The Basics of Combustible Dust
Combustible Dust

- What is it?
- Who needs to recognize it?
- Where is it found?
- How does combustible dust become a hazard?
- When is it a problem?
- What can you do to minimize the risk?
What is it?

NFPA 654 (2013) definition of combustible dust:

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

-very small particles (<500 microns Traditional) that when dispersed in air have the ability to ignite under certain conditions
Particles

Size

- Pellets: > 2000 microns diameter
- Granules: 500 microns - 2000 microns
- Dust particles: < 500 microns

Hazard increases as particle size decreases

- Larger surface area for combustion
- Fine particles may have a larger role in dust cloud ignition and explosion propagation.
### NFPA standards re: combustible dust hazards

<table>
<thead>
<tr>
<th>NFPA Number</th>
<th>Title</th>
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<tbody>
<tr>
<td><strong>61</strong></td>
<td>Prevention of Fires and Dust Explosions In Agricultural and Food Products Facilities</td>
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<td><strong>68</strong></td>
<td>Venting of Deflagrations</td>
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<td><strong>69</strong></td>
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<tr>
<td><strong>484</strong></td>
<td>Standard for Combustible Metals, Metal Powders, and Metal Dusts</td>
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## NFPA standards re: combustible dust hazards

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<tr>
<td>499</td>
<td><strong>Recommended Practice for the Classification of Combustible Dusts and Of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas</strong></td>
</tr>
<tr>
<td>652</td>
<td><strong>Standard on the Fundamentals of Combustible Dust</strong></td>
</tr>
<tr>
<td>654</td>
<td><strong>Prevention of Fire and Dust Explosions From the Manufacturing, Processing, And Handling of Combustible Particulate Solids</strong></td>
</tr>
<tr>
<td>655</td>
<td><strong>Prevention of Sulfur Fires and Explosions</strong></td>
</tr>
<tr>
<td>664</td>
<td><strong>Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities</strong></td>
</tr>
</tbody>
</table>
# Particle size of common materials

<table>
<thead>
<tr>
<th>Common Material</th>
<th>Size (microns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt</td>
<td>100</td>
</tr>
<tr>
<td>Granulated white sugar</td>
<td>450 - 600</td>
</tr>
<tr>
<td>Sand</td>
<td>50+</td>
</tr>
<tr>
<td>Talc, Dust (baby)</td>
<td>10</td>
</tr>
<tr>
<td>Mold Spores</td>
<td>10 – 30</td>
</tr>
<tr>
<td>Human Hair</td>
<td>40 - 300</td>
</tr>
<tr>
<td>Flour</td>
<td>1 - 100</td>
</tr>
</tbody>
</table>

Source: OSHA and Filtercorp International Ltd.
Who needs to recognize it?

- Industry
- Event promoters
- Agriculture
Industrial

- Rubber, plastics
- Pharmaceuticals
- Food (grain, sugar, corn starch)
- Metals (aluminum, iron)
- Paper and pulp
Event Promoters

Color Runs and color events – This pretty powder is corn starch…harmless in small amounts but catastrophic in large quantities when suspended in air.
Taiwan Water Park Color Explosion

Agriculture

- Grain
- Sugar
- Corn starch
- Cotton
Where is it found?

- Sugar
- Metal
- Coal
- Plastic
- Medicines
- Wood
Plastic powder/rubber

- Polyethylene
- Melamine and its resin
- Polypropylene
- Epoxy or phenolic resin

Source for photos: osha.gov
Food

- Sugar
- Celullose
- Dry powdered milk
- Wheat starch
- Barley
- Cotton
Metal powders

- Aluminum
- Iron Carbonile
- Zinc
- Bronze
- Magnesium

Source for photos: osha.gov
How does combustible dust become a hazard?

Fire Triangle

1. Air
2. Ignition
3. Fuel
Combustible Dust Explosion Pentagon

- **Ignition Source**
- **Confinement**
- **Dispersion**
- **Fuel (dust)—at/above MEC**
- **Air/Oxidant**
Deflagration

Propagation of a combustion zone at a velocity slower than the speed of sound [1100 feet/sec]:

A pushing force;
- Mechanism of destruction in most combustible dust explosions.
- Liberates large quantities of heat very rapidly;
- High pressures developed within confined space (e.g. ventilation duct, dust control equipment,
- Pressures can cause structural failure
Why do we need to recognize it?

