamber
4. Vacuum pump
5. Exhaust valve
6. Vacuum valve
7. Pressure transducers
8. Rebound nozzle

10 kJ ignition source

Source: Fauske & Associates, LLC
(dP/dt)_{max} and P_{max} needed for K_{st} and Explosion Vent Sizing Calculations

- Same test done around the world:
  - ASTM E1226, EN 14034/1 & 2
- Performed in 20 liter (or larger) spherical test bomb, unvented
- 10 kJ pyrotechnic ignition source
- Test measures “gas generation rate” of a dust explosion
- Tests repeated to give statistical average
20 Liter Testing

Typical Data Plot – Kst Test

<table>
<thead>
<tr>
<th>Hazard Class</th>
<th>$K_{St}$ (bar·m/sec)</th>
<th>Example</th>
<th>$P_{MAX}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>St-1</td>
<td>&lt; 200</td>
<td>Bronze 31, Coal 129, Sugar 138</td>
<td></td>
</tr>
<tr>
<td>St-2</td>
<td>200–300</td>
<td>Cork 202, Cellulose 229, Phenolic 269</td>
<td></td>
</tr>
<tr>
<td>St-3</td>
<td>&gt;300</td>
<td>Al Dust 415, Magnesium 508</td>
<td></td>
</tr>
</tbody>
</table>

Rate of Pressure Rise

dP/dT
# Commonly Measured Properties of Combustible Dusts

<table>
<thead>
<tr>
<th>Property</th>
<th>Definition</th>
<th>ASTM Test Method</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_{St}$</td>
<td>Dust deflagration index</td>
<td>ASTM E 1226</td>
<td>Measures the relative explosion severity compared to other dusts</td>
</tr>
<tr>
<td>$P_{max}$</td>
<td>Maximum explosion overpressure generated in the test chamber</td>
<td>ASTM E 1226</td>
<td>Used to design enclosures and predict the severity of the consequence</td>
</tr>
<tr>
<td>$(dP/dt)_{max}$</td>
<td>Maximum rate of pressure rise</td>
<td>ASTM E 1226</td>
<td>Predicts the violence of an explosion. Used to calculate $K_{St}$</td>
</tr>
<tr>
<td>MIE</td>
<td>Minimum Ignition Energy</td>
<td>ASTM E 2019</td>
<td>Predicts the ease and likelihood of ignition of a dispersed dust cloud</td>
</tr>
<tr>
<td>MEC</td>
<td>Minimum Explosible Concentration</td>
<td>ASTM E 1515</td>
<td>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</td>
</tr>
<tr>
<td>LOC</td>
<td>Limiting Oxygen Concentration</td>
<td>ASTM standard under development</td>
<td>Determines the least amount of oxygen required for explosion propagation through the dust cloud</td>
</tr>
<tr>
<td>ECT</td>
<td>Electrostatic Charging Tendency</td>
<td>No ASTM standard</td>
<td>Predicts the likelihood of the material to develop and discharge sufficient static electricity to ignite a dispersed dust cloud</td>
</tr>
</tbody>
</table>
Evaluate: Combustible Dust Hazard Analysis (DHA)
Dust Hazards Analysis required
- Requirement is retroactive
  - During Modifications/Construction or
  - Complete within 3 years (from when??)
- Must be validated every 5 years
- Must be led by a qualified person

NFPA 654, 2017
Complete within 5 years
A 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.

 DOES DHA = OSHA PHA ?
DOES DHA = OSHA PHA?

- Dust Hazards Analysis – *In the context of this definition,*

**NO.** *It is not intended that the DHA must comply with the Process Hazards Analysis (PHA) requirements contained in OSHA regulation 29 CFR 1910.119.*

- While the DHA can comply with OSHA PHA requirements, other methods can also be used.

**YES.** *Some processes may fall within the scope of the OSHA regulation, 29 CFR 1910.119 and there may be a legal requirement to comply with that regulation*
Where are Combustible Dust Requirements and Enforcement Today?

