Combustible Dust in the Workplace
An overview of its recognition, evaluation, and control

Combustible Dust
Oxygen in Air
Ignition Source
Dispersion
Deflagration
Explosion
Confinement
FIRE

DIOSH Day- Peoria, IL Civic Center
March 5, 2014
Mark Knezovich, M.S.

- Industrial Hygienist
- US DOL – OSHA
- Enforcement Programs – Region V

knezovich.mark@dol.gov

- (312) 886-6288
Takeaways

1. Am I aware of the properties of my dust(s)? *(recognition)*

2. Have I evaluated whether or not my dust presents fire, deflagration, or explosion hazards in the production process? *(evaluation)*

3. If hazards are present, do I have proper controls in place? *(control)*

4. What resources exist to assist me?
Today’s Agenda

- Basic Fundamental Concepts – Elements (recognition)
- Examples of Combustible Dusts (recognition)
- Summary of case studies (recognition)
- Applicable OSHA standards / Enforcement Avenues
- Basic Definitions / Lab Test Summary (evaluation)
- Secondary explosion event mechanisms/hazard criteria (evaluation)
- Housekeeping (control)
- Primary explosion event mechanisms/hazard criteria (evaluation)
- Engineering control concepts (venting, suppression, isolation) (control)
- Resources
Requirements for an Explosion; Deflagration; Fire
Increased Surface Area of a Solid Material (Subdivision)

Influences the Rate of Combustion; Ease of Ignition
What Dusts are Combustible/Explosible?

• Metal dusts
• Wood dusts
• Agricultural dusts
• Food products
• Carbonaceous
• Chemical Dusts
• Plastic Dusts
• Many others!
Examples of Combustible Dusts

<table>
<thead>
<tr>
<th>Agricultural Products</th>
<th>Agricultural Dusts</th>
<th>Chemical Dusts</th>
<th>Plastic Dusts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg white</td>
<td>Alfalfa</td>
<td>Adipic acid</td>
<td>(poly) Acrylamide</td>
</tr>
<tr>
<td>Milk, powdered</td>
<td>Apple</td>
<td>Anthraquinone</td>
<td>(poly) Acrylonitrile</td>
</tr>
<tr>
<td>Milk, nonfat, dry</td>
<td>Beet root</td>
<td>Ascorbic acid</td>
<td>(poly) Ethylene</td>
</tr>
<tr>
<td>Soy flour</td>
<td>Carrageen</td>
<td>Calcium acetate</td>
<td>(low-pressure process)</td>
</tr>
<tr>
<td>Starch, corn</td>
<td>Carrot</td>
<td>Calcium stearate</td>
<td></td>
</tr>
<tr>
<td>Starch, rice</td>
<td>Cocoa bean dust</td>
<td>Carboxy-methylcellulose</td>
<td></td>
</tr>
<tr>
<td>Starch, wheat</td>
<td>Cocoa powder</td>
<td>Dextrin</td>
<td></td>
</tr>
<tr>
<td>Sugar</td>
<td>Coconut shell dust</td>
<td>Lactose</td>
<td></td>
</tr>
<tr>
<td>Sugar, milk</td>
<td>Coffee dust</td>
<td>Lead stearate</td>
<td></td>
</tr>
<tr>
<td>Sugar, beet</td>
<td>Corn meal</td>
<td>Methyl-cellulose</td>
<td></td>
</tr>
<tr>
<td>Tapioca</td>
<td>Cornstarch</td>
<td>Paraformaldehyde</td>
<td></td>
</tr>
<tr>
<td>Whey</td>
<td>Cotton</td>
<td>Sodium ascorbate</td>
<td></td>
</tr>
<tr>
<td>Wood flour</td>
<td></td>
<td>Sodium stearate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sulfur</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carbonaceous Dusts</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Charcoal, activated</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Charcoal, wood</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coal, bituminous</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coke, petroleum</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lampblack</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lignite</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peat, 22%H₂O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soot, pine</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cellulose</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cellulose pulp</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cork</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Corn</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Metal Dusts</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aluminum</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bronze</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Iron carbonyl</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Magnesium</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Zinc</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Epoxy resin</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Melamine resin</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Melamine, molded</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(phenol-cellulose)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Melamine, molded</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(wood flour and mineral filled phenol-formaldehyde)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(poly) Methyl acrylate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(poly) Methyl acrylate, emulsion polymer</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Phenolic resin</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(poly) Propylene</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Terpene-phenol resin</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Urea-formaldehyde/ cellulose, molded</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(poly) Vinyl acetate/ ethylene copolymer</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(poly) Vinyl alcohol</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(poly) Vinyl butyral</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(poly) Vinyl chloride/ ethylene/vinyl acetylene suspension copolymer</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(poly) Vinyl chloride/ vinyl acetylene emulsion copolymer</td>
<td></td>
</tr>
</tbody>
</table>