CSB has found 197 dust fire and explosion incidents in the United States between 1980 and 2006, causing 109 fatalities and 592 injuries.
Since 2010 we have had at least 5 major explosions:

**METALS:**  [AL Solutions [WV]] [12/2010] [3 fatalities]
- Powderpart, Inc. Dust Explosion [MA] [11/2013] [1 injury, 3rd degree burn]
- Kunshan Zhongrong Metal Products Co, [Shanghai, China] [8/2/14], [146 fatalities];

**GRAINS:**  [International Nutrition Dust Explosion] [Omaha, NE] [1/2014] [2 fatalities]:
- Bunge North America, [Cincinnati, Ohio] [8/22/14], [no injuries/fatalities];
Chemical Safety Board Video: Combustible Dust: An Insidious Hazard

- [Link](http://www.csb.gov/videoroom/detail.aspx?vid=30&F=0&CID=1&pg=1&F_All=y)
### Top 8 states for combustible dust incidents (~50% incidents)

<table>
<thead>
<tr>
<th>STATE</th>
<th>Number of incidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois</td>
<td>21</td>
</tr>
<tr>
<td>California</td>
<td>19</td>
</tr>
<tr>
<td>Ohio</td>
<td>13</td>
</tr>
<tr>
<td>Indiana</td>
<td>12</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>11</td>
</tr>
<tr>
<td>Iowa</td>
<td>10</td>
</tr>
<tr>
<td>North Carolina</td>
<td>8</td>
</tr>
<tr>
<td>Maryland</td>
<td>8</td>
</tr>
</tbody>
</table>
Risk Factors

- **Ventilation** system design flaws: poor dust capture and inadequate transport velocity;
- **Poor housekeeping:** unacceptable accumulations of combustible dust of surfaces;
- **Lack of explosion prevention and mitigation technologies.**
- Lack of **hazard assessment** and **Management of Change (MOC)**
Dust Layer: Housekeeping 1910.22

- Accumulations deep enough to present explosion, deflagration or other fire hazards

- Small dust accumulations in isolated spots of the floor or other areas not normally hazardous

- How much dust is too much dust???
## Accumulation criteria

<table>
<thead>
<tr>
<th>Dust type (Document)</th>
<th>Thickness</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural (NFPA 61)</td>
<td>None specified</td>
<td>29 CFR 1910.272 specifies 1/8 in (3.2 mm)</td>
</tr>
<tr>
<td>Combustible metals (NFPA 484)</td>
<td>≥1/8 in (3.2 mm)</td>
<td>Only in Chapter 12 which applies to other metals</td>
</tr>
<tr>
<td>Chemical, pharmaceutical, rubber, miscellaneous (NFPA 654)</td>
<td>≥1/32 in (0.8 mm)</td>
<td>Option to pro-rate the layer thickness based on bulk density for specific material</td>
</tr>
<tr>
<td>Sulfur (NFPA 655)</td>
<td>≥1/32 in (0.8 mm)</td>
<td>Specified in definition</td>
</tr>
<tr>
<td>Wood (NFPA 664)</td>
<td>≥1/8 in (3.2 mm)</td>
<td></td>
</tr>
</tbody>
</table>

**Prorate Dust Layer Thickness:**  
Allowable thickness (in) = \([(1/32)(75)]/\text{bulk density (lb/ft}^3\))
What are the hazards?
Two Explosion Types

An initial primary explosion within processing equipment or in an area where fugitive dust has accumulated:

- may shake loose more accumulated dust; or,
- damage a containment system (such as a duct, vessel, or collector).

