Combustible Dust: Food That Goes Boom
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Iowa–Illinois Safety Council
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Product brand names are examples only
Protect property from dust explosions

- Merrill’s Objectives
  - Protect people from dust explosions
  - Protect property from dust explosions
  - Regulatory Compliance
  - Appropriate level of control

Agenda
- Why common dust explodes
- History of dust explosions
- OSHA ????????
- NFPA Combustible Dust standards
- Combustible dust properties (Kst, Pmax, MIE)
- Dust Explosion Prevention
- Explosion venting
- Explosion suppression
- Explosion isolation
- Housekeeping and flash fires
- Demonstration of small dust explosion

Fire Triangle
- Oxygen
- Heat
- Fuel

Dust Explosion Pentagon
- Confinement
- Suspension
- Combustible Dust
- Ignition
Demonstration of Dust Explosion

20 Liter Sphere

1 m³ Vessel

How Can Food Dust Explode?

How much dust is needed?

Appearance of an Explosible Dust Cloud
A cloud of 48 kg/m³ of coal dust is so dense that a glowing 25W light bulb can hardly be seen through a dust cloud of 2 cm thickness.

Source: Kuhner

Combustible Dust
Does your company or firm process any of these products or materials in powdered form?

Includes:
- Corn Starch
- Cocoa Powder
- Sugar (10x)
- Rice Flour
- Powdered Milk
- Carrot Dust
- Tea

For a 20 l Test Apparatus the following equation applies:

$P_{max} = \frac{682 \times 10^{1.7} \times 42 \times 48 \times 0.1}{V} \times K_{st}$
Are All Dusts the Same?

- \( K_{ST} \) - Deflagration Index (Speed of reaction)
  - St 0: 0 Weak to Moderate
  - St 1: 0–200 Strong
  - St 2: >300 Very Strong

- \( P_{max} \) - Maximum Pressure (bar)
  - 1 bar = 15 psi

- MIE - Minimum Ignition Energy (millijoule)
  - Discharges from human body, up to 25–30 mj
  - Pneumatic conveying up to 1000 mj

Sample of Data

<table>
<thead>
<tr>
<th>Product</th>
<th>( K_{ST} )</th>
<th>( P_{max} ) (bar)</th>
<th>MIE (mj)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar</td>
<td>138</td>
<td>8.5</td>
<td>400–700</td>
</tr>
<tr>
<td>Corn Starch</td>
<td>143–202</td>
<td>7.8–10.3</td>
<td>30–300</td>
</tr>
<tr>
<td>Coal Dust</td>
<td>152</td>
<td>8.3</td>
<td>60–700</td>
</tr>
<tr>
<td>Corn</td>
<td>75/169</td>
<td>9.4/7.8</td>
<td>40</td>
</tr>
<tr>
<td>Gluten Meal</td>
<td>116</td>
<td>7.3</td>
<td>50–100</td>
</tr>
<tr>
<td>Feed/Bran</td>
<td>67–120</td>
<td>7.3–8.3</td>
<td>300–500</td>
</tr>
<tr>
<td>Soy Flour</td>
<td>117</td>
<td>7.4</td>
<td>&gt;500</td>
</tr>
<tr>
<td>Wheat Flour</td>
<td>87, 88</td>
<td>8.3</td>
<td>60</td>
</tr>
<tr>
<td>Cocoa</td>
<td>62–108</td>
<td>6.5–9.1</td>
<td>120</td>
</tr>
<tr>
<td>Cottonseed Hulls</td>
<td>46</td>
<td>7.4</td>
<td>&gt;500</td>
</tr>
<tr>
<td>Cellulose</td>
<td>82–86</td>
<td>8.6</td>
<td>1000–10,000</td>
</tr>
<tr>
<td>Citric Acid</td>
<td>100–105</td>
<td>6.8</td>
<td>&gt;400,000</td>
</tr>
<tr>
<td>Glucosamine</td>
<td>105, 102</td>
<td>10.2</td>
<td>&gt;28,000</td>
</tr>
<tr>
<td>Erythritol</td>
<td>255, 72</td>
<td>7.2</td>
<td>4</td>
</tr>
</tbody>
</table>

Why So Dangerous?