Source: OSHA Poster (2008): Combustible Dust: Does your company or firm process any of these products or materials in powdered form?
### Region V – FY 2012 to date

#### 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

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

#### Carbonaceous Dusts
- Charcoal, activated
- Charcoal, wood
- Coal, bituminous
- Coke, petroleum
- Lamplblack
- Lignite
- Peat, 22% H₂O
- Soot, pine

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

#### Plastic Dusts
- (poly) Acrylamide
- (poly) Acrylonitrile
- (poly) Ethylene (low-pressure process)

#### Powder coating pigments
- Humic acid
- Zirconium
- Niobium

#### Titanium
- Hafnium

#### Vegetable oil prill dust
- Foam insulation

#### Chicken manure
- Beverage powders
- Artificial sweetener

#### Straw
- Foam insulation
- 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

#### Recognition
- 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
Sampling of U.S. Combustible Dust Incidents 1980 - 2005

119 killed!
718 injured!

BY INDUSTRY

Sampling of U.S. Combustible Dust Incidents 1980 - 2005

119 killed!
718 injured!

Industries Visited*

- Wood pellet
- Woodworking
- Powder coating
- Fertilizer
- Animal feed
- Flame retardant chemical
- Automotive components
- Drink mix/dry food product
- Egg
- Coal tar pitch
- Motor brush
- Activated charcoal
- Coal fire power
- Bakery
- Whey
- Sugar
- Grain
- Hydrogenated oil prilling

- Metals recycling
- Metals polishing
- Hazardous waste
- Aluminum casting
- Steel media abrasive blasting
- Metal coating
- Sheet metal
- Plastics
- Friction material
- Rubber
- Asphalt
- Soybean
- Fiberglass resin
- Straw matting
- Paper conversion
- Ethanol
- Tobacco
- Foam insulation

*Region V – FY 2012 to date
West Pharmaceutical – Kinston, NC
Rubber stoppers for medical uses /polyethylene dust
January 29, 2003
6 killed, 38 injured

CSB Case Study
CTA Acoustics – Corbin, KY
Fiberglass insulation for the automotive industry / phenolic resin dust
February 20, 2003
7 killed, 37 injured

CSB Case Study
Hayes Lemmerz – Huntington, IN
Aluminum wheel castings / aluminum dust
October 29, 2003
1 killed, 2 injured

CSB Case Study
Imperial Sugar - Port Wentworth, GA
Sugar refining / sugar dust
February 7, 2008
14 killed, 38 injured

CSB Case Study
Cumberland AL Solutions – New Cumberland, WV
Titanium powder processing
December 9, 2010
3 killed
Hoeganaese – Gallatin, TN

Powdered iron production / iron dust

January 31, 2011 (2 killed)
March 29, 2011 (1 injured)
May 27, 2011 (3 killed, 2 injured)*

*Primary source attributed to a hydrogen gas line leak and ignition
Malden Mills – Methuen, MA
Nylon fabric manufacturer / nylon flock fiber

December 11, 1995
37 injured
Ford River Rouge– Dearborn, MI
Secondary coal dust
February 1, 1999
6 killed
37 injured
Jahn Foundry– Springfield, MA
Metal castings / phenolic resin dust

February 29, 1999
3 killed
9 injured
Rouse Polymetrics – Vicksburg, MS
Rubber recycling plant / rubber dust

May 16, 2002
5 killed
7 injured
Combustible Dust National Emphasis Program CPL 03-00-008 (reissue)

- Effective 3/11/08
- Programmed and unprogrammed inspections
- Trained inspectors
  - Combustible Dust Hazards and Controls, OTI Course No. 3320
- Dust accumulation guidance
- SLTC test descriptions
- Interaction with vertical standards
Section 5(a)(1) – General Duty Clause

“Each employer shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees.”