- **Major Players**
  - OSHA
  - NFPA
  - ASTM
  - U. S. Chemical Safety Board
  - U. S. Congress
  - Individual States
    - California
    - Georgia
5 Occupancy Standards that Address Combustible Dust

- NFPA 652, *Standard on the Fundamentals of Combustible Dust*
- NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities*
- NFPA 484, *Standard for Combustible Metals*
- NFPA 654, *Standard for Prevention of Fire and Dust Explosions from the manufacturing, Processing, and Handling of Combustible Particulate Solids*
- NFPA 655, *Standard for Prevention of Sulfur Fires and Explosions*
- NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*
Many NFPA Standards Affect CD
OSHA has deemed that 2113 is the standard to follow when determining the personal protective equipment workers should wear.
Personal Protective Equipment (PPE)

PPE based on documented analysis of the potential for personnel to be exposed to hazards

- 29 CFR 1910.132 (General requirements);
- 29 CFR 1910.133 (Eye and face protection);
- 29 CFR 1910.135 (Head protection);
- 29 CFR 1910.136 (Foot protection);
- 29 CFR 1910.137 (Electrical protective equipment);
- 29 CFR 1910.138 (Hand protection)

- NFPA 2113 (selection and care of FR clothing)
Where are Combustible Dust Requirements and Enforcement Today?

The NFPA has no power, nor does it undertake to police or enforce compliance.

The NFPA does not list, certify, test, or inspect products, designs, or installations for compliance.
Understand the Risk Factors

Dust Hazard Analysis (DHA)

- Dust properties:
  - type
  - particle size
  - moisture content
- Ignition sensitivity
- Ignition sources
- Explosion Severity
- Quantity of material (fuel)
- Dispersion mechanisms
- Confinement

Source: U.S. Chemical Safety Board (U.S. CSB) Report #2003-09-I-KY
Identify Hazards: Dust Hazard Analysis (DHA)

- Review Material Handling Equipment
  - Receiving, storage, use, processing and disposal of all fine particulate materials
  - Fire/explosion suppression and venting system(s), warning devices and onsite extinguishing capabilities

- Fugitive Dust
  - Identify accumulation and possible sources, consider spills

- Identify sampling points and collect sample(s), as necessary

Identify Equipment Where Hazard Exists
Dust Hazard Analysis (DHA)

- Air material separators: dust collectors, cyclones
- Bulk storage: hoppers, bins
- Blending/mixing
- Material transfer: pneumatic conveying, vacuum system
- Material feeding systems
- Bucket elevators
- Enclosed conveyors
- Size Reduction Equipment
- Dryers

Source: Donaldson Torit
Evaluate Compliance with Relevant National, Local and Industry Standards (e.g. National Fire Protection Association [NFPA] and International Fire Code [IFC])

Perform Gap Analysis Per Prescriptive-based Requirements

Recommendations for Risk Reduction

Electrical Area Classification Evaluation
Determine Consequences
Dust Hazard Analysis (DHA)

- Flash fire
  - Deflagration Diamond ?
- Vessel failure due to explosion
  - Blast Effects ?
- Possibility for secondary explosion
  - How’s Your House keeping ?
- Potential personnel exposure
  - PPE Considerations ?

Source: U.S. CSB

about PPE,... I think you should at least consider FR/AR clothing... see NFPA 2113, not 2112

Proprietary property of Fauske & Associates, LLC
Evaluate Risk
Dust Hazard Analysis (DHA)

- Identify where fire, flash fire and explosion hazards exist
- Identify current safeguards in place
- Identify safe operating ranges
- Recommend additional safeguards
- Prioritize recommendations
8.9.3.1* General. Where an explosion hazard exists within any operating equipment greater than 8 ft³ (0.23 m) of containing volume, the equipment shall be protected from the effects of a deflagration.
Mitigative & Preventive Safeguards

- Equipment and building design
- Explosion prevention/protection
- Fire protection
- Dust control
- Ignition source control
- Electrical area classification
- Personal protective equipment (PPE)

Source: Fenwal – IEP Technologies
Equipment Protection

- Oxidant concentration reduction
- Fuel concentration reduction
- Deflagration venting
- Deflagration pressure containment
- Deflagration suppression
- Deflagration venting through a flame-arresting device
- Isolation of equipment
Deflagration Chemical Suppression

Time:

- Ignition Occurs: 0 msec
- Explosion Detected: 20 msec
- Suppression Begins: 30 msec
- Suppression continues: 40 msec
- Total Suppression: 80 msec
Explosion Prevention Systems: Passive Vents

Proprietary property of Fauske & Associates, LLC
Deflagration Propagation with Vent but Without Isolation
Deflagration Propagation Using Mechanical Isolation

