Understanding Combustible Dust Hazards: Basic Measures you can take to Ensure Safety

Michigan Safety Conference
April 17, 2019

Mike Snyder PE CSP CFPS
Executive Vice President, Process Safety
Email: process-safety-usa@dekra.com
Phone: (609) 799-4449
Outline for Today’s Discussion:

• Introduction
• Combustible Dust Basics
  • Assessing Flash Fire & Explosion Dust Hazards
  • What Makes a Dust Become a Combustible Hazard?
• Data & Information for Combustible Dust Classification
• Establishing a “Basis of Safety” for Combustible Dust Ops
• New (and Old) Requirements in IFC (2018)
• Introduce the Table of References
• Discussion & Questions
DEKRA Process Safety: Serving as a Trusted Safety Advisor

- Integrated Solutions Provider
  - Process Safety Consulting, Engineering and Laboratory Testing
  - Combustible Dust Testing & Analysis
  - Data Management & Analytics
  - Organizational Safety
  - Organizational Reliability (Human Error & Fatigue)

For more information:
www.Dekra.us/process-safety
US Chemical Safety Board’s Drivers of Critical Chemical Safety Change

• Key Focus Areas of CSB Recommendations & Improvement Need

• 5 Targeted Areas:
  • Combustible Dust Safety
  • Process Safety Management for the 21st Century
  • Emergency Planning & Response
  • Preventative Maintenance
  • Safe Hot Work Practices

• Each Area “Championed” by CSB Board Member

• Web Information: https://www.csb.gov/mostwanted/
Combustible Dust Hazard Basics
Conditions for a Combustible Dust Explosion

- OXIDANT
- FUEL
- IGNITION SOURCE
- CONFINEMENT
- SUSPENSION
Secondary Explosions Present Additional Risks

1. PRIMARY EXPLOSION

2. BLAST WAVE

3. SECONDARY EXPLOSION

- DUST LAYER
- DUST CLOUD FORMED
Remove the CONFINEMENT Leg $\Rightarrow$ Flash Fire
Remove the SUSPENSION Leg $\Rightarrow$ “Regular” Fire
Remove any other Leg $\Rightarrow$ NO Explosion or Fire!
Assessing Combustible Dust Hazards