1) A workplace condition that constituted a hazard to employees (own)

2) The employer or the employer’s industry recognized that the activity or condition was hazardous

3) The hazard was causing or likely to cause death or serious physical harm

4) Feasible means exists to eliminate or materially reduce the hazard
Current Enforcement

- Section 5(a)(2)
  “Each employer shall comply with the occupational safety and health standards promulgated under this Act”.

- 1910.22, housekeeping
- 1910.38, emergency action plans
- 1910.94, ventilation
- 1910.157, portable fire extinguishing systems
- 1910.158, employee alarm systems
- 1910.176, material handling
- 1910.178, powered industrial vehicles
- 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
- 1910.307, electrical; hazardous (classified) locations
- 1910.1200, hazard communication
Important Definitions

• **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.

• **Noncombustible Material.** A material that, in the form which it is used and under the conditions anticipated, will not ignite, support combustion, burn, or release flammable vapors when subjected to fire or heat.
  – NFPA 654 (2013)
• **Minimum Explosible Concentration (MEC).** The minimum concentration of a combustible dust suspended in air, measured in mass per unit volume, that will support a deflagration.  
  – NFPA 654 (2013)

• **Minimum Ignition Energy (MIE).** The lowest capacitive spark energy capable of igniting the most ignition-sensitive concentration of a flammable vapor-air mixture or a combustible dust-air mixture as determined by a standard test procedure.  
  – NFPA 654 (2013)
MEC Comparison

Health Concerns

Safety Concerns

Dust Deposit

Mass of dust per unit volume [g/m$^3$]

• **Deflagration.** Propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium.
  – NFPA 654 (2013)

• **Explosion.** The bursting or rupture of an enclosure or container due to the development of internal pressure from a deflagration.
  – NFPA 654 (2013)
The Influence of Particle Size

- **Decrease in particle size**
  - Decrease in MEC
  - Decrease in MIE
  - Decrease in dust layer ignition temperature (LIT) and minimum auto ignition temperature (MAIT)
  - Increase in $K_{St}$ (rate of combustion)
  - Increase in explosion pressure (psi or barg)

# Lab Tests – Knowing Your Dust

<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>$P_{\text{max}}$</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>$(\text{dp/dt})_{\text{max}}$</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>
</tbody>
</table>

• **Deflagration Index ($K_{st}$).** Maximum rate of pressure rise when dust is tested in a confined enclosure.
  
  – OSHA combustible dust national emphasis program (NEP CPL-03-00-08)

<table>
<thead>
<tr>
<th>Dust explosion class</th>
<th>$K_{st}$ (bar.m/s)</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>St 0</td>
<td>0</td>
<td>No explosion</td>
</tr>
<tr>
<td>St 1</td>
<td>&gt;0 and $\leq$200</td>
<td>Weak explosion</td>
</tr>
<tr>
<td>St 2</td>
<td>&gt;200 and $\leq$300</td>
<td>Strong explosion</td>
</tr>
<tr>
<td>St 3</td>
<td>&gt;300</td>
<td>Very strong explosion</td>
</tr>
</tbody>
</table>
Evaluation

Rate of pressure is relatively slower compared to St 2 and St 3, however maximum pressures generated can still be strong enough to rupture vessels and/or produce significant overpressure!!! (‘Weak’ is a relative term).

