Combustible Dust
Objectives

- In this course, we will cover:
  - Dust versus combustible dust
  - Industries with combustible dust
  - Management of combustible dust areas
  - Applicable occupational safety and health standards
  - Case studies
From 1980 to 2005

- 281 combustible dust fires and explosions in general industry
  - 44 different states affected
  - 119 workers killed
  - 718 injured
  - Seven of the explosions were catastrophic, involving multiple fatalities and a significant community economic impact

Source: CSB Report 2006-H-1
Types of Dust Involved in Incidents

- Wood: 24%
- Plastic: 14%
- Metal: 20%
- Coal: 8%
- Inorganic: 4%
- Food: 23%
- Other: 7%
Definition of Dust

“Solid particles generated by handling, crushing, grinding, rapid impact, detonation, and decrepitation of organic or inorganic materials, such as rock, ore, metal, coal, wood, and grain.”
Definition of Combustible Dust (NEP)

“A combustible particulate solid that presents a fire or deflagration hazard when suspended in air or some other oxidizing medium over a range of concentrations, regardless of particle size or shape.”
“Any finely divided solid material that is 420 microns or smaller in diameter (material passing through a No. 40 Standard Sieve) and presents a fire or explosion hazard when dispersed and ignited in air.”
# Common Types of Combustible Dust

## Agricultural Products
- Egg white
- Milk, powdered
- Milk, nonfat, dry
- Soy flour
- Starch, corn
- Starch, rice
- Starch, wheat
- Sugar
- Sugar, milk
- Sugar, beet
- Tapioca
- Whey
- Wood flour

## Agricultural Dusts
- Alfalfa
- Apple
- Beet root
- Carrageen
- Carrot
- Cocoa bean dust
- Cocoa powder
- Coconut shell dust
- Coffee dust
- Corn meal
- Cornstarch
- Cotton

## Soybean dust
- Spice dust
- Spice powder
- Sugar (10x)
- Sunflower
- Sunflower seed dust
- Tea
- Tobacco blend
- Tomato
- Walnut dust
- Wheat flour
- Wheat grain dust
- Wheat starch
- Xanthan gum

## Chemical Dusts
- Adipic acid
- Anthraquinone
- Ascorbic acid
- Calcium acetate
- Calcium stearate
- Carboxymethylcellulose
- Dextrin
- Lactose
- Lead stearate
- Methyl-cellulose
- Paraformaldehyde
- Sodium ascorbate
- Sodium stearate
- Sulfur

## Carbonaceous Dusts
- Charcoal, activated
- Charcoal, wood
- Coal, bituminous
- Coke, petroleum
- Lampblack
- Lignite
- Peat, 22%H₂O
- Soot, pine
- Cellulose
- Cellulose pulp
- Cork
- Corn

## Metal Dusts
- Aluminum
- Bronze
- Iron carbonyl
- Magnesium
- Zinc

## Plastic Dusts
- (poly) Acrylamide
- (poly) Acrylonitrile
- (poly) Ethylene (low-pressure process)
- Epoxy resin
- Melamine resin
- Melamine, molded (phenol-cellulose)
- Melamine, molded (wood flour and mineral filled phenol-formaldehyde)
- (poly) Methyl acrylate
- (poly) Methyl acrylate, emulsion polymer
- Phenolic resin
- (poly) Propylene
- Terpene-phenol resin
- Urea-formaldehyde/cellulose, molded
- (poly) Vinyl acetate/ethylene copolymer
- (poly) Vinyl alcohol
- (poly) Vinyl butyral
- (poly) Vinyl chloride/ethylene/vinyl acetylene suspension copolymer
- (poly) Vinyl chloride/vinyl acetylene emulsion copolymer
Dust Identified in the NEP

- Dusts specifically identified in the NEP
  - Metal dusts such as aluminum and magnesium
  - Wood dust
  - Coal and other carbon dust
  - Plastic dust and additives
  - Biosolids
  - Other organic dust such as sugar, flour, paper, soap, and dried blood
  - Certain textile materials
# Size of Dust Particles

<table>
<thead>
<tr>
<th>Common Materials</th>
<th>Size (Microns)</th>
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<tbody>
<tr>
<td>Talcum powder, fine silt, red blood cells, cocoa</td>
<td>5 to 10</td>
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<tr>
<td>Saw dust, ginger</td>
<td>25 to 600</td>
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<tr>
<td>Pollen, milled flour, coarse silt</td>
<td>44 to 74</td>
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<tr>
<td>Table salt</td>
<td>105 to 149</td>
</tr>
<tr>
<td>Coarse sand</td>
<td>297 to 1,000</td>
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</tbody>
</table>