Cost Effectively Collecting Proper Data
### Examples of Combustible Materials

**Focus is on particles < 500 microns (35 mesh)**

<table>
<thead>
<tr>
<th>Agricultural Products</th>
<th>Chemical Dusters</th>
<th>Epoxy resin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg white</td>
<td>Adipic acid</td>
<td>Melamine resin</td>
</tr>
<tr>
<td>Milk, powdered</td>
<td>Anthraquinone</td>
<td>Melamine, molded</td>
</tr>
<tr>
<td>Milk, nonfat, dry</td>
<td>Ascorbic acid</td>
<td>(phenol-cellulose)</td>
</tr>
<tr>
<td>Soy flour</td>
<td>Calcium acetate</td>
<td>Melamine, molded</td>
</tr>
<tr>
<td>Starch, corn</td>
<td>Calcium stearate</td>
<td>(wood flour and</td>
</tr>
<tr>
<td>Starch, rice</td>
<td>Carboxy-methylcellulose</td>
<td>mineral filled phenol-</td>
</tr>
<tr>
<td>Starch, wheat</td>
<td>Dextrin</td>
<td>formaldehyde)</td>
</tr>
<tr>
<td>Sugar</td>
<td>Lactose</td>
<td>(poly) Methyl acrylate</td>
</tr>
<tr>
<td>Sugar, milk</td>
<td>Lead stearate</td>
<td>(poly) Methyl acrylate,</td>
</tr>
<tr>
<td>Sugar, beet</td>
<td>Methyl-cellulose</td>
<td>emulsion polymer</td>
</tr>
<tr>
<td>Tapioca</td>
<td>Paraformaldehyde</td>
<td>Phenolic resin</td>
</tr>
<tr>
<td>Whey</td>
<td>Sodium ascorbate</td>
<td>(poly) Propylene</td>
</tr>
<tr>
<td>Wood flour</td>
<td>Sodium stearate</td>
<td>Terpene-phenol resin</td>
</tr>
<tr>
<td></td>
<td>Sulfur</td>
<td>Urea-formaldehyde/</td>
</tr>
<tr>
<td></td>
<td></td>
<td>cellulose, molded</td>
</tr>
<tr>
<td><strong>Agricultural Dusts</strong></td>
<td><strong>Carbonaceous Dusts</strong></td>
<td>(poly) Vinyl acetate/</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>Charcoal, activated</td>
<td>ethylene copolymer</td>
</tr>
<tr>
<td>Apple</td>
<td>Charcoal, wood</td>
<td>(poly) Vinyl alcohol</td>
</tr>
<tr>
<td>Beet root</td>
<td>Coal, bituminous</td>
<td>(poly) Vinyl butyral</td>
</tr>
<tr>
<td>Carrageen</td>
<td>Coke, petroleum</td>
<td>(poly) Vinyl chloride/</td>
</tr>
<tr>
<td>Carrot</td>
<td>Lampblack</td>
<td>ethylene/vinyl acetylene</td>
</tr>
<tr>
<td>Cocoa bean dust</td>
<td>Lignite</td>
<td>suspension copolymer</td>
</tr>
<tr>
<td>Cocoa powder</td>
<td>Peat</td>
<td>(poly) Vinyl chloride/</td>
</tr>
<tr>
<td>Coconut shell dust</td>
<td>Potato</td>
<td>emulsion copolymer</td>
</tr>
<tr>
<td>Coffee dust</td>
<td>Potato flour</td>
<td></td>
</tr>
<tr>
<td>Corn meal</td>
<td>Potato starch</td>
<td></td>
</tr>
<tr>
<td>Cornstarch</td>
<td>Raw yucca seed dust</td>
<td></td>
</tr>
<tr>
<td>Cotton</td>
<td>Rice dust</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rice flour</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rice starch</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rye flour</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Semolina</td>
<td></td>
</tr>
</tbody>
</table>

| Soybean dust                               | Sunflower                                            |                                                   |
|                                            | Sunflower seed dust                                  |                                                   |
|                                            | Tea                                                  |                                                   |
|                                            | Tobacco blend                                        |                                                   |
|                                            | Tomato                                               |                                                   |
|                                            | Walnut dust                                          |                                                   |
|                                            | Wheat flour                                          |                                                   |
|                                            | Wheat grain dust                                     |                                                   |
|                                            | Wheat starch                                         |                                                   |
|                                            | Xanthan gum                                          |                                                   |

| Chemical Dusters                          | **Metal Ducts**                                      |                                                   |
| Adipic acid                                | Aluminum                                             |                                                   |
| Anthraquinone                              | Bronze                                               |                                                   |
| Ascorbic acid                              | Iron carbonyl                                         |                                                   |
| Calcium acetate                            | Magnesium                                            |                                                   |
| Calcium stearate                           | Zinc                                                 |                                                   |
| Carboxy-methylcellulose                    |                                                      |                                                   |
| Dextrin                                    |                                                      |                                                   |
| Lactose                                    |                                                      |                                                   |
| Lead stearate                              |                                                      |                                                   |
| Methyl-cellulose                           |                                                      |                                                   |
| Paraformaldehyde                           |                                                      |                                                   |
| Sodium ascorbate                           |                                                      |                                                   |
| Sodium stearate                            |                                                      |                                                   |
| Sulfur                                     |                                                      |                                                   |