Source: OSHA Publication 3371-08 2009  Hazard Communication Guidance for Combustible Dusts
Sugar is a class St 1 dust!!!
OSHA Compliance Screen vs. ASTM E1226 Design Test

• Chemical Igniter
  – OSHA – 2,500 J ignition source
  – ASTM – 10,000 J ignition source

• 20 L chamber
  – OSHA low turbulence
  – ASTM high turbulence

• Dust particle size
  – OSHA – as received
  – ASTM – less than 75 microns (200 mesh)
OSHA Compliance Screen vs. ASTM E1226 Design Test

- OSHA is simply screening the dust for combustibility, explosibility

- ASTM design protocols are determining the worst case scenarios so that explosion, deflagration controls can be designed appropriately

- OSHA methods therefore under report values and ARE NOT intended for design
  - Explosion vents could be \( \frac{1}{4} \) size needed if mis-used for design
OSHA Compliance Screen vs. ASTM E1226 Design Test

- The results obtained from this equipment/test CAN NOT be used in designing or engineering protective safety equipment
Secondary dust explosion mechanism

Some event disturbs the settled dust into a cloud.

Dust settles on flat surfaces.

Dust cloud is ignited and explodes.

Source: Adapted from CSB
Secondary Explosion Hazard?  
OSHA NEP Dust Layer Thickness Guidelines

- 1/8” in grain standard

  - 1/32” over 5% of area (all surfaces)
  - Bar joist surface area ~ 5%
  - Up to room of 20,000 ft² – 1,000 ft² limit
  - Assumes certain bulk density, concentration, and cloud height

- Measurement tools
  - 1/32” = paper clip thickness / U.S. dime
  - 1/16” = U.S. quarter
  - 1/8” = Two U.S. quarters

- References for guidance
  - NFPA 654 (2013)
  - FM Global Loss Prevention Data Sheet 7-76 (2012)
Secondary Explosion Hazard?
Current NFPA Layer Depth Criterion Method

• NFPA 654 (2013) Section 6.1.3
  – Layer Depth Criterion Formula (LDC):

\[ LD \ (\text{in.}) = \left( \frac{1}{32} \text{ in.} \right) \left( \frac{75 \frac{\text{lb}}{\text{ft}^3}}{BD} \right) \]

where:
- \( LD \) = layer depth (in.)
- \( BD \) = Bulk density (lb/ft\(^3\))
Secondary Explosion Hazard?  
NFPA Layer Depth Criterion Method

- NFPA (654) Section 6.1.3.2

A dust flash fire or dust explosion hazard exists in any building or room when*:

1. The total area of dust accumulations (exceeding the LDC) is > 5% of footprint area

2. Any single dust accumulation (exceeding the LDC) is > 1,000 ft$^2$

*Other potential criteria based on volume of dust present, are not discussed here, but are addressed in NFPA 654 (2013)

- Floors, beam flanges, piping, duct work, equipment, suspended ceilings, light fixtures, and walls.
Sample Conversion of LDC
NFPA Layer Depth Criterion Method

• Calculate the Layer Depth Criterion (LDC) for corn flour having a bulk density of 39 lb/ft$^3$:

Answer:

$LDC = \frac{1/32 \text{ (inch)}}{39 \text{ (lb/ft}^3)} \times 75 \text{ (lb/ft}^3) = 0.06 \text{ in.} \approx 1/16 \text{ in.}$
Floors

Overhead ducting

Ledges

Equipment
Major Elements of a Good Housekeeping Program

• Equipment is maintained and operated in a manner that minimizes the escape of dust

• Regular cleaning frequencies established for floors and other surfaces such as pipes, ducts, ledges, beams, and hoods to minimize dust accumulations

• Surfaces cleaned in a manner that minimizes dust clouds. Vigorous sweeping or blowing down with steam or compressed air to be avoided

• Employer commitment

• Employee involvement and education

• Engineering controls
Do I have Primary/Equipment Explosion Hazards?