CYCLONE

ISOLATION VALVE

DUST COLLECTOR

VENT

IGNITION POINT

Proprietary property of Fauske & Associates, LLC
Deflagration Propagation Using Chemical Suppression for Isolation
Explosion Protection Systems: Flameless Vent

Stainless steel riveted design allows to absorb pressure shock

Reusable flame arrester made of a special stainless steel mesh filter

Stainless steel dust filter with specially developed pressure absorbing coils

Integrated REMBE® rupture disc with signal unit and gasket

Monitoring unit in cabled IP-65 housing
Management Systems

Identify

Evaluate

Protect

Manage

Audit
Mitigative & Preventive Safeguards
Management Systems

- Housekeeping
- Operating procedures and practices
- Inspection, testing and maintenance
- Training and hazard awareness for employees and contractors
- Emergency planning and response
- Incident investigation
- Management of change (MOC)
- Document retention
- Management systems review
- Employee participation

Source: U.S. Chemical Safety Board (U.S. CSB)
Housekeeping

- Comprehensive cleaning
- Visual baseline
- Cleaning methods and frequency
- Inspections

Source: U.S. Chemical Safety Board (U.S. CSB)
Housekeeping – Fugitive Dust Control

- Contain and remove combustible dust

- Design of facility and process equipment

- Continuous suction...where combustible dust is liberated in normal operation

- Dust-tight system components
  - Pneumatic conveying systems
  - Dust collection systems
  - Centralized vacuum systems

- Bin vents properly sized

Source: FAI
Ignition Source Control:
Hot Work and Open Flames

- Smoking
- Open flames
- Welding
- Abrasive cutting
- Grinding
- Tools
- Vehicles
Ignition Source Control: Hot Surfaces or Sparks

- Electric sparks from equipment
- Electric sparks from electrostatic discharge
- Hot surfaces on process or electrical equipment
  - Light fixtures
  - Electric Motors
- Smoldering/burning conveyed process materials
- Mechanical impact → heat or sparks
- Exothermic reactions
Fire Prevention and Control

- Hot work permits
- Lockout/tagout policies
- Design specifications for storage of flammable materials
- Severity reduction policies, practices and procedures designed to minimize the spread of fire
- Emergency plans
- Alarm systems
Fire Prevention and Control

- Portable fire extinguishers
- Cleanup policies, practices and procedures designed to return the affected area to an operational level
- Recharging portable extinguishers
- Removal of debris to an appropriate waste site
- Equipment and facility repair
Establish procedures and schedules for maintaining safe operating conditions for facility and equipment.

| Fire and explosion protection and prevention equipment | Dust control equipment | Potential ignition sources | Electrical, process, and mechanical equipment, including process interlocks | Lubrication of bearings |
Initial & Refresher Training
Combustible Dust Awareness and Affected Procedures

- Hazards of their workplace
- General orientation, including plant safety rules
- Process description
- Equipment operation, safe startup and shutdown, and response to upset conditions
- Proper functioning of related fire and explosion protection systems
- Equipment maintenance requirements and practices
- Housekeeping requirements
Recognizing Dust Hazards

Combustible Dust Awareness

- All employees should be trained to recognize the hazards
  - Conduct general facility wide appraisals of dust explosion possibilities on a periodic basis.
  - Conduct internal and external audits in order to identify potential explosion hazards.
  - Encourage a preventative attitude among employees for dust explosions.
  - Have employees and supervisors identify explosion hazards through JHAs.
    - Pay particular attention to dust collection systems and other areas not in plain view during the assessment.
Management of Change (MOC)

- Process materials
- Facilities
- Technology
- Procedures
- Equipment
Management of Change

- This is a **Retroactive Requirement**

- Must have **Written procedures** to manage proposed changes to process materials, technology, equipment, procedures, and facilities.

- Not required for **replacements–in–kind**.

- Must Update Design documentation
Management of Change
Must addressed the following:

(1) The technical basis for the proposed change

(2) Safety and health implications, including hazard analysis

(3) Whether the change is permanent or temporary

(4) Modifications to operating and maintenance procedures

(5) Employee training requirements

(6) Authorization requirements for the proposed change

(7) Results of characterization tests used to assess the hazard, if conducted
Self-Audit

Identify

Evaluate

Protect

Manage

Audit
Evaluate the effectiveness of the management systems by conducting a periodic review of each management system.

This is an ongoing effort.

Verify that procedures and schedules are being followed.
Example: Housekeeping

- Verify housekeeping effectiveness based on routine, scheduled cleaning and inspections.