- Dust Explosions produce
  - Flame ball over 30 feet long in controlled venting
  - Pressure from air heating up rapidly can be over 150 psig if pressure is contained
  - Both occur in less than 100 milliseconds
  - Equipment or enclosures are not rated for the peak pressure that is generated in about 100msec can catastrophically fail resulting in personnel injury and significant property damage.

First Recorded Dust Explosion

- Dec 14, 1785
- Turin, Italy
- Bakery
- Very dry flour
- 2 boys injured

Cedar Rapids, Iowa

On May 22, 1919, the Douglas Starch Works exploded at about 6:30 p.m. There were 109 men in the plant at the time of the explosion. The pillar of dust and flames shot skyward about 5000 feet and the explosion was felt 30 miles away. Doors were blown open and windows shattered at the Cedar Rapids Country Club three and one-half miles away.

Of the 43 men who lost their lives, 10 bodies were never found, 10 bodies were partially found and buried in a common grave in Linwood Cemetery.
DeBruce Elevator Explosion
- June 8, 1998 near Wichita, Kansas
- 11 people were injured, and seven died

This dust explosion appeared to propagate through almost the entire complex, both in the tunnels below, and the structures across the top of the silos. Almost no part of the elevator was untouched by the explosion. Many of the silos had their tops blown out. A prime example of the force of the explosion was a heavy steel door which covered one of the tunnel entrances, approximately 7 feet by 7 feet, weighing about 600-800 pounds, which was missing. Initially rescue workers wondered where it had gone, until someone looked up...and saw that it appeared to be “shrink-wrapped” into the I beams of the gallery floor 120 feet straight up!

Imperial Sugar Explosion
- Feb 7, 2008
- 14 Fatalities


Dust in the News

Bartlett Grain – Atchison Kansas
October 29, 2011
- 6 Dead
- 2 Burn Unit
- 4 Escaped?

FOX NEWS Link
**Flash Fire**

**Bartlett Milling– Statesville, NC**  
April 7, 2013  
Flash after turning power back on after repair  
One Burn Injury

**Aug 13, 2014  Coshocton, OH**  
Seven injured. Likely cause was a spark amid the grain dust as several rail cars were being filled with corn

**Aug 22, 2014  Evendale, OH**

**Sept 14, 2014  Flagstaff, AZ**  
Nestle Purina Pet Food
- 4 Burned
- Maintenance
- No Operators on site
- Flash Fire

**Combustible Dust Incidents**
- Corbion: Grandview MO
  - Emulsifiers
  - March 11, 2015
  - 3 Injuries
  - Started in Packaging dust Collector
  - Outside walls designed to relieve
More Incidents

- Wrigley-Chattanooga 3-18-15
  - Starch dust collector
  - Explosion and fire

- OK Foods Feed Mill 3/23/15
  - Flash Fire from welding on bin
  - 3 burned

- Vita Line Pet Food – PA 3/31/15
  - Silo explosion after fire
  - No Injuries

...and still more

- Feed mill silo explosion in Netherlands
  - April 13, 2015

- LaPorte County Grain, IN
  - April 16, 2015
  - 4 injured – 2 LifeFlight

- Pilgrim’s Pride Chicken Feed, GA
  - Explosion with significant damage

Wood Flour Mills–England

- July 17, 2015
- 3 Explosions and Fire
- 4 Fatalities
- 4 Hospitalized

Simmons Poultry Feed Mill –12/1/15

- Fairland, OK
- Fire smoldered for weeks
- Explosion blew top off silo

- 3 people seriously burned 5 years ago from an explosion and fire

Perfetti Van Melle – 12/4/15

- Airheads Candy
- Erlanger, KY (South of Cincinnati)
- Sugar silo explosion and fire