- NFPA 654 (2013) Section 6.1.7

An explosion hazard shall be deemed to exist in enclosed process equipment where both of the following conditions are possible:

1) Combustible dust is present in sufficient quantity to cause enclosure rupture if suspended and ignited

2) A means of suspending the dust is present
Explosion Control Methods (equipment)

- Oxidant concentration reduction
- Dilution with a non-combustible dust
- Deflagration pressure containment
- Deflagration chemical suppression
- Deflagration venting
Deflagration venting

- A protective measure that prevents unacceptably high explosion pressures by ensuring that most of the [deflagration] takes place in a safe open area and not inside a building or dust handling enclosure. (Barton, 2002)
  - Engineered weak areas designed to open at early stages of a deflagration
  - Burning material and combustion products released
  - Vessel over-pressure avoided
  - $K_{St}$
  - $P_{max}$
  - $P_{red}$
• Maximum Pressure ($P_{max}$). The maximum pressure developed in a contained deflagration of an optimum mixture.

• Reduced Pressure ($P_{red}$). The maximum pressure developed in a vented enclosure during a vented deflagration.

• Static Activation Pressure ($P_{stat}$). Pressure that activates a vent closure when the pressure is increased slowly.

Vented Deflagration Graph [time-pressure] (NFPA 654, 2013)
Explosion venting testing of a baghouse – dual vent
Source: www.gexconus.com

Explosion venting testing of a baghouse and container
Source: www.fike.com
Flame-Arresting / Dust Retention Venting – Indoor Applications

Deflagration venting with and without flame-arresting / dust retention devices
Source: www.fike.com

Examples of flame-arresting / dust retention devices
Sources: www.bsbsystems.com ; www.fike.com ; www.rembe.us
Deflagration chemical suppression

- The technique of detecting and arresting combustion in a confined space while combustion is still in its incipient stage, thus preventing the development of pressures that could result in an explosion (NFPA 69)
  - 30 to 100 ms to build up destructive pressures (Barton, 2002)
  - Pressure and infrared sensors
  - Control systems
  - Injection suppressor (pressurized)
    - Dry powders
      - Sodium bicarbonates
      - Fluorinated hydrocarbons
      - Water
  - Lockout/PRCS isolation for maintenance
Chemical suppression container test
Source: www.fike.com
Isolation

- Preventing certain stream properties from being conveyed past a predefined point. (NFPA 69)
  - Chemical Isolation via chemical suppression
  - Mechanical Isolation

1) Passive Isolation Techniques
2) Active Isolation Techniques
Passive Isolation

• Protects against:
  – Flame front
  – Deflagration pressures
  – Pressure piling
  – Flame-jet ignition

• Types:
  – Flame front diverters
  – Passive float valve
  – Material chokes
  – Static dry flame arrestors
  – Back-blast damper

• Ducts need to withstand estimated maximum pressures ($P_{\text{max}}$)
Active Isolation

• Protects against:
  – Flame front
  – Deflagration pressures
  – Pressure piling
  – Flame-jet ignition

• Types:
  – Chemical flame front extinguishing/suppressing
  – Fast-acting mechanical valve
  – Actuated pinch valve
Explosion venting testing of a baghouse w/out isolation
Source: www.fike.com

Explosion venting testing of a baghouse with isolation
Source: www.fike.com
Control of Ignition

- Multiple potential sources of ignition

- 1st step, not the last step

- Extremely difficult to guarantee total elimination of ignition sources

  - Open flames and hotwork: indirect burners, no-smoking policies, hot work programs, fire extinguishment
  
  - Impact sparks: tramp metal screening / elimination
  
  - Electrostatic discharges: grounding and bonding of equipment, personnel
  
  - Embers: spark/ember detection and suppression
  
  - Spontaneous self heating: layer reduction controls
  
  - Electrical equipment sparks: classified electrical equipment
  
  - Thermite reactions (alloy metals and rust): inspection and material substitution
  
  - Elevated surface temperatures: insulation, inspection, maintenance
Examples of equipment which may require explosion protection

