PREVENTION AND MITIGATION OF DUST EXPLOSIONS

Marc Van de Velde

XL Global Asset Protection Services (XL GAPS)

Centre of Excellence
Why being concerned about Dust?

Loss Statistics by Industry

**FM Dust Explosion Losses 1983-2006**

- Woodworking: 38%
- Lumber and Wood: 24%
- Food: 15%
- Chemical Manufacturing: 12%
- Primary Metal: 8%
- Rubber and Plastic: 8%
- Electric Services: 7%
- Other: 7%
- Pulp/Paper: 6%
- Printing: 5%
- Textile: 3%
- Metal: 2%
- Chemical/Pharmaceutical: 1%
- Mineral: 1%
- Fabricated Metal: 1%
- Furniture and fixtures: 1%
- Utility: 1%

166 losses

FM-DS-7-76 January 2014

**CSB Data Analysis 1980 - 2005**

- Food: 24%
- Lumber and Wood: 15%
- Chemical Manufacturing: 12%
- Primary Metal: 8%
- Rubber and Plastic: 8%
- Electric Services: 7%
- Other: 7%
- Pulp/Paper: 6%
- Printing: 4%
- Textile: 3%
- Metal: 2%
- Chemical/Pharmaceutical: 1%
- Mineral: 1%
- Fabricated Metal: 1%
- Furniture and fixtures: 1%
- Utility: 1%

281 incidents

Excludes grain handling, coal mines

http://www.csb.gov/assets/1/19/Dust_Final_Report_Website_11-17-06.pdf
Why being concerned about Dust?

• Correctly identifying dust hazards is an ongoing issue
• Does the MSDS have correct and enough information?
• Are the Hazards of the process and materials (really) understood?
• Are the operators aware of the hazards and do they understand them?
• Are the protection methods understood?

We always have had dust issues and even some small fires.

This is normal for our operations!

Nothing serious has happened in the last 30 years !!!
Triangle and Pentagon

Fire Triangle

Dust Explosion Pentagon

Heat
Fuel

Dispersion
Confinement
Oxygen
Heat
Fuel
## Fuel = Combustible Dust

<table>
<thead>
<tr>
<th>Types</th>
<th>Organic, metal, some inorganic</th>
</tr>
</thead>
<tbody>
<tr>
<td>When</td>
<td>Material grinding, buffing, polishing, shaping, cutting, cleaning, packaging</td>
</tr>
<tr>
<td>Where</td>
<td>Inside equipment – dryers, mills, grinders ; outside</td>
</tr>
</tbody>
</table>

### Industries

<table>
<thead>
<tr>
<th>Agriculture, food</th>
<th>Flour, wheat, sugar, milk powder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood</td>
<td>Wood flour, sawdust, paper tissue</td>
</tr>
<tr>
<td>Plastics / polymers</td>
<td>Polyethylene, epoxy, melamine, phenol resins</td>
</tr>
<tr>
<td>Chemical</td>
<td>Benzoic acid, organic dyestuff, petroleum coke, sulphur</td>
</tr>
<tr>
<td>Pharmaceutical</td>
<td>Ascorbic acid,</td>
</tr>
<tr>
<td>Mines</td>
<td>Coal</td>
</tr>
<tr>
<td>Metal Processing</td>
<td>Aluminum, Magnesium, Titanium</td>
</tr>
</tbody>
</table>
Combustible Dust = Powders / Materials with particle size < 500 micro meter (0.50 mm) that presents a flash fire/explosion hazard when dispersed in air (or process specific oxidizing medium)

Minimum Explosible Concentration (MEC) in g/m³

Relation between particle size and MEC

Moisture Content

Material shape

High surface to mass, less heat absorbed, that heat accelerates the reaction

Losses by Dust Type

**FM Dust Explosion Losses 1983 - 2006 by Dust Group**

- Wood: 42%
- Food: 15%
- Chemical: 10%
- Metal: 9%
- Plastic/Rubber/Resin: 8%
- Paper: 5%
- Various: 2%

166 losses

**CSB Data Analysis 1980 - 2005 by Dust Group**

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

281 incidents
Excludes grain handling, coal mines

[FM-DS-7-76 January 2014](http://www.csb.gov/assets/1/19/Dust_Final_Report_Website_11-17-06.pdf)
Ignition Sources

• Open Flames

• Hot Surfaces (heaters, bearings, steam or heat transfer fluid pipe)

• Cutting and Welding

• Flaming embers (frictional e.g. sanding; radiant e.g. curing wood panels; convective e.g. dryers)

• Self Heating

• Dust cloud Minimum Ignition Temperature (MIT) in °C

<table>
<thead>
<tr>
<th>Material</th>
<th>MIT  °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain</td>
<td>490</td>
</tr>
<tr>
<td>Flour</td>
<td>400</td>
</tr>
<tr>
<td>Sugar</td>
<td>480</td>
</tr>
<tr>
<td>Aluminum</td>
<td>650</td>
</tr>
<tr>
<td>Magnesium</td>
<td>620</td>
</tr>
<tr>
<td>Phenolic resin</td>
<td>610</td>
</tr>
</tbody>
</table>

