COMBUSTIBLE DUST
Pinnacle Engineering, Inc. (Pinnacle) was formed in 1991 by Jim Holland to serve the expanding environmental needs of industrial and manufacturing businesses.

As an environmental engineering and consulting company, Pinnacle provides a full range of environmental, industrial, civil engineering, and remedial field services -- serving the expanding environmental needs of railroad, industrial, commercial, utility, manufacturing, and renewable energy clientele.
Our staff is a multi-disciplined team of mechanical, civil, chemical, and geological engineers, who are focused on providing the professional expertise our clients have come to expect. Pinnacle takes pride in our systematic and common sense approach to the issues you face – achieving compliance without duplication of effort. Pinnacle also employs hydrologists, geologists, and natural resource scientists.

Pinnacle has grown steadily through our development of long term client relationships. Historically, over 90% of our revenue has been generated from past clients of the firm. Our loyalty client relationships are the cornerstone to our strong and steady growth. We will continue to partner with our clients to build strong relationships – resulting in effective, innovative solutions.
OUR LOCATIONS

MINNEAPOLIS, MN
763-315-4501

ROCHESTER, MN
507-280-5966

OMAHA, NE
402-932-2045

BISMARCK, ND
701-361-1574

BILLINGS, MT
406-570-5267
OUR MISSION

Comprehensive Solutions to Complex Environmental Engineering Problems

INTEGRITY
Adherence to moral and ethical principles, soundness of moral character and honesty.

CHANGE
Envision what could be and strive for adaptability. Challenge the status quo.

HUMILITY
Practice modesty, sincerity, and patience.

SAFETY FIRST
Safety is integral to the Pinnacle Culture

RESPECT
Encourage and practice teamwork. Treat others with dignity and sensitivity.

CUSTOMER FOCUS
Develop relationships with clients and anticipate and satisfy their needs.

KNOWLEDGE
Seek and use knowledge. Share knowledge with clients and co-workers.
COMBUSTIBLE DUST
“I KNOW IT WHEN I SEE IT”

Justice Potter Stewart; Jacobellis v. Ohio

**COMBUSTIBLE DUST**

No standard OSHA, EPA, or other regulatory definition

**DEFINITIONS**

OSHA National Emphasis Program (NEP)
National Fire Protection Association (NFPA)
“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.”

(OSHA CPL 03-00-008 “Combustible Dust NEP”)
“Combustible Particulate Solid: Any solid material composed of distinct particles or pieces, regardless of size, shape, or chemical composition, that, when processed, stored, or handled in the facility, has the potential to produce a combustible dust.”

(NFPA 61 and 652)
SIMPLE DEFINITION

DUST THAT IGNITES IN THE AIR
### EXAMPLES 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

#### Cottonseed
- Garlic powder
- Gluten
- Grass dust
- Green coffee
- Hops (malted)
- Lemon peel dust
- Lemon pulp
- Linseed
- Locust bean gum
- Malt
- Oat flour
- Oat grain dust
- Olive pellets
- Onion powder
- Parsley (dehydrated)
- Peach
- Peanut meal and skins
- Peat
- Potato
- Potato flour
- Potato starch
- Raw yucca seed dust
- Rice dust
- Rice flour
- Rice starch
- Rye flour
- Semolina

#### 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

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

#### Dextrin
- Lactose
- Lead stearate
- Methyl-cellulose
- Paraformaldehyde
- Sodium ascorbate
- Sodium stearate
- Sulfur

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

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

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**Combustible Dust - OSHA**

Does your company or firm process any of these products or materials in powdered form?
OSHA NEP
CPL 03-00-008

NO UNIFORM OVERARCHING OSHA STANDARD
*INCLUDED IN OVER 50 SEPARATE OSHA STANDARDS

GENERAL DUTY CLAUSE
Imminent hazard
HAZARD COMMUNICATION REQUIRES TRAINING ON:

- PHYSICAL
- HEALTH
- SIMPLE ASPHYXIATION
- COMBUSTIBLE DUST
- PYROPHORIC GAS HAZARDS
- AND ALL OTHER HAZARDS NOT OTHERWISE CLASSIFIED
FIRE MARSHAL
Each state is different

INSURANCE COMPANIES
Might be the largest driver

*May require compliance with codes or standards outside of OSHA
Not just about regulatory compliance

**OSHA's Mission:** “to assure safe and healthful working conditions for working men and women by setting and enforcing standards and by providing training, outreach, education and assistance.”