- Document the cleaning.

- Document the Audit and Corrective Actions
Summary: 5 Steps to Managing Combustible Dust Hazards

1. Identify hazards – Testing
2. Evaluate hazards
3. Equipment Protection
4. Management Systems
5. Self-audits

Managing combustible dust
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Because of that, people think it’s Saw Mill Explosion and Fire

FALSE

THE PERFECT STORM
What happened in BC?

• Many woodworking facilities process feedstock with high moisture content (i.e., fresh cut trees) and the resulting dust is large, wet, and coarse in nature.

• These dynamics can change if the sawdust is allowed to accumulate on elevated surfaces which typically allow the dust to dry out and become smaller in size.
Huge swaths of central BC forests have been killed, with over 40 million acres. Harvesting affected stands aids fire management by removing the forest fire hazard and breaking the continuity of the fuels.
Circumstances Change
Your safety programs must be dynamic and forward looking
# Typical Explosion Properties of Some Agricultural Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Mean Particle Size (µm)</th>
<th>MEC (g/m³)</th>
<th>P&lt;sub&gt;max&lt;/sub&gt; (bar)</th>
<th>K&lt;sub&gt;St&lt;/sub&gt; (bar m/s)</th>
<th>MIE (mJ)</th>
<th>MIT Cloud (°C)</th>
<th>MIT Layer (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton (flocks)</td>
<td>44</td>
<td>30</td>
<td>7.2</td>
<td>24</td>
<td>560</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>Wood Dust</td>
<td>14</td>
<td>15</td>
<td>8.5</td>
<td>99</td>
<td>420</td>
<td>335</td>
<td></td>
</tr>
<tr>
<td>Dextrose</td>
<td>80</td>
<td>60</td>
<td>4.3</td>
<td>18</td>
<td>500</td>
<td>570</td>
<td></td>
</tr>
<tr>
<td>Oats</td>
<td>295</td>
<td>750</td>
<td>6.0</td>
<td>14</td>
<td>410</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>Coffee</td>
<td>10</td>
<td>60</td>
<td>9.0</td>
<td>90</td>
<td>470</td>
<td>450</td>
<td></td>
</tr>
<tr>
<td>Maize Starch</td>
<td>15</td>
<td>60</td>
<td>10.1</td>
<td>169</td>
<td>460</td>
<td>435</td>
<td></td>
</tr>
<tr>
<td>Wheat flour</td>
<td>30</td>
<td>125</td>
<td>8.8</td>
<td>70</td>
<td>480</td>
<td>450</td>
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</table>

Data from BGIA
# Typical Explosion Properties of Some Plastic Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Mean Particle Size (µm)</th>
<th>MEC (g/m³)</th>
<th>P&lt;sub&gt;max&lt;/sub&gt; (bar)</th>
<th>K&lt;sub&gt;St&lt;/sub&gt; (bar m/s)</th>
<th>MIE (mJ)</th>
<th>MIT Cloud (°C)</th>
<th>MIT Layer (°C)</th>
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</thead>
<tbody>
<tr>
<td>ABS</td>
<td>200</td>
<td>60</td>
<td>9.2</td>
<td>147</td>
<td></td>
<td>480</td>
<td>450</td>
</tr>
<tr>
<td>Acrylic Resin</td>
<td>37</td>
<td></td>
<td>7.8</td>
<td>174</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epoxy Resin</td>
<td>13</td>
<td>&lt;15</td>
<td>8.7</td>
<td>169</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melamine Resin</td>
<td>56</td>
<td>125</td>
<td>9.7</td>
<td>88</td>
<td></td>
<td>470</td>
<td>500</td>
</tr>
<tr>
<td>Polypropylene</td>
<td>162</td>
<td></td>
<td>7.7</td>
<td>38</td>
<td></td>
<td>440</td>
<td></td>
</tr>
<tr>
<td>Polypropylene</td>
<td>35</td>
<td>15</td>
<td>8.4</td>
<td>123</td>
<td></td>
<td>440</td>
<td></td>
</tr>
<tr>
<td>PVC emulsion</td>
<td>73</td>
<td>125</td>
<td>9.3</td>
<td>101</td>
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<td>700</td>
<td>450</td>
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</table>