| Carbonaceous Dusts                        | **Plastic Dusts**                                    |                                                   |
| Charcoal, activated                       | (poly) Acrylamide                                     | (poly) Acrylonitrile                             |
| Charcoal, wood                            | (poly) Acrylonitrile                                  | (poly) Ethylene                                 |
| Coal, bituminous                          |                                                      | (low-pressure process)                           |
| Coke, petroleum                           |                                                      |                                                   |
| Lampblack                                  |                                                      |                                                   |
| Lignite                                    |                                                      |                                                   |
| Peat, 22%H₂O                              |                                                      |                                                   |
| Soot, pine                                |                                                      |                                                   |
| Cellulose                                 |                                                      |                                                   |
| Cellulose pulp                            |                                                      |                                                   |
| Cork                                      |                                                      |                                                   |
| Corn                                      |                                                      |                                                   |

**Source:** [OSHA Combustible Dust Poster](http://www.osha.gov)
Combustibility / Explosibility of Dusts

- Determination of combustibility or explosibility shall be permitted to be based on the following:
  - Historical facility data or published data that are deemed to be representative of current materials & process conditions
  - Laboratory analysis of representative samples
    - Permitted to test a sample sieved to <75μm
    - Permitted to test the as-received sample
    - Permitted to assume a material is explosible, forgoing the laboratory analysis
  - Absence of previous incidents shall not be used as basis for deeming a particulate non-combustible or non-explosible

Note:
- Test results strongly influenced by particle size, moisture content, presence of contaminants
- Be sure test results are representative for your material!
# Typical Combustible Dust Tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Hazard Evaluated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Go/No Go Test (ASTM E1226)</td>
<td>Does the Dust Explode? (with a High Energy Ignition Source)</td>
</tr>
<tr>
<td>Minimum Ignition Energy (MIE)</td>
<td>The energy required to ignite a dust cloud under fairly ideal conditions.</td>
</tr>
<tr>
<td>Minimum Explosible Concentration (MEC)</td>
<td>The minimum amount of dust (dispersed in air) for an explosion.</td>
</tr>
<tr>
<td>Maximum Pressure Rise (Pmax) and Max Rate of Pressure Rise (Kst)</td>
<td>Dust Explosion Pressure Factors for Design of Containment and Relief Systems</td>
</tr>
<tr>
<td>Minimum Ignition Temperature (MIT) for Clouds and Layer</td>
<td>Used for Electrical Area Classification and for Dust Analysis if handled at Elevated Temperatures</td>
</tr>
<tr>
<td>Limiting Oxygen Concentration</td>
<td>Ignition prevention below what level of oxygen (used for inerting system design)</td>
</tr>
<tr>
<td>Electrostatic Chargeability</td>
<td>Determines How Easily a Material Develops and Retains Charge</td>
</tr>
</tbody>
</table>
Strategy for Dust Explosion Testing & Implications for Basis of Safety

3. Dust Explosion Screening
   - Can the dust form a cloud?

4. Dust Explosion Screening
   - Group Go/NoGo classification

5. Ignition Sensitivity
   - MIE (both IEC methods)
   - MIT
   - MIT Layer

6. Flammable Limits
   - LOC
   - MEC

Basis Of Safety
   - Avoidance of flammable atmospheres
   - Inering

Basis Of Safety
   - Avoidance of ignition sources

7. Explosion Severity
   - Pmax
   - Kst

Basis Of Safety
   - Containment
   - Explosion venting
   - Explosion suppression

Source: DEKRA Process Safety SAFETY GUIDE:
A strategic guide to characterization and understanding Handling Dusts and Powders Safely
Case Study: Hazards of Color Runs

June 27, 2015 Flash Fire (Formosa Fun Coast, Taiwan)

- Colored Corn Starch Deployed using Air Blowers
- “An Extremely Dense Dust Cloud over the Stage and its Immediate Vicinity”
- People near the Stage were “Ankle Deep” in Corn Starch
- **What Hazards Existed with Air Dispersed Corn Starch?**
- **497 People Injured; 15 Fatalities**
An Overview of Dust Hazard Analysis (DHA)