**NFPA Purpose:** Standards are developed to Preserve Life, Safety, and Continuity of Mission
PRIOR INCIDENTS

CTA Acoustics
West Pharmaceuticals
Hayes Lemmerz
Imperial Sugar
Didion Milling

Images taken from CSB Combustible Dust Gallery
PRIOR INCIDENTS – CTA ACOUSTICS

CTA Acoustics

Location: Corbin, Kentucky
Date: February 20, 2003

Produced acoustic insulation products for automobiles

Result: 7 Fatalities; 37 injuries

Images from CSB
West Pharmaceuticals

Location: Kinston, North Carolina
Date: January 29, 2003

Produced syringe plungers, intravenous components, and rubber compounding

Result: 6 Fatalities; 38 injuries

Images from CSB
PRIOR INCIDENTS – HAYES LEMMERZ

Hayes Lemmerz
Location: Huntington, Indiana
Date: October 29, 2003
Produced cast aluminum alloy wheels
Result: 1 Fatality; 6 injuries

Images from CSB
PRIOR INCIDENTS – IMPERIAL SUGAR

Imperial Sugar
Location: Port Wentworth, Georgia
Date: February 7, 2008
Produced granulated sugar and sugar products
Result: 14 Fatalities; 36 injuries

Images from CSB
Didion Milling
Location: Cambria, Wisconsin
Date: May 31, 2017
Corn milling
Result: 5 Fatalities; 12 injuries
Images from CSB
HAZARD RECOGNITION

Combustible Dust

Fire Triangle

Explosion

Pentagon
Hazard prone areas

- Areas that handle dry bulk materials are capable of producing and gathering dust.
- Equipment in these areas with moving parts or electrical sources.
- Any areas that are subject to shock or dispersal of dust.
Key areas to focus on.

- Grain handling.
  - conveyors
  - elevators
  - mills
- DDGS
- Areas that provide sufficient confinement and potential for heat source.
- Recall the Combustible Dust Pentagram
652 - Standard on the Fundamentals of Combustible Dust

61 - Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities

484 - Standard for Combustible Metals

664 - Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities

655 - Standard for Prevention of Sulfur Fires and Explosions

654 - Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids
NFPA STANDARDS
Combustible Dust

652 - Fundamentals of Combustible Dust

- Industry Specific Standards
  61 - Agricultural and Food Processing Facilities
  484 - Combustible Metals
  664 - Wood Processing and Woodworking Facilities
  655 - Sulfur Fires
  654 - Everyone Else

- Guide to Combustible Dust
NFPA STANDARDS
Combustible Dust

652 - Fundamentals of Combustible Dust

Industry Specific Standards

61 - Agricultural and Food Processing Facilities

- Guide to Combustible Dust
Before diving in...Housekeeping items

- Who is NFPA?
- Consensus Standards
- Retroactivity
- Conflicts
New standard
September 7th, 2015 -- Effective Date

- Provides the general requirements for management of combustible dust fire and explosion hazards
- Directs the user to NFPA’s industry- or commodity-specific standards, as appropriate
- Establishes relationship and hierarchy between the standards
First developed in 1923 -- Grain Elevators and Flour Mills

1995 The four NFPA standards were combined into NFPA 61

2013 -- Requirements for bucket elevators, written housekeeping program for dust control systems, pneumatic conveying systems, and standpipes were added/revised

2017 Current version -- “Substantial” changes
2017 Current version -- “Substantial” changes

Chapter 3 - New definitions
Chapter 4 - “General Requirement”
Chapter 5 - “Hazard Identification”
Chapter 6 - “Performance-Based Design Option”
Chapter 7 - “Dust Hazard Analysis (DHA)”
Chapter 8 - “Hazard Management”
Chapter 9 - “Management Systems”
NFPA OBJECTIVES

Combustible Dust

1. Life Safety
2. Mission Continuity
3. Mitigation of fire spread and explosions
NFPA COMPLIANCE OPTIONS
Combustible Dust

A. Prescriptive
B. Performance Based

What is the design bases of your facility?
OVERVIEW - COVERED MATERIAL?
Combustible Dust

Do you have Dust?