• Dust Layer Minimum Ignition Temperature (LIT) in °C
Ignition Sources

• Impact / friction

• Size reduction operations in mills

• Mixers and blenders (misaligned impeller, inadequate clearance)

• Grinding and polishing operations

• Tramp material

• Electrical equipment not properly rated (zones 20, 21, 22; Group II; Categories 1D, 2D, 3G)
Ignition Sources

- No proper grounding and bounding
- Electrostatic discharges, brush discharges

**Minimum Ignition Energy (MIE) in mJ**

- Smallest electrostatic spark energy needed to ignite an optimum concentration of material

<table>
<thead>
<tr>
<th>Grain</th>
<th>(100)</th>
<th>Flour</th>
<th>50</th>
<th>Sugar</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>50</td>
<td>Magnesium</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phenolic resin</td>
<td>&lt;10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Ignition Sources**

- Agricultural dusts: NFPA 61 Table A.6.2.1
- Metal dusts: NFPA 484 Table A.1.1.3. (b)
- Various: NFPA 68 – Table F1
Losses by Ignition Type

FM Dust Explosion Losses 1983 - 2006 by Ignition Type

- Friction: 30%
- Spark: 23%
- Chemical Action: 10%
- Hot Work: 8%
- Burner Flame: 6%
- Static Electricity: 4%
- Electricity: 3%
- Overheating: 2%
- Hot Surface: 1%
- Unknown/No Data: 13%

166 losses
FM-DS-7-76 January 2014
Where do Explosible Concentrations Exist?

- Dust Collectors (bag houses, cyclones)
- Hammer mills, grinders, blenders, spray dryers
- Conveyor transfer points
- Sack filling and unloading stations

How much Combustible dust in the workplace is too much?

- NFPA 654 and FM use a dust layer of 0.8 mm (bulk density material 1200 kg/m³) not exceeding 5% of building area or maximum 93 m²
- An old FIA saying: If the dust is deep enough to write you name in it, it is too deep!!

- What does Explosible dust cloud look like? : Serious visual impairment and well above health limits
Losses by Equipment Type

FM Dust Explosion Losses 1983 - 2006 by Equipment Type

166 losses
FM-DS-7-76 January 2014

Impact equipment = grinders, sanders, pulverizers, ball and hammer mills, chippers, shredders, etc
Dust Explosions

- **No Confinement** → Flash fire

- **Partial Confinement** → fireball and limited pressure rise in enclosure and vented flame outside

- **Complete confinement** → Ignition will produce a deflagration with $P_{\text{max}}$

- Deflagration: Propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium.
Dust Explosions

- $P_{\text{max}}$ Maximum pressure developed in a contained deflagration of an optimum mixture
- $\frac{dP}{dt}_{\text{max}}$ Maximum Rate of Pressure Rise

Slope of the steepest part of the pressure-versus-time curve recorded during deflagration in a closed vessel.
Dust Explosions

- $K_{st}$ Normalized Rate of Pressure Rise in bar.m/s
- Gives a relative indication of the explosion hazard

<table>
<thead>
<tr>
<th>St Class</th>
<th>$K_{st}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>St 1</td>
<td>&gt;0 – 200</td>
</tr>
<tr>
<td>St 2</td>
<td>210 – 300</td>
</tr>
<tr>
<td>St 3</td>
<td>&gt;300</td>
</tr>
</tbody>
</table>

Burning behavior of a dust layer ($BZ = Brenn-Zahl$) or $CC = $ Combustibility Class

<table>
<thead>
<tr>
<th>CC</th>
<th>Comment</th>
<th>CC</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No self-sustained combustion</td>
<td>4</td>
<td>Propagating smoldering</td>
</tr>
<tr>
<td>2</td>
<td>Local combustion of short duration</td>
<td>5</td>
<td>Propagating open flame</td>
</tr>
<tr>
<td>3</td>
<td>Local sustained combustion, no propagation</td>
<td>6</td>
<td>Very rapid combustion</td>
</tr>
</tbody>
</table>
Case Study – Hayes Lemmerz

Hayes Lemmerz, Huntington, IN          October 29, 2003          1 death          6 injured

Aluminum wheel plant
Scrap aluminum
Dust collector

Figure 13. Damaged roof above furnace 5.

http://www.csb.gov/assets/1/19/Hayes_Report.pdf
https://www.osha.gov/dte/grant_materials/fy08/sh-17797-08/combustible_dust.ppt
Case Study – Hayes Lemmerz

https://s3.amazonaws.com/csbsafetyvideos/2_8_Combustible_Dust_an_Insidious_Hazard.mov
Primary and Secondary Explosions