Establishing a Basis of Safety
Basis of Safety

- Avoidance of flammable atmospheres
- Elimination of ignition sources
- Provision against consequences of ignition
Managing Combustible Dust Fire and Explosion Hazards Requires…

Detailed knowledge of:

• Combustible material properties
• Process equipment
• Operating conditions
• Maintenance practices
• Existing controls (safeguards)
• and More…

• These are Generally Collected and Analyzed through a Dust Hazard Analysis (DHA), using NFPA 652

• Owner/operator of facility with potentially combustible dust shall be responsible for:
  • Determining combustibility and explosibility hazards of materials (Chapter 5)
  • Conducting a Dust Hazard Analysis (DHA) - Identifying and assessing fire, flash fire, and explosion hazards (Chapter 7)
  • Managing identified fire, flash fire, and explosion hazards
    • Prescriptive Approach (Chapters 5, 7, 8, 9)
    • It shall be permitted to use performance-based alternative designs for a building, equipment, ignition source control, and explosion protection in lieu of prescriptive requirements in Chapter 9 (Chapter 6)
  • Establishing Safety Management Systems (Chapter 8)
NFPA 652 (2019): Updates & Changes

• Issued as Consent Document (April 2018)

• Changes to DHA Timelines
  • DHA must be completed for Existing Processes by Sept 7, 2020
    • 2 Year Extension from NFPA 652 (2016)
  • 5 Year Revalidation Schedule

• Coordination with other NFPA Dust Standards
  • 2020 Edition of NFPA 654 proposes same Deadline
  • 2020 Editions of NFPA 61 and 664 will also be extending deadlines also

• Rearrangement of Chapter 8 & Chapter 9
  • Hazard Management: Mitigation & Prevention
  • Management Systems
Control of Combustible Dust Atmospheres (Control of Fugitive Emissions)

- Equipment should be maintained and operated in a manner that minimizes the escape of dust.
- Continuous local exhaust ventilation should be provided for processes where combustible dust is liberated in normal operation so as to minimize the escape of dust.
  - The dust should be conveyed to dust collectors.
- Regular cleaning frequencies should be established for floors and horizontal surfaces, such as ducts, pipes, hoods, ledges, and beams, to minimize dust accumulations within operating areas of the facility (1/32 inch; 0.8 mm – with adjustments).
  - **Warning Indicators that your Dust Accumulations are too large:**
    - Can you tell the color of the surface below the dust?
    - Can you write your name in the dust?
The Important Role of Dust Collectors

- Prevents Dust Accumulations
  - Collection & Removal of Fugitive Dusts
  - Controls Fugitive Dust Accumulations

- Key Design Considerations
  - Adequate Air Transport Velocity in Ductwork
    - Need to Prevent Dust Settling & Accumulation
  - Proper Design (and Direction) of Explosion Venting
  - Typically Installed Outdoors
  - Specific design features required to recirculate air
  - Never Store Dust in the Hopper
Implications of International Fire Code (2018) on Combustible Dust Operations
Sources of Requirements for Managing Combustible Dust

• OSHA
  • CPL 00-03-08 – Combustible Dust NEP

• Non-Regulatory Requirements
  • Insurance Company Standards (e.g. FM Global)
  • NFPA Codes & Standards

• Building & Fire Codes
  • Typically Adopted at Local & State Level
  • Applied for Issuance of Building Permits
  • Routine Inspections
  • Post-Incident
Regulatory Landscape: International Fire Code

What is an Occupancy Classification?