The additional dust dispersed into the air may cause one or more secondary explosions. These can be far more destructive than a primary explosion.
A dust explosion event

Primary deflagration inside process equipment

Time, msec. 
(Timing of actual events may vary)
A dust explosion event

Pressure wave caused by primary deflagration

Time, msec.
A dust explosion event

Pressure waves reflected by surfaces within the building cause accumulated dust to go into suspension.
A dust explosion event

Dust clouds thrown in the air by the pressure waves

Time, msec.
A dust explosion event

Primary deflagration breaks out of the equipment enclosure - creating a source of ignition

Time, msec.
A dust explosion event

Secondary deflagration ignited
A dust explosion event

Secondary deflagration is propagated through the dust clouds
A dust explosion event

Secondary deflagration bursts from the building
## Hazard classes versus $K_{st}$

<table>
<thead>
<tr>
<th>Material</th>
<th>Particle Size (Microns)</th>
<th>$P_{max}$ (bar)</th>
<th>$K_{st}$ (bar-m/sec)</th>
<th>Hazard Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal (bituminous)</td>
<td>24</td>
<td>9.2</td>
<td>129</td>
<td>1</td>
</tr>
<tr>
<td>Sugar</td>
<td>30</td>
<td>8.5</td>
<td>138</td>
<td>1</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>&lt; 10</td>
<td>8</td>
<td>156</td>
<td>1</td>
</tr>
<tr>
<td>Cornstarch</td>
<td>7</td>
<td>10.3</td>
<td>202</td>
<td>2</td>
</tr>
<tr>
<td>Magnesium</td>
<td>28</td>
<td>17.5</td>
<td>508</td>
<td>3</td>
</tr>
<tr>
<td>Wood Dust</td>
<td>43</td>
<td>10.3</td>
<td>102</td>
<td>1</td>
</tr>
</tbody>
</table>

Dust classes are function of rate of pressure rise and not maximum pressure
When is it a problem?
You might have a problem if:

- You have fine particles if dust suspended in the air
- You have dust layers on horizontal surfaces
- Ignition sources present in area where dust are
- Unapproved electrical fixtures, components and equipment
- Static electrical charges in dust suspended areas
An ignitable combustible dust concentration is almost totally light obscuring at a distance of 6-9 feet.
Ignition sources

- Vehicles
- Process Equipment
- Illumination
- Hot Surfaces
- Cleaning
Static electricity ignition sources

- Fans and blowers
- Air separation devices
- Ducts
- Process equipment
- Dust control equipment
- Friction
- Persons
The potential on the human body can reach a charge of 10 kV to 15 kV during normal activity

- Spark from a person can reach **20 millijoules (mJ)** to 30 mJ

- The Minimum Ignition Energy (MIE) is:
  - 5 mJ for Zirconium
  - 10 mJ for Aluminum
  - 20 mJ for Magnesium
  - 25 mJ for Titanium
  - 30 mJ for Sugar
What can you do to minimize the risk?
Combustible Dust Hazard Analysis (DHA)

The DHA shall evaluate the fire, deflagration, and explosion hazards and provide recommendations to manage the hazards (NFPA 652- 7.2.1)
Combustible Dust Hazard Assessment

• NFPA 652 (2016) dust hazard analysis (DHA) requirements apply retroactively.

• Because so many of the investigation findings conclude that owners appear to be unaware of the hazards posed by combustible particulate solids

• DHA as a fundamental step in creating a plan for safeguarding such facilities
DHA Team Expertise

- Familiarity with the process
- Operations and maintenance
- Process equipment and ancillary equipment
- Safety systems
- History of operations
- Properties of the material
- Emergency procedures
Why do a Dust Hazard Analysis

- A systematic review to identify and evaluate the potential hazards associated with the presence of combustible particulate solids in a facility
- It is required by NFPA 652 Chapter 7 (Annex B example)
- Hazard/risk controls are expensive, so we seek confidence that:
  - We understand the hazards in the process
  - We can identify the most appropriate means of controlling those hazards
  - Those controls will be effective
  - We know how to maintain the effectiveness of those controls over time
  - We are not wasting resources
Dust Hazard Analysis Strategy

- Determine dust combustibility—do I have a hazard?
  - If combustibility or explosibility exist—identify where particulate is handled, released, or concentrated and where ignition could occur