- 2003 Explosion
  - Maltodextrin
  - Ignited by static
  - 1 person injured

Feed Mill Explosion–Rockmart, GA

- JCG Farms, February 7, 2016
  - 1 Fatality plus 5 injuries
    - 1 still hospitalized a week later
    - If during week, 35 vs 8 people on site
  - $3 million damage
  - ATF: Series of dust explosions
    - Originated at base of concrete tower near receiving area
    - Ignited natural gas line
### Hinton IA Grain Elevator
- Central Valley Ag elevator
- March 17, 2016
- Explosion and fire
  - Dump control house in flames
  - 2 people severely burned

![Image of Hinton IA Grain Elevator]

### WestPine MDFB
- Quesnel, BC
- March 9, 2016
- Explosion and fire involve 4 baghouses
- Facility had demonstrated it had a compliant program for management of combustible wood dust

![Image of WestPine MDFB]

### Oregano Explosion
- April 5, 2016
- Spice plant in Reno, NV
- Dust explosion in grinding hopper
- No injuries

![Image of Oregano Explosion]

### Emsland-Stärke (Germany)
- June 7, 2016
- Explosion when workers opened inspection hatch of a mixing machine for corn starch
- 1 fatality

![Image of Emsland-Stärke (Germany)]

### Fish Meal Explosion
- Dutch Harbor, Alaska
- September 19, 2016
- Explosion of fine fish meal
- No injuries

![Image of Fish Meal Explosion]

### Tate & Lyle
- September 26, 2016
- Francesville, Indiana
- Explosion started in bucket elevator leg
- 2 people severely injured and later died

![Image of Tate & Lyle]
Didion Milling
- May 31, 2017
- Didion Milling in Cambria, Wisconsin
- Reports of 2 distinct explosions
- 16 employees on site
  - 4 fatalities after first week
  - 12 treated for burns and four extended hospital
  - June 23rd a fifth person died from injuries

Grain Bin Collapse
- July 31, 2017
- Farm near Switz City, Indiana
- No injuries

Cinnamon Shower?
- Denmark Bachelor Tradition

Are You a Believer?
 Regulatory: OSHA

  - Held up as an effective model
- OSHA developing a new standard
  - Enforcement by using the General Duty Clause
  - OSHA process delayed GHS (Globally Harmonized System) March 2012
  - Dust included as a “Hazardous Chemical”
- The CSB (Chemical Safety Board) designated general dust standard as first “Most Wanted Safety Improvement.”

 GHS Label Elements

- Hazard: Combustible Dust
- Signal word: Warning
- Hazard Statement: May form combustible dust concentrations in air
- Pictogram: No Pictogram
- Precautionary Statement (possible language):
  - Keep away from heat/sparks/open flames/hot surfaces. – No smoking. Keep container tightly closed. Ground/bond container and receiving equipment. Prevent dust accumulation to minimize explosion hazard.

 NFPA Dust Standards

- Consensus Standards
- Guidance for Prevention and Mitigation
- RAGAGEP (Recognized And Generally Accepted Good Engineering Practices)
- Great resource
- Not Directly Enforceable by OSHA
  - General Duty Clause

 NFPA: Free Access

http://www.nfpa.org/codes-and-standards/free-access

 NFPA Standards—Basis for Safety

- Prevent or limit formation of hazardous atmosphere
- Prevent ignition
- Limit the consequences of a deflagration to an acceptable level
  - Including secondary explosions
**NFPA Occupancy Standards**

- NFPA 652: Fundamentals of Combustible Dust
  - New September 7, 2015
- Industry Specific
  - NFPA 61: Agriculture and Food Processing
  - NFPA 484: Combustible Metals
  - NFPA 655: Sulfur
  - NFPA 664: Wood Processing and Woodworking
  - NFPA 654: Combustible Particulate Solids

*Industry Specific Standard Prevails*

**NFPA Design Standards**

- NFPA 68: Deflagration Venting
- NFPA 69: Explosion Prevention Systems
- NFPA 77: Static Electricity
- NFPA 91: Air Conveying
- NFPA 499: Classification of Hazardous Locations
- NFPA 70: NEC (National Electrical Code)
- NFPA 13: Sprinkler Systems
- NFPA 15: Water Spray for Fire Protection
- NFPA 72: Fire Alarm and Signaling