- No → Outside Scope
- Yes → Exempt?

- Yes
- No
Determined Combustibility or Explosibility?

No

Determine.

Yes

OVERVIEW - COMBUSTIBLE?
Combustible Dust
Is material Combustible?

Yes

No

Stop: Document
OVERVIEW - DHA?
Combustible Dust

DHA Done?

Yes

No

Perform DHA
Mitigation Plan to manage hazards?

- No
  - Develop written Plan in Conjunction with industry specific standard

- Yes
  - Implement and Maintain Plan
1. Determine if Combustible
2. DHA
3. Mitigation Plans
DETERMINE COMBUSTIBLE
Combustible Dust

Two Options

A. Assume dust is combustible / use tabulated data
B. Test Dust
## Assume dust is combustible

Table A.5.2.2(a) 20-L Sphere Test Data – Agricultural Dusts

<table>
<thead>
<tr>
<th>Dust Name</th>
<th>$P_{max}$ ((\text{bar g}))</th>
<th>$K_{st}$ ((\text{bar m/sec}))</th>
<th>Percent Moisture</th>
<th>Particle Size ((\mu\text{m}))</th>
<th>Minimum Explosive Concentration ((\text{g/m}^3))</th>
<th>Percent Greater Than 200 Mesh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>6.7</td>
<td>94</td>
<td>2.1</td>
<td>36</td>
<td>125</td>
<td>98</td>
</tr>
<tr>
<td>Apple</td>
<td>6.7</td>
<td>34</td>
<td></td>
<td>155</td>
<td>125</td>
<td></td>
</tr>
<tr>
<td>Beet root</td>
<td>6.1</td>
<td>30</td>
<td></td>
<td>108</td>
<td>125</td>
<td></td>
</tr>
<tr>
<td>Carrageen</td>
<td>8.5</td>
<td>140</td>
<td>3.8</td>
<td>29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carrot</td>
<td>6.9</td>
<td>65</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cocoa bean dust</td>
<td>7.5</td>
<td>152</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cocoa powder</td>
<td>7.3</td>
<td>128</td>
<td></td>
<td></td>
<td></td>
<td>51</td>
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<tr>
<td>Coconut shell dust</td>
<td>6.8</td>
<td>111</td>
<td>6.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coffee dust</td>
<td>6.9</td>
<td>55</td>
<td>4.8</td>
<td>321</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn meal</td>
<td>6.2</td>
<td>47</td>
<td>8.2</td>
<td>403</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cornstarch</td>
<td>7.8</td>
<td>163</td>
<td>11.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotton</td>
<td>7.2</td>
<td>24</td>
<td></td>
<td>44</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
**DETERMINE COMBUSTIBLE**