Particles may resemble: fibers, needles, flakes and sphere
Combustible Dust

- These very small particles become airborne and settle on surfaces and in crevices throughout the manufacturing area.
  - Lighting, pipes, dust collectors, other equipment

- When disturbed, they can generate potentially explosive dust clouds.
Fire Triangle

- Heat
- Oxygen
- Fuel
Which wood picture is likely to ignite first?
Dust Explosion Pentagon

Fuel
Suspension
Oxygen
Ignition
Confinement
Other NEP Definitions

- **Deflagration** – Propagation of a combustion zone at a speed that is less than the speed of sound in the unreacted medium (vs. detonation).
  - Deflagration *isolation* and deflagration *suppression* are two associated terms.

- **Explosion** – The bursting or rupture of an enclosure (including a room or building) or a container due to the development of internal pressure from deflagration.
Before a deflagration can occur ...

- Dust has to be combustible, **and**

- Dust has to be dispersed in air or another oxidant **AND** the concentration must be > the minimum explosive concentration (MEC), **and**

- There is an ignition source to ignite the mixture, such electrostatic discharge, spark, glowing ember, hot surface, friction heat, or a flame.
Ignition Sources

- Hot Surfaces
- Electrically produced sparks
- Sparks from metal to metal contact
- Flame or glowing ember
- Static electricity
Explosion Types

- Primary dust explosion occurs when dust suspension within container, room, or piece of equipment ignites and explodes.

- Secondary dust explosion occurs when dust accumulated on floors or other surfaces is lifted into the air and ignites by primary explosion.
  - Depending on the amount of dust in the area, a small deflagration or primary explosion may cause very powerful secondary dust explosions.
  - A secondary dust explosion may follow a primary non-dust explosion (e.g., natural gas or pressure vessel.)
The “Typical” Explosion Event

Initial Internal Deflagration

Process Equipment

Time, msec.
The “Typical” Explosion Event

Initial Internal Deflagration

Shock Wave

Process Equipment

Time, msec.

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

Dust Clouds Caused by Elastic Rebound

Secondary Deflagration Initiated

Process Equipment

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.

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

Dust Control Measures

- Minimize escape of dust from process equipment or ventilation systems
- Use dust collection systems and filters
- Use surfaces that reduce dust accumulation
- Conduct regular inspections
- Clean dust residues at regular intervals
Dust Control Measures

- Use cleaning methods that do not generate dust clouds

- Use vacuum cleaners approved for combustible dust collection

- Locate relief valves away from dust hazard areas

- Develop and implement written program for hazardous dust inspection, housekeeping and control
Dust Layer Thickness Guidelines

- Grain handling standard - 1910.272
  - Exceeds 1/8"

- NFPA 654
  - 1/32 " over 5% of area
  - 5 % factor should not be used if floor area exceeds 20,000 ft²

  » Overhead beams and ledges should also be considered
Ignition Control Measures

- Electrically powered cleaning devices
  - Vacuum cleaners and electrical equipment approved for Class II locations

- Ignition control program
  - Grounding, bonding and other methods used for dissipating electrostatic charge

- Hot work permit program

- Cartridge activated tools used properly
Ignition Control Measures

- Posted “No Smoking” signs
- Duct systems, dust collectors, and dust-producing machinery bonded and grounded
- Industrial trucks approved for the combustible dust locations
Prevention Measures

- Separator devices used to remove foreign materials capable of igniting combustible dusts
- MSDSs available for chemicals which could become combustible dust
- Employees trained on explosion hazards
Damage Control Measures

- Separation of the hazard
- Segregation of the hazard
- Deflagration venting of a building, room or area
- Pressure relief venting for equipment
- Spark detection and extinguishing systems
- Explosion protection systems
- Sprinkler systems
Protection Measures—Human

- Emergency Action Plan
  - Practice your plan

- Maintain emergency exit routes
Protection Measures—Physical

- Dust collectors not located inside buildings (exceptions)
- Rooms, buildings, or other enclosures (dust collectors) have explosion relief venting
- Explosion venting directed toward safe location away from employees
- Facility has isolation devices to prevent deflagration propagation between equipment connected by ductwork
- Spark detection and explosion/deflagration suppression systems in dust collector systems
General Industry Standards