**NFPA: DHA (Dust Hazard Analysis)**

- Evaluate fire, deflagration, and explosion hazards
- Specific fire and deflagration scenarios
  - ID safe operating ranges
  - ID safeguards in place
- Recommendation of additional safeguards to manage the hazards
- Performed or led by a qualified person
- Documented including action items

**DHA Techniques**

- Checklist Analysis
- What If Analysis
- What If with Checklist
- HAZOP (Hazard and Operability Analysis)
- LOPA (Layers of Protection Analysis)
- FEMA (Failure Modes and Effects Analysis)

**NFPA 652: DHA Retroactivity**

- For existing processes undergoing material modification (25% of original cost), DHAs as part of the project
- For other existing processes complete DHAs within a 3 5-year period and demonstrate reasonable progress in each of the 3 years
  - NOTE: Originally 5 years

**NFPA 652: Hazard Management**

- Follow Prescriptive Standards
  - or -
- Performance Based Design
  - Risk based
  - Permitted to use in lieu of prescriptive
  - Design prepared by person with qualifications acceptable to the owner/operator
  - Design documented in a format and content acceptable to the AHJ
NFPA 652: Management of Change
- Written procedures to manage changes to:
  - Process materials
  - Technology and equipment
  - Procedures and facilities
  - Staffing
  - Job tasks

NFPA: Housekeeping
- Included in all NFPA Occupancy Standards
- Housekeeping strategy
- Accumulation depths

FM Global
- 5-1 Elect Equip in Hazardous Locations
- 5-8 Static Electricity
- 7-17 Explosion Protection Systems
- 7-73 Dust Collectors and Collection Systems
- 7-75 Grain Storage and Milling
- 7-76 Prevention and Mitigation of Combustible Dust Explosion & Fire

Dust Explosion Prevention
- Confinement
- Oxygen
- Suspension
- Ignition
- Combustible Dust

Layers of Protection
- Confinement
- Explosion Vents
- Sanitation
- Ignition Source Control
- High Humidity
- Recycle Flue Gas
- Oxygen
Ignition Prevention System

- No Smoking on site
- Management of Hot Work
  - Welding
  - Cutting
  - Grinding

Ignition Prevention

- Magnets to remove tramp metal
- Bonding and Grounding
- Bearing Temperature Monitoring
- Belt alignment switches (rub blocks)
- Belt slow down switch
- Electrical Classifications
  - Class II, Div 1, Group G
  - Dust usually present
  - Rated enclosures
  - Class II, Div 2, Group G
  - Dust not usually present
  - Dust tight enclosures
Non SCOF Conveyor Belt

- Static Conductive Oil-resistant Fire-retardant
Suspension and Concentration

- Aspiration Systems
  - Big Vacuum Cleaners
  - Reduces concentration inside equipment
  - Reduces dust leakage outside of equipment
**Explosion Protection**
- Containment – 10 bar (150 psi) construction
- Explosion Relief Venting
- Explosion Suppression
- Explosion Isolation

**Explosion Relief Venting**

**Explosion Vents**
- Low burst pressure
- Wide range of sizes
- Stainless Steel
- one piece clean type
- composite type
- high temp type
- Replace after use
- Low inertia / fast to open
- No Fragmentation
- Open Vent sensor option
- Sized in accordance with NFPA 68 or VDI 3673 or EN 14491:2006
Brixon Latch
Venting Considerations

- Environment
- Operating Conditions
- Vessel Location
- Vessel Strength
- Interconnections;
  - Isolate ducting
- Post Explosion Fires
- Reaction Forces
- Line of Fire

Fireball Size

<table>
<thead>
<tr>
<th>Vessel Size (cubic ft)</th>
<th>Fireball with 1 vent (ft)</th>
<th>Vents</th>
<th>Fireball (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>17</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>50</td>
<td>30</td>
<td>2</td>
<td>23</td>
</tr>
<tr>
<td>100</td>
<td>37</td>
<td>3</td>
<td>26</td>
</tr>
<tr>
<td>500</td>
<td>63</td>
<td>4</td>
<td>40</td>
</tr>
</tbody>
</table>

Exposure to Explosion Vents
Flameless Vents

Designed for applications where equipment is indoors & safe venting through ducting is not possible or flameball is not acceptable.