**Combustible Dust**

Assume dust is combustible

---

**Table A.5.2.2 20-L Sphere Test Data — Agricultural Dusts**

<table>
<thead>
<tr>
<th>Dust Name</th>
<th>Percent Moisture</th>
<th>Median Particle Size (µm)</th>
<th>Percent &lt; 200 Mesh (%)</th>
<th>$P_{\text{max}}$ (bar g)</th>
<th>$(1)\ K_S$ (bar m/sec)</th>
<th>Minimum Explosive Concentration (g/m³)</th>
<th>Minimum Ignition Energy (mJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cocoa powder</td>
<td>3.9</td>
<td>194</td>
<td>14</td>
<td>8.0</td>
<td>162</td>
<td>65</td>
<td>100–180*</td>
</tr>
<tr>
<td>Coconut shell dust</td>
<td>6.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coffee dust – coarse</td>
<td>4.8</td>
<td>321</td>
<td>0.4</td>
<td>6.9</td>
<td>55</td>
<td></td>
<td>160*</td>
</tr>
<tr>
<td>particles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coffee dust – fine particles</td>
<td>4</td>
<td>40</td>
<td>100</td>
<td>7.7</td>
<td>158</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn (maize)</td>
<td>9.0</td>
<td>165</td>
<td>100</td>
<td>8.7</td>
<td>117</td>
<td>30</td>
<td>&gt;10</td>
</tr>
<tr>
<td>Corn meal</td>
<td>8.2</td>
<td>403</td>
<td>0.6</td>
<td>6.2</td>
<td>47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cornstarch – coarse</td>
<td>2.2</td>
<td>217</td>
<td>0.1</td>
<td>7.9</td>
<td>186</td>
<td></td>
<td>30–60*</td>
</tr>
<tr>
<td>particles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cornstarch – fine particles</td>
<td>11</td>
<td>100</td>
<td>9.5</td>
<td>141</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotton</td>
<td>44</td>
<td>72</td>
<td>7.2</td>
<td>24</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DETERMINE COMBUSTIBLE

Combustible Dust

Assume dust is combustible

Before using tabulated data:

1. Is the data representative of your dust?
2. Is it the same material?
3. Does data exist?
DETERMINE COMBUSTIBLE
Combustible Dust

Test Dust

1. Develop sampling Plan
2. Test Dust
3. Interpret / document results
Test Dust – Sampling Plan

1. Locations of where dust is present
2. Identification/collection of representative samples
3. Sample integrity preservation
4. Sample handling
5. Documentation of samples taken
6. Safe collection practices
2. Representative Samples...
Do we?
Test a worst case sample (finest)
Dry the sample prior to testing
Mill the sample prior to testing
Test “as received”
DUST TESTING

1. Initial characterization (Particle size and moisture levels)
2. Deflagration Index \((K_{st})\) [ASTM E1226] Includes maximum pressure \((P_{\text{max}})\)
3. Minimum explosible concentration (MEC) [ASTM E1515]
4. Minimum Ignition Energy (MIE) [ASTM E2019]
5. Layer Ignition Temperature (LIT) [ASTM E2021]
6. Minimum Autoignition Temperature (MAIT) [ASTM E1491]
7. Limiting Oxygen Concentration (LOC) [ASTM E2079 or ASTM WK1680]
## Test Dust -- Dust testing...

<table>
<thead>
<tr>
<th>Method</th>
<th>Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM E1226</td>
<td>$K_{st}$ and $P_{Max}$</td>
</tr>
<tr>
<td>ASTM E1515</td>
<td>MEC</td>
</tr>
<tr>
<td>ASTM E2019</td>
<td>MIE</td>
</tr>
<tr>
<td>ASTM E1491</td>
<td>$T_c$ Dust clouds</td>
</tr>
<tr>
<td>ASTM E2021</td>
<td>$T_c$ Dust layers</td>
</tr>
<tr>
<td>ASTM E2931</td>
<td>LOC</td>
</tr>
</tbody>
</table>
The DHA is intended to be a detailed survey at the process to identify hazards and then control those hazards

New Facilities

Required DHA as a part of the project
Before operation of the equipment
Existing Facilities

NFPA 652 versus NFPA 61

Both retroactive provisions

- 652 – Three years from 9/7/15
- 61 – Five years from 6/2/16
DUST HAZARD ASSESSMENT

Combustible Dust

DHA is a Team Sport

Qualified Leader
Facility Operators
Facility Engineers
Facility Owners
Equipment Manufacturers / Consultant
DHA must be documented

DHA Methodology -- Shall include:

1. Identification and evaluation of the process where fire/explosion hazards exist

2. Where hazards exist:
   a) Identify safe operating ranges
   b) Identify safeguards
   c) Recommend additional safeguards (as needed)
DHA Methodology:

3. Based on data obtained and representative of dust on site

4. Each part of the process shall be evaluated:
   a) Potential intended and unintended dust transport between process systems
   b) Potential fugitive dust emissions in buildings
   c) Deflagration propagation
DHA Methodology:

5. Each building or compartment shall be evaluated:

a) Potential intended and unintended dust transport between process systems
b) Potential fugitive dust emissions in buildings
c) Deflagration propagation
d) Include comparison of actual or intended accumulation to hazard threshold
DHA should consider the four conditions required for deflagration:

1. Small enough particle
2. Particle suspended in air
3. Sufficient concentration to ignite
4. Ignition source
Dust Hazard Assessment

Combsitible Dust

DHA:

Systematic Approach
Six Questions

1. What does “normal” look like for the process?
2. What can go wrong (and how)?
3. How bad, and how likely, can it be?
4. What protections currently exist?
5. What is the risk of continuing to operate as now?
6. Is additional protection warranted (if so, what)?

Intent is to control ALL hazards
SAMPLE DHA
Combustible Dust
SAMPLE DHA
Combustible Dust

1. Process input
2. Offload fan
3. Duct from fan to cyclone
4. Cyclone
5. Silo
6. Duct
7. Outfeed screw conveyor
8. Mill and discharge fan
9. Discharge duct to screens
10. Screens
11. Screw conveyor
12. Product screw conveyor
13. Duct
14. Duct
15. Duct
16. Duct
17. Dust collector
18. Fan
19. Duct for return air
20. Relay fan

1. What does “normal” look like for the process?
2. What can go wrong (and how)?
3. How bad, and how likely, can it be?
4. What protections currently exist?
5. What is the risk of continuing to operate as now?
6. Is additional protection warranted (if so, what?)
SAMPLE DHA
Combustible Dust

FIGURE B.4.5.4 The Operating Cyclone in Cross-Section. (Source: J. M. Cholin Consultants, Inc.)

FIGURE B.4.5.5 A Silo Serves as a Particle Size Separator and Becomes an Explosion Hazard. (Courtesy: J.M. Cholin Consultants, Inc.)
HAZARD MITIGATION
Combustible Dust

From NFPA 61 Chapter 8:

a. Building Design
b. Equipment Design
c. Housekeeping
d. Ignition Source Control
e. Personal Protective Equipment
f. Dust Control
g. Explosion Prevention/Protection
h. Fire Protection
NFPA 61 Chapter 9 Management Systems:

a. Operating Procedures and Practices (hot work—2013)
   i. Written Procedures
   ii. Safe work limits
   iii. Consequences of deviation

b. Inspection, Testing, and Maintenance

c. Training and Hazard Awareness
   i. Operations training
   ii. Annual Refresher / Documented

d. Contractors (outside contractors—2013)
   i. Knowledgeable Contractors for modifications
   ii. Awareness training/orientation and ER procedures
HAZARD MITIGATION
Combustible Dust

NFPA 61 Chapter 9 Management Systems:

e. Emergency Planning and Response
   i. Emergency Action Plan
   ii. Annual Training
   iii. Coordinate with local responders

f. Incident Investigation

g. Management of Change
   i. Qualified person
   ii. Changes comply with NFPA 61
HAZARD MITIGATION
Combustible Dust

More on Management of Change:

NFPA 652 [9.9]

i. Written Procedures
   1) The basis for the proposed change
   2) Safety and health implications
   3) Permanent or temporary, (authorized duration)
   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

ii. Update Design and Procedures
    Documentation after change

NFPA 61 [9.9]

i. Only Requires Evaluation and Compliance with 61
HAZARD MITIGATION
Combustible Dust

NFPA 61 Chapter 9 Management Systems:

h. Document Retention
   i. Training records
   ii. Inspection, testing, Maintenance
   iii. Incident reports
   iv. Dust hazard analysis
   v. Process technology information
   vi. Management of Change records
   vii. Contractor records

i. Management Systems Review

j. Employee Participation
SUMMARY
Combustible Dust

- Extensive changes to non-regulatory standards
- Reduce risk of fire and explosion from combustible dust

Action Items:
1. Identify dusts in facility
2. To Test or To Not Test...
3. DHA
4. Prepare and implement mitigation programs
QUESTIONS?
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MANAGER of MIDWEST OPERATIONS
PHONE: 402-932-2045
EMAIL: mhenry@pineng.com