• Blenders/Mixers
• Dryers
• Spray dryers
• Second stage dryers (fluid beds)
• Dust Collectors / Air-Material Separators
• Pneumatic Conveyors
• Size Reduction Equipment (Grinders)
• Silos and Hoppers
• Hoses, Loading Spouts, Flexible Boots
• Bucket elevators
• Many more!
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Incidents</td>
<td>%</td>
</tr>
<tr>
<td>Dust Collectors</td>
<td>156</td>
<td>42</td>
</tr>
<tr>
<td>Grinders</td>
<td>35</td>
<td>9</td>
</tr>
<tr>
<td>Silos/Bunkers</td>
<td>27</td>
<td>7</td>
</tr>
<tr>
<td>Conveying System</td>
<td>32</td>
<td>9</td>
</tr>
<tr>
<td>Dryer/Oven</td>
<td>22</td>
<td>6</td>
</tr>
<tr>
<td>Mixers/Blenders</td>
<td>&gt;12</td>
<td>&gt;3</td>
</tr>
<tr>
<td>Other or Unknown</td>
<td>84</td>
<td>23</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>372</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Source: Guidelines for Safe Handling of Powders and Bulk Solids, CCPS, AIChE
Putting it all together: example

• Dust screened as explosive
  – Fiberglass stock, 30 – 55% polymerized polyester resin

• Primary explosion hazard present / secondary possible

• Dust collector located indoors

• Lacked a means of explosion protection

• Lacked a means of isolation

• Recycled exhaust air indoors

• Poor housekeeping
Adequate Conveying Velocities

– 3500 to 4500 fpm for most dusts

Aluminum chip and dust accumulation in ducting – Hayes Lemmerz International Investigation
Source: CSB
OSHA Resources

• A-Z index – C -Combustible Dusts

  -Hazard Communication Guidance
  -Rulemaking Stage
  -OSHA’s Combustible Dust National Emphasis Program (NEP)
  -Stakeholder Meeting Summary Notes 2009-2010.
  -OSHA Safety and Health Information Bulletin
  -OSHA Fact Sheet
Resources – NFPA Standards

• NFPA 654 (2013): “Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids”


• NFPA 61 (2013): “Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities”
Resources – NFPA Standards

• NFPA 484 (2012): “Standard for Combustible Metals”


• NFPA 86 (2011): “Standard for Ovens and Furnaces”
Resources – NFPA Standards

• NFPA 2113 (2012): “Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire”

• NFPA 499 (2013): “Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas”

• NFPA 77 (2014): “Recommended Practice on Static Electricity”
Resources – NFPA Standards

• NFPA 68 (2013): “Standard on Explosion Protection by Deflagration Venting”

Resources – FM Global Property Loss Prevention Data Sheets

• 7-73 (2012): “Dust Collectors and Collection Systems”

• 7-76 (2013): “Prevention and Mitigation of Combustible Dust Explosion and Fire”

• 5-1 (2012): “Electrical Equipment in Hazardous (Classified) Locations”

• 5-8 (2012): “Static Electricity”

• 7-85 (2013): “Metals and Alloys”

http://www.fmglobal.com/fmglobalregistration/
Resources – Government Directives / Guidance


• OSHA Instruction CPL 03-00-08 “Combustible Dust National Emphasis Program” (2008)
Resources - Publications


Resources - Publications

Resources - Publications

Regulatory Agenda

• Combustible Dust (Pre-rule)
  – 2005 OSHA Safety and Health Information Bulletin
  – 2008 OSHA NEP
  – 2009 ANPRM
  – 2009 – 2010 Stakeholder meetings
  – 2010 ANPRM comment period end
  – 2011 Expert Forum
  – 2014 Initiate SBREFA
Disclaimer

This information is intended to assist employers, workers, and others as they strive to improve workplace health and safety. While we attempt to thoroughly address specific topics or hazards, it is not possible to include discussion of everything necessary to ensure a healthy and safe working environment in a presentation of this nature. Thus, this information must be understood as a tool for addressing workplace hazards, rather than an exhaustive statement of an employer’s legal obligations, which are defined by statute, regulations, and standards. Likewise, to the extent that this information references practices or procedures that may enhance health or safety, but which are not required by a statute, regulation, or standard, it cannot, and does not, create additional legal obligations. Finally, over time, OSHA may modify rules and interpretations in light of new technology, information, or circumstances; to keep apprised of such developments, or to review information on a wide range of occupational safety and health topics, you can visit OSHA’s website at www.osha.gov.