NFPA 68– Inspection and Maint

- 5.2.4.1 Deflagration venting shall be regularly inspected and maintained to confirm the ability of the venting to perform as designed.
- 5.2.4.2 Inspection and maintenance shall be documented and retained for at least 1 year or the last three inspections.
Sequence of Events:
1. Explosion Sensed
2. Cannons Activated
3. Suppression Agent Released Into Process
4. Explosion Suppressed & Burning Material Isolated
5. Process Shutdown

IPD System applied to Dust Collector
How Suppression Protects Equipment

- Suppression typically over 100 psi
- Fire typically less than 3 psi

By mitigating the impact of an explosion, the pressure generated remains below a safe level for the process equipment.

**Isolation**

Prevent propagation of flame through piping
- Mechanical Methods
  - Fast acting Knife gate valve.
  - Pinch Valve
- Rotary valve of suitable construction

Chemical Isolation

**Mitigation: Passive Inlet Explosion Isolation**

- Positive Explosion Isolation for Collector Inlet Ducts
- Lower Cost Alternative to High-Speed Valves or Chemical Isolation
- Ensure improve reliability, reduce inspection frequency
- Third-Party Performance-Based Approvals per NFPA Requirements

**Secondary Explosions**

1. Dust accumulates on work surfaces
2. An event disperses dust, creating a cloud
3. The cloud ignites and explodes

Catastrophic Results
- Building Collapse
- Fatal Burns

**Sanitation**

- Conditions
  - Can I see my footprints?
  - Can I write in the dust?
  - Can I see the underlying color?
- Cleaning Frequency
  - Before it is unacceptable
  - Procedure in case of upset
Sanitation – Cleaning Methods

- Maintain dust level to < 1/32” over 5% of area
- Exception procedure if exceed 1/8”
- Sanitation Procedure
  - Vacuum
  - Sweep or wash down (not stir up dust)
  - Compressed air blow down (NOT RECOMMENDED)
  - Only for inaccessible surfaces
- Ignition sources and hot surfaces eliminated

Until it finds an ignition source...

- 498 Burned
- 221 Intensive Care
- June 29 – 1st fatality
- July 2 – 2nd death
- July 6 – 3rd fatality
- July 30 – 10th fatality
- Oct 29 – 13th fatality
- 44 still hospitalized with 11 in intensive care
- Nov 29 – 15 victims
  - Also 2 related suicides

Color Play Asia

- Taiwan Water Park
- June 27, 2015
- 1000 having fun
- Safe, non-toxic
  - Corn Starch
  - Food Coloring
  - NO Heavy Metals
  - NO Lead

NOT Recommended
Fire Fighting
- Furniture manufacturing
- Abbotsford, B.C.
- September 12, 2016

Top 3
- 1. Sanitation
- 2. Sanitation
- 3. Sanitation
  - The single biggest difference between a small explosion and a disaster
    - NFPA 654: 1/32” over 5% of area
    - NFPA 61: 1/8” over 5% of area

Key Take-Aways
- Food dust can be explosive
- Dust explosions can be devastating
- NFPA dust standards
  - Know your dust
  - Scenarios and protection layers
- Secondary explosions are the most dangerous!

Questions?

Demonstration

References
- NFPA (National Fire Protection Association)
  - [www nfpa org/codes-and-standards/free-access](http://www nfpa org/codes-and-standards/free-access)
- CSB (Chemical Safety Board)
  - [www csb gov](http://www csb gov)
- FM Global Data Sheets
  - [www fmglobal com](http://www fmglobal com)
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