- Housekeeping
  - 1910.22

- Means of Egress
  - 1910 Subpart E

- Ventilation
  - 1910.94

- Process Safety Management
  - 1910.119

- Warning Signs
  - 1910.145
General Industry Standards

- Permit-Required Confined Spaces
  - 1910.146

- Portable Fire Extinguishers
  - 1910.157

- Handling Materials
  - 1910.176

- Powered Industrial Trucks
  - 1910.178

- Welding, Cutting and Brazing
  - 1910.252
General Industry Standards

- Hazardous ( Classified ) Locations
  - 1910.307

- Hazard Communication
  - 1910.1200

- General Duty Clause
  - N.C. General Statute §95-129(1)
Special Industries—1910 Subpart R

- Bakery Equipment
  - 1910.263

- Sawmills
  - 1910.265

- Electric Power Generation, Transmission and Distribution
  - 1910.269

- Grain Handling Facilities
  - 1910.272
<table>
<thead>
<tr>
<th>NFPA Number</th>
<th>Title</th>
<th>Current Edition</th>
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<tbody>
<tr>
<td>61</td>
<td>Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities</td>
<td>2008</td>
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<tr>
<td>68</td>
<td>Guide for Venting of Deflagrations</td>
<td>2007</td>
</tr>
<tr>
<td>69</td>
<td>Standard on Explosion Prevention Systems</td>
<td>2008</td>
</tr>
<tr>
<td>70</td>
<td>National Electrical Code</td>
<td>2008</td>
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<tr>
<td>77</td>
<td>Recommended Practice on Static Electricity</td>
<td>2007</td>
</tr>
<tr>
<td>85</td>
<td>Boiler and Combustion Systems Hazards Code</td>
<td>2007</td>
</tr>
<tr>
<td>86</td>
<td>Standard for Ovens and Furnaces</td>
<td>2007</td>
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<tr>
<td>91</td>
<td>Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids</td>
<td>2004</td>
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<tr>
<td>484</td>
<td>Standard for Combustible Metals</td>
<td>2006</td>
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<tr>
<td>499</td>
<td>Recommended Practice for the classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas</td>
<td>2008</td>
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<tr>
<td>654</td>
<td>Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing and Handling of Combustible Particulate Solids</td>
<td>2006</td>
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<tr>
<td>664</td>
<td>Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities</td>
<td>2007</td>
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Catastrophic Combustible Dust Incidents Since 1995
Malden Mills, Methuen, MA

- December 11, 1995

- 37 injured

- Nylon fiber
  - Polartec fleece fibers
Ford River Rouge, Dearborn, MI

● February 1, 1999

● 6 killed

● 36 injured

● Initial event was natural gas explosion

● Secondary coal dust explosion
Jahn Foundry, Springfield, MA

- February 26, 1999
- 3 killed
- 9 injured
- Phenolic resin dust
Rouse Polymerics, Vicksburg, MS

- May 16, 2002
- 5 killed
- 7 injured
- Rubber dust
CTA Acoustics, Inc., Corbin, KY

- February 20, 2003
- 7 killed
- 37 injured
- Series of dust explosions
- Facility destroyed
CTA Acoustics, Inc.

- Phenolic resin powder was deposited onto a fiberglass web.

- In the mat-former, air-suction dispersed the phenolic resin powder throughout the web to create a resin-impregnated fiberglass mat.
  - Suction air with resin and fiberglass traveled to a 40K cfm pulse-jet baghouse.
Line 405 oven temperature controller stopped working four days before incident
  - Oven running too hot
  - Controls switched to manual by line operators
  - Oven temperature controlled by opening and closing doors on east/west side of oven

Line 405 oven had history of fires
  - Accumulated phenolic resin/fiberglass materials ignited
  - Extinguished with a garden hose or portable fire extinguisher
  - Seven fires in six months preceding the incident. Five of those seven originated inside line 405 oven
    » Sparks from the oven flight chain were listed as most frequent source of ignition
Crew was cleaning the baghouse for line 405 at 7 a.m.

- Transition leading to the baghouse was plugged
- Compressed air lance used to blow material out of transition – which fell back into the production area
- Cloud of combustible dust was generated in the plant around line 405
CSB determined that air currents probably transported the dust cloud (from bag house cleaning) to the Line 405 oven, where it likely ignited.
Collapsed firewall and metal panels – south end of line 405 blend room
Hayes-Lemmerz International, Huntington, IN

- October 29, 2003
- 1 killed
- 6 injured
- Aluminum dust explosion
- Fireball that erupted from furnace sidewell was likely result of an aluminum dust explosion in dust collector system
West Pharmaceuticals, Kinston, NC

- January 29, 2003
- 6 killed
- 38 injured including two firefighters
- Facility manufactured rubber drug delivery components
West Pharmaceuticals

- Production process included use of finely powdered (12 microns) grade of polyethylene as an antitack agent
  - Zinc stearate had been used as antitack agent until 1996

- Small amounts of dried powder that did not remain on the folded rubber likely became airborne
Simplified Automated Rubber Compounding System Process

Raw materials from kitchen

Concrete slab

Drop ceiling

Rubber batch off

Antitack slurry dip tank

Mixer

Mill
Due to the amount of damage, investigators were not able to establish what dispersed the dust or what ignited it.
What Caused Initial Explosion?