- A classification of buildings and structures that manages the use and occupancy
- To provide a rationale criteria that is relative to fire hazard and life safety considerations
- Implications on Building Construction, Size, & Layout

- Typical Classifications
  - Group F: Factory Industrial
  - Group S: Moderate- and Low-Hazard Storage
  - Group H: High Hazard

- **Group H Occupancy Classification**
  - Uses Tables in Chapter 50, Section 5003
  - General Rule based on “Exempt Amounts” for Storage & Use.
    - Amounts Greater than these levels become Group H
  - Adjustments allowed for Sprinkler Protection

- **Combustible Dust Classification (2012)**
  - No “Exempt Amounts”
  - Dust Manufactured or Used in a Fashion Presenting a Fire or Explosion Hazard (Table 5003.1.1(1))
    - Occupancy Group H2 Classification
  - Engineering Evaluation in Section 104.7.2 is required to quantitatively document risk analysis to **not** classify as Group H2
Chapter 22: Combustible Dust-Producing Operations

• Existing Requirements
  • Forced air or similar methods shall not be used to remove dust from surfaces
    • More stringent than existing NFPA requirements
  • Operational permits required for operations producing combustible dusts, such as flour mills and grain elevators

• New Requirements in 2018 Edition
  • Dust Hazard Analysis Required (NFPA 652)
    • 3 Year Implementation Cycle
  • Explosion Protection per NFPA Industry- or Commodity- Specific Standards
References

Sources of Recognized and Generally Accepted Good Engineering Practices (RAGAGEP)
References (with Free Access)

- National Fire Protection Association (NFPA)
  - NFPA 68 (2018), Explosion Protection by Deflagration Venting
  - NFPA 69 (2019), Standard on Explosion Prevention Systems
  - NFPA 61 (2017), Dusts in Agricultural and Food Processing Facilities
  - NFPA 484 (2019), Standard for Combustible Metals
  - NFPA 655 (2017), Standard for Prevention of Sulfur Fires and Explosions
  - NFPA 664 (2017), Dusts in Wood Processing and Woodworking Facilities
References (with Free Access)

- OSHA Dust Resources
  - OSHA Combustible Dust National Emphasis Program
  - Firefighting Precautions at Facilities with Combustible Dust

- FM Global

- United Kingdom Health & Safety Executive
  - Safe handling of combustible dusts: Precautions against explosions

- DEKRA Process Safety
  - SAFETY GUIDE: A strategic guide to characterization and understanding Handling Dusts and Powders Safely
Thank you for Participating in Today’s Presentation

Process-safety-usa@dekra.com
Mike.Snyder@dekra.com

609-799-4449
## DEKRA Process Safety

We help our clients to **adapt PSM to their needs & to build internal PS competence**

<table>
<thead>
<tr>
<th>Consulting</th>
<th>Laboratory Testing</th>
<th>Competence Development</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Process Safety Engineering</strong></td>
<td><strong>- Combustible Dust Fire &amp; Explosion</strong></td>
<td><strong>- Courses Covering all Key Aspects of Process Safety</strong></td>
</tr>
<tr>
<td>- Dust Flash Fire &amp; Explosion Hazards</td>
<td><strong>- Gas &amp; Vapor Flammability</strong></td>
<td><strong>- Continuing Education Units (CEU’s)</strong></td>
</tr>
<tr>
<td>- Gas &amp; Vapor Flammability Hazards</td>
<td><strong>- Thermal Instability</strong></td>
<td><strong>- Multiple Languages</strong></td>
</tr>
<tr>
<td>- Electrostatic Hazards</td>
<td><strong>- Chemical Reactivity</strong></td>
<td><strong>- Multimedia</strong></td>
</tr>
<tr>
<td>- Chemical Reaction Hazards</td>
<td><strong>- Static Electricity</strong></td>
<td><strong>- Instructor-Led Content</strong></td>
</tr>
<tr>
<td></td>
<td><strong>- DOT &amp; UN Transportation of Hazardous Materials</strong></td>
<td><strong>- Computer-Based Training</strong></td>
</tr>
</tbody>
</table>
| | **- Explosivity / Energetic Materials** | | }

<table>
<thead>
<tr>
<th>Process Safety Management</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Program Implementation &amp; Improvement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Gap Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Process Hazard Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Quantitative Risk Assessments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Consequence Modeling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Incident Investigations</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>