Data from BGIA
## Typical Explosion Properties of Some Metallic Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Mean Particle Size (µm)</th>
<th>MEC (g/m³)</th>
<th>$P_{\text{max}}$ (bar)</th>
<th>$K_{\text{St}}$ (bar m/s)</th>
<th>MIE (mJ)</th>
<th>MIT Cloud (°C)</th>
<th>MIT Layer (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>&lt;10</td>
<td>60</td>
<td>11.2</td>
<td>515</td>
<td>560</td>
<td>430</td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td>70</td>
<td>60</td>
<td>11.5</td>
<td>292</td>
<td>560</td>
<td>450</td>
<td></td>
</tr>
<tr>
<td>Iron</td>
<td>32</td>
<td>500</td>
<td>5.1</td>
<td>41</td>
<td></td>
<td>520</td>
<td>450</td>
</tr>
<tr>
<td>Magnesium</td>
<td>28</td>
<td>30</td>
<td>17.5</td>
<td>508</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silicon</td>
<td>21</td>
<td>125</td>
<td>10.8</td>
<td>135</td>
<td>&gt;100</td>
<td>850</td>
<td>450</td>
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<tr>
<td>Steel/Al</td>
<td>63</td>
<td>60</td>
<td>8.8</td>
<td>149</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>26</td>
<td>1.3</td>
<td>23</td>
<td>530</td>
<td>750</td>
<td></td>
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</tr>
</tbody>
</table>

Data from BGIA
OSHA Fines Manufacturer $197k for Explosion, Fire Hazards

- July 13, 2016

- RWS Manufacturer facing $197,820 in fines from OSHA

- Company exposed its employees to uncorrected explosion and recurring fire hazards.

- OSHA said RWS Manufacturing did not address combustible dust hazards involving the dust collection system that the company had agreed to correct.
OSHA Fines Manufacturer
$197k for Explosion, Fire Hazards

- Inspectors also found new and recurring hazards because RWS Manufacturing failed to:
  - Address combustible dust related fire and explosion hazards for conveyor equipment,
  - Repair an inoperable spark detection/fire suppression system
  - Inspect fire extinguishers annually, and maintain them in fully charged and operable condition
  - Remove accumulations of combustible wood dust and shavings on rafters and other surfaces
  - Remove piles of wood dust and shavings on floors that create fire, slip, trip, and fall hazards.
Where are Combustible Dust Requirements and Enforcement Today?

- Introductions to the other Major Players
  - U. S. Chemical Safety Board
  - OSHA
  - NFPA
  - ASTM
  - U. S. Congress
  - Individual States
    - California
    - Georgia
General Industry Standards
Applicable to Combustible Dust

1910 Subpart D, Walking-working surfaces
- 1910.22, Housekeeping

1910 Subpart E, Emergency Action Plans, and Fire Prevention Plans
- 1910.38, Emergency action plans
- 1910.39, Fire prevention plans

1910 Subpart G, Occupational health and environmental control
- 1910.94, Ventilation

1910 Subpart J, General environmental controls
- 1910.138, Personal Protective Equipment
- 1910.146, Permit-required confined spaces
General Industry Standards
Applicable to Combustible Dust

1910 Subpart L, Fire protection
- 1910.157, Portable fire extinguishers
- 1910.165, Employee alarm systems

1910 Subpart N, Materials handling and storage
- 1910.176, Handling materials – general
- 1910.178, Powered industrial trucks

1910 Subpart S, Electrical
- 1910.307, Hazardous (classified) locations

1910 Subpart Z, Toxic and hazardous substances
- 1910.1200, Hazard communication
Specific Industry Standards
Applicable to Combustible Dust

- 1910 Subpart R, Special industries
  - 1910.261, Pulp, paper, and paperboard mills
  - 1910.263, Bakery equipment
  - 1910.265, Sawmills
  - 1910.269, Electric power generation, transmission, and distribution
  - 1910.272, Grain handling facilities
If a hazard is not addressed by an OSHA standard, then

Section 5(a)(1) of the OSH Act

But, we will come back to these later
Where are Combustible Dust Requirements and Enforcement Today?

- Major Players, of a 2\(^{nd}\) kind

  Many Insurance Companies Provide some guidance documents, About Combustible Dust Safety...

  But few, if any, provide the level of details as these FM Global Documents

- OSHA
- NFPA
- ASTM
- U. S. Chemical Safety Board
- Insurance Companies
- Trade Associations

Most Notably - FM Global

- California
- Georgia
PREVENTION AND MITIGATION OF COMBUSTIBLE DUST EXPLOSION AND FIRE

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