- Not known for sure, but several theories:
  - Deflagration of vapors emitted by decomposing rubber
  - Ignition of dust:
    » By overheated electrical ballast or fixture
    » By an electrical spark, or
    » In a motor cooling duct
CSB Recommendations to OSHA

- Issue a standard designed to prevent combustible dust fires and explosions in general industry

- Revise the Hazard Communication Standard (HCS) (1910.1200) to clarify that the HCS covers combustible dusts

- Communicate to the United Nations Economic Commission (UNECE) the need to amend the Globally Harmonized System (GHS) to address combustible dust hazards
CSB Recommendations to OSHA

● Provide training through the OSHA Training Institute (OTI) on recognizing and preventing combustible dust explosions

● While a standard is being developed, implement a National Special Emphasis Program (SEP) on combustible dust hazards in general industry
NCDOL Resources

- Combustible Dust Industry Guide
- Combustible Dust Alerts
- Training Calendar and Newsletter
- A-Z Topics on Combustible Dust
- Combustible Dust Compliance Directive
Summary

- Dust versus combustible dust
- Industries with combustible dust
- Management of combustible dust areas
- Applicable occupational safety and health standards
- Case Studies
Thank You For Attending!

Final Questions?
Handouts

Appendix B of CPL 03-00-008

Sample questions CSHOs may use during the course of an inspection.
(CSHOs may refer to appropriate NFPA standards in developing additional questions.)

What types of combustible dust does the facility have?
(Note: Please see Table 4.5.2 of NFPA 699 and Table 1 in NMB 335-3 for additional information on the various types of dust along with their properties.)

Does the facility have a housekeeping program with regular cleaning frequencies established for floors and horizontal surfaces, such as ducts, pipes, hoods, ledges, and beams, to minimize dust accumulations within operating areas of the facility? Under the housekeeping program, is the dust on floors, structural members, and other surfaces removed concurrently with operations? Is there dust accumulation of 1/32 inch thick, or greater? For housekeeping violations, what are the dimensions of the room and the dimensions of the area covered with the dust?

Are the dust-containing systems (duets and dust collectors) designed in a manner that fugitive dusts are not allowed to accumulate in the work area?

Are dust collectors greater than 8 cubic feet in volume located inside of buildings?

If dust explosion hazards exist in rooms, buildings, or other enclosures, do such areas have explosion relief venting distributed over the exterior walls of buildings and enclosures? Is such venting directed to a safe location away from employees?

Does the facility have isolation devices to prevent deflagration propagation between pieces of equipment connected by ductwork?

Does the facility have an ignition control program, such as grounding and bonding and other methods, for dissipating any electrostatic charge that could be generated while transporting the dust through the ductwork?

Does the facility have separator devices to remove foreign materials capable of igniting combustible dusts?

Are electrically-powered cleaning devices, such as sweepers or vacuum cleaners used in dusty areas, approved for the hazardous classification, as required under 1910.307(b)?

Is smoking permitted only in safe designated areas?

Are areas where smoking is prohibited posted with “No Smoking” signs?

Is the exhaust from the dust collectors recycled?

Does the dust collector system have spark detection and explosion/delagation suppression systems? (There are other alternative measures.)

Are all components of the dust collection system constructed of noncombustible materials?

Are ducts designed to maintain sufficient velocity to ensure the transport of both coarse and fine particles?

Are duct systems, dust collectors, and dust-producing machinery bonded and grounded to minimize accumulation of static electrical charge?

Is metal ductwork used?

In areas where a hazardous quantity of dust accumulates or is present in suspension in the air, does all electrical wiring and equipment comply with 1910.307(b) requirements?

Does the facility allow hot work only in safe, designated areas?

Are bulk storage containers constructed of noncombustible materials?

Does the company use methods to dissipate static electricity, such as by bonding and grounding?

Are employees who are involved in operating, maintaining, and supervising facilities that handle combustible dust trained in the hazards of the combustible dust?

Are MSDSs for the chemicals which could become combustible dust under normal operations available to employees?