- Determine primary dust explosion potential
  - Dust control equipment
  - Process and connected equipment
  - Ignition sources

- Determine secondary dust explosion potential
  - Fugitive dust emissions; accumulations of fine dust, even in hidden areas
  - Housekeeping
  - Dust layer thickness
Assess your work place:

- Considerations
  - Normal/abnormal operating condition
  - Cloud formation
  - Layers or accumulation (24 hours)
  - Equipment condition
  - Maintenance practices
  - Dust collection equipment
  - Type of system (open or enclosed)
  - Storage consideration
Dust on electrical equipment
Static electricity control

- Pipe and ductwork should be metal
- Grounding and bonding
- Use non sparking tools
- Mechanical sparks & friction
Use Proper Electrical Classifications

- The NEC defines the classes of hazardous locations, based upon materials present:
  - Flammable gases and vapors - Class I
  - Combustible dusts - Class II
  - Combustible fibers and flyings - Class III
Explosion proof receptacle
Industrial vacuum for combustible dust
Explosion proof motor
Explosion proof motor nameplate
Housekeeping

- Minimize accumulation of dust on surfaces
  - Provide dust collection
  - Minimize horizontal surfaces
  - Establish housekeeping program
    - regular cleaning frequencies established for floors and horizontal surfaces.
    - Preferred method for cleaning is a fixed-pipe vacuum system or electric vacuum cleaners approved for Class II.

- Provide access to hidden areas

- Utilize safe cleaning methods
Compressed air usage

Vigorous sweeping or blow down w/compressed air is permitted when the following requirements are met:

- Vacuum prior to blow down
- Sweeping or water-wash, and finally
- No ignition sources
- Pressure relief nozzle 30psi (NFPA 654 8.2.2.4 note 3)
- No hot surfaces or flames

These may not be required for minor accumulation of dust between shifts.
Prevention principles

- Know combustibility characteristics of dust [*fuel*]
- Control ignition sources [*ignition sources*]
  - Minimize/prevent accumulation of dust on surfaces
  - Select approved electrical equipment
  - Control static electricity
  - Utilize of safe work practices
- Inerting (*oxygen*)
- Protect process equipment [*confinement*]
- Protect/locate dust control equipment [*confinement/dispersion*]
- Implement dust explosion prevention program
- Increase worker training and awareness
Employee safety training

• Combustible Dust Hazards of the workplace

• Process hazards description

• Equip operation/maintenance, startup/shutdown, and upset hazards

• Tasks and safe work practices required to safely conduct job

• Explosion and Fire prevention system

• Housekeeping

• Emergency Response
Safe work practices

- Prohibit smoking
- Ensure adequate distance between open flames and combustible dust sources
- Open Light (bulbs)
- Ensure effective hot work permit system for welding, and cutting, and grinding when done away from designating area.
- Use conductive shoes [when in hazardous environment]
What’s OSHA looking at?
Combustible Dust NEP
CPL 03-00-008

OSHA INSTRUCTION

Purpose: This instruction contains policies and procedures for inspecting workplaces that create or handle combustible dusts. In some circumstances, these dusts may cause a deflagration, deflagrated, or an explosion. These dusts include, but are not limited to:

- Metal dust such as aluminum and magnesium.
- Wood dust.
- Coal and other carbon dusts.
- Plastic dust and additives.
- Flour.
- Other organic dust such as sugar, flour, paper, sawdust, and chaff.
- Carbonized materials.

Scope: This instruction applies OSHA area offices.

References: See paragraph VII.

Cancellations: This directive supersedes OSHA Instruction CPL 03-00-006 Combustible Dust National Emphasis Program, October 18, 2007.

State Plan Impact: Notice of effect required. See paragraph VII.

Action Office: National, Regional, and Area Offices.

Originating Office: Division of Enforcement Programs.

Combustible Dust NEP Focus

- Dust accumulations
- Equipment producing dust clouds
- Equipment processing dust-air mixtures i.e. dust collection systems
Let’s take action to prevent dust explosions!