Primary explosion caused by dust or other source

Dust layer on structures, equipment is stirred up and dust cloud formed

Blast wave

Extensive secondary explosion can result
Case Study – Ford Motor Co

Ford Motor Company, Dearborn, MI  February 1, 1999  6 deaths  24 injured

Power Plant
Joint Venture Ford – Rouge Steel

Boiler gas explosion
Secondary Coal Dust Explosion

[Image]

http://www.csb.gov/assets/1/19/Dust_Final_Report_Website_11-17-06.pdf (Page 26)
Hazard Assessment

• Identify – Hazard Assessment

• Where do I locate the equipment

• Eliminate or minimize consequences (enclosures, collections systems, equipment design)

• Dust collection systems, Mist eliminators, Wet Scrubbers

• Prevention and / or protection techniques

• Mechanisms that control release

• Management of Change (MOC) program
Hazard Assessment - Dust Control

- Provide smooth surfaces for walls
- Particular attention to roof structural members

- **Housekeeping = good, but subject to human factors**
- What is the required schedule?
- How much dust is too much?
- How do we Clean? System Effective?
- Budget Cuts?
West Pharmaceuticals, Kinston, NC  January 29, 2003  6 deaths  38 injured

Rubber syringe plungers
Polyethylene dust

http://www.csb.gov/assets/1/19/CSB_WestReport.pdf
Case Study – West Pharmaceuticals

http://www.csb.gov/west-pharmaceutical-services-dust-explosion-and-fire/
https://s3.amazonaws.com/csbsafetyvideos/2_8_Combustible_Dust_an_Insidious_Hazard.mov
Hazard Assessment

- Management needs to be fully aware of the hazards
- Develop safe working practices
- Provide Operator training
- Emphasize importance of procedures
- Allocate financial resources
- Method to report unsafe conditions
## Explosion Loss

| Imperial Sugar, Port Wentworth, GA | February 7, 2008 | 14 deaths | 40 injured |

Sugar Dust

http://www.csb.gov/assets/1/19/imperial_sugar_report_final_updated.pdf
https://www.osha.gov/dte/grant_materials/fy08/sh-17797-08/combustible_dust.ppt
Case Study – CTA Acoustics

CTA Acoustics, Corbin, KY  February 20, 2003  7 deaths  37 injured

Acoustic insulation
automotive industry

Fiberglass
impregnation with
phenolic resin

Curing oven

http://www.csb.gov/assets/1/19/CSB_CTA_Investigation_Report.pdf
https://www.osha.gov/dte/grant_materials/fy08/sh-17797-08/combustible_dust.ppt
Case Study – CTA Acoustics

https://s3.amazonaws.com/csbsafetyvideos/2_8_Combustible_Dust_an_Insidious_Hazard.mov
• ATEX – Workplace Directive

• Directive 99/92/EC

• ATEX 137 (Originally ATEX 118a)

• Minimum Requirements for improving the health and safety protection of workers potentially at risk from explosive atmospheres.

• Directive 94/9/EC

• ATEX 95 (originally 100a) requirements for Manufacturers

• Directive 94/9/EC to be replaced by Directive 2014/34/EU in April 2016
• If equipment handles coarse materials, remove small fines or use a liquid mist

• Inert combustible with noncombustible dust (watch out for possible separation)

• Reduce the oxygen Level through inert gas injection
• Deflagration Venting is a common method of explosion protection.
• Vent to a safe location.

Diagram:
- $P_{\text{max}}$
- $P_{\text{es}}$
- $P_{\text{red}}$
- $P_{\text{stat}}$

Unvented explosion vs. Vented explosion.
• Design Vessels / Equipment to withstand the maximum explosion pressure $P_{\text{max}}$
  • Explosion Pressure Resistant Design (EPRD) – no deformation
  • Explosion Pressure Shock Resistant Design (EPSRD) - deformation
Deflagration Suppression

- Generally a very quick operating Special Extinguishing system

Suppression System

Ignition

Pressure Detector

Pressure Waves

Agent Release

Vessel Inerted

Explosion Suppressed
Deflagration in one piece of equipment is prevented from traveling to another piece of equipment

- Detector sees pressure wave or fire traveling down ductwork
- Fast-acting valve closes and prevents deflagration from propagating
NFPA Documents

- 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
- NFPA 484 – 2015 - Standard for Combustible Metals
- NFPA 664 – 2012 - Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities
- NFPA 655 – 2012 – Standard for Prevention of Sulfur Fires and Explosions
- NFPA 120 – 2010 - Coal mines
- NFPA 850 – 2010 - Electric Generating Plants
- NFPA 68 – 2013 – Standard on Explosion Protection by Deflagration Venting
- NFPA 70 and 499 – Electrical Installations
- NFPA 77 – 2014 - Static Electricity

FM Data Sheets

- DS 7-73 - Dust Collectors and Collection Systems
- DS 7-76 - Combustible Dust Prevention and Mitigation of Combustible Dust Explosions and Fires
- DS 7-85 – Metals and Alloys
- DS 7-75 – Grain Storage and Milling
- D 7-59 – Inerting and purging of Tanks, Process Vessels, and Equipment

Thank You

Obrigado

Questions?

Perguntas?

Links were checked on September 5 - 12, 2014
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