Industrial Dust Explosions
Causes & Case Studies

Presented by Geof Brazier
at Expocorma, Concepcion, Chile
10th November 2017
Introduction

Increased global demand for Wood products = increased industrial scale manufacturing >>> increased focus on Wood Industry Safety.

The last 10 years have seen an increased global frequency of large scale combustible dust explosions with a sometimes catastrophic risk to the safety of Personnel & Plant that arose unexpectedly.

USA Sugar Plant Explosion 14 killed 36 injured. Corn Starch plant explosion, 21 killed, 47 injured.
Statistical Information Is Rare, but the biggest study arises from the USA OSHA Combustible Dust National Emphasis Program began in late 2007. Over the next 4 years:

- 2,636 plants inspected (all industries)
- 12,292 safety violations issued (all industries)
- 8,140 serious safety violations issued (all industries)

In a country with over 50 years of combustible dust safety standards experience (NFPA Standards), the risks identified are considerable.

This program was updated in October 2015.
Global Response To Increased Understanding Of Combustible Dust Safety

China: Development of broad industrial standards for combustible dust safety related to the most common industries and types of equipment. ‘GB Standards’

Europe: Implementation of EN Standards providing technical acceptance criteria for all of the typical methods of dust explosion protection and prevention technology. EN Standards are under ATEX umbrella.

USA: Update of NFPA Standards providing application guidance for the protection of process equipment, including the new general requirements Standard NFPA 652 and the Wood Industry Standard NFPA 664 which was revised in 2017.

Brasil: Adoption of NFPA 654 as a national Standard for combustible dust safety and published in Portuguese.
Dust Explosions – Why it is so Dangerous?

Dust Explosions produce:

- Flame ball
  (can be 10 to 30 meters long, same diameter)

- Pressure Spike
  (potential for over 7 bar with Wood dust)

Both occur in less than 100 milliseconds

Amateur Demonstration of Sawdust Explosion
How Do Dust Explosions Occur?

All the elements of the Explosion Pentagon occur at the same time.

In some processes, only Ignition is normally absent.

The Explosion Pentagon
How Do We Measure Wood Dust Combustion Risk?

Technical Parameters For Wood Dust:

• **Kst**: deflagration index
  – Can range from around 50 to 205 bar.m/s
  – A measure of the speed of combustion

• **Pmax**: maximum explosion pressure
  – Can range from 8 bar to 10.5 bar
  – A measure of the power of combustion

• **MIE**: minimum ignition energy
  – From about 20 milliJoules
  – Indicates how easily the wood dust will be ignited

• **MIT**: minimum ignition temperature
  – From about 250°C
  – Indicates temperatures that must be avoided in processes

• **Dust Density**
  – Concentrations as low as 30 grams per cubic meter will support explosive combustion
Typical Wood Industry Activities Requiring Dust Explosion Risk Management

**Wood Processing:**
MDF Plants (Medium Density Fibreboard)
OSB (Oriented Strand Board)
Plywood plants
Window Manufacturers
Door Manufacturers
Wood Flour Producers

…wherever the raw material particle size is reduced.

The smaller the particle size, the greater the reactivity of Wood dust.
Influence Of Particle Size

Smaller Particles Burn Fast & Ignite Easily:

Particle size < 500 microns are a concern.

Kst value increases as particle size gets smaller:
- Mean 1500 micron; no ignition
- Mean 150 micron; Kst 114 bar.m/s
- Mean 90 micron; Kst 188 bar.m/s
- Mean 30 micron; Kst 228 bar.m/s
Influence Of Particle Size Dust Testing?

Smaller Particles Burn Fast & Ignite Easily:

Explosion protection design is driven by Kst and Pmax information.

Having the correct data ensures safe design.

Risk of using ‘assumed’ data:
- Too much protection….higher $$
- Too little protection = no protection!

Dust testing follows Standards ASTM E1226 and EN 14034, which use the same methods and give the same results
Industrial Loss History Reveals The Type of Process Equipment at Risk

Cyclones

Dust Collectors

These are items of process equipment where dust becomes concentrated and strongly mixed with air.
Industrial Loss History Reveals
The Type of Process Equipment at Risk

Dryers

Bins

Mills

Silos
Industrial Loss History Reveals
The Type of Process Equipment at Risk

Bucket Elevators
How Does A Dust Explosion Start? - Causes

The US OSHA National Emphasis Program has found many root causes:

- Electrical – static electricity
  - Absence of grounding & bonding
  - Use of flexible piping that can build static charge
  - Lack of awareness of dusts that can ignite with a light spark
The US OSHA National Emphasis Program has found many root causes:

- **Electrical – unsuitable design**
  - Equipment not safety rated per electrical code
    - Zone 20 / Zone 21 / Zone 22 / Non Hazardous
The US OSHA National Emphasis Program has found many root causes:

- **Deficient Protection**
  - For example, *venting to an unsafe area*
  - Triggering a larger secondary dust explosion
The US OSHA National Emphasis Program has found many root causes:

- **Deficient Protection**
  - Absence of *Isolation* between connected equipment
  - A small primary explosion is able to expand to a series of larger secondary events
The US OSHA National Emphasis Program has found many root causes:

- **Housekeeping**
  - Absence of internal & external cleanliness
  - Lack of Secondary Risk Management

### Other Recent Dust Incidents

- **West Pharmaceutical Services, Kinston, NC**
  - January 29, 2003
  - Polyethylene dust
  - 6 employees died
  - 38 others injured
Severity Of Secondary Dust Explosions

Secondary Events Triggered By An Initial Small Scale Dust Explosion:

- **Housekeeping**
  - Lack of Secondary Risk Management >> Building Failure
Secondary Events Triggered By An Initial Small Scale Explosion:

- **Housekeeping**
  - Lack of Secondary Risk Management
    >>>> Building Failure
    >>>> Putting workers at risk!

Severity Of Secondary Dust Explosions

Process Equipment

Equipment Failure from Initial Deflagration

Dust Clouds Caused by Elastic Rebound of Building
Severity Of Secondary Dust Explosions

Secondary Events Triggered By An Initial Small Scale Explosion:

- **Housekeeping**
  - Lack of Secondary Risk Management
    >>> Building Failure
    >>>> Putting workers at risk!

Process
---
Secondary Deflagration Propagates Through Weak Building Structure
Management Of Change Is Forgotten:
• For example, insufficient vent area is about the same as no safety mechanism…

Result of Change Without Risk Review

The dust risk was changed to a more aggressive material but the vent area was not increased.
Can You Handle Explosion Venting?

Lack of understanding, for example, the consequences of venting...

- Fast
- No warning and no time for humans to respond
- Extensive downstream flameball risk zone (whose size can be calculated)
Examples of Well Designed & Protected Equipment

Outdoor silo / Dust collector protected by Explosion Venting

FBD protected by Suppression System

Indoor Dust filter / silo protected by Flameless Vent

Dust Collector protected by Suppression system
Building Protection
A Strong Emphasis of New NFPA 652 & NFPA 664

Vent Panels for Buildings:
- Low set pressure; in the range of 10~30 mbar to follow building codes.
- Wind and Weather resistant
- Low mass/fast dynamic performance
- Translucent or opaque finish; can replace windows
- No fragmentation
- No routine maintenance requirements
- Standard periodic inspection, as for all vents

Dynamic Testing of Building Vents
Protection Strategies: Venting

• Relatively simple & cost effective = popular

Vent area must be sized to meet the application conditions; this includes consideration of at least:

Kst,
Pmax,
Volume,
Shape,
Design Strength,
Operating Pressure,
Operating Temperature,
Flameball path
Protection Strategies: FlameFree Venting

- **Combines Explosion Venting With Flame Arresting**

Vent area must first be calculated according to standard vent sizing. Vent area is then increased to account for the vent efficiency of the flame arresting device that is used.

FlameFree venting devices have vent efficiencies as high as 95% and as low as 25% depending upon the design and application conditions. Applications must be very carefully engineered.
Protection Strategies: Suppression

- **Very Fast Extinguishing that stops the combustion before it fully develops**

  The application information required is the same as for explosion venting.

  **Successful Suppression requires detection & extinguishing that is positioned to engage the early stages of combustion.**

Pressure or Optical, or combined detection.
Protection Strategies: Containment

- The design pressure of the process equipment must at least be the $P_{\text{max}}$ for the dusty material.

This means at least 8 bar, and typically over 10 bar for Wood dust.

This is a high cost strategy that is seldom used in the Wood Industry.

Can you afford to build this strong?
Protection Strategies:
Isolation

- There are many options:

Chemical Isolation

Ventex® Float Valve

Flap Valve

Knife Gate Valve
Protection Strategies: Isolation

- There are many options: some of them unexpected…

Isolation devices must be carefully designed into a safety system with their position along piping / ducting properly defined to allow for the response time of the device.

Use ATEX certified isolation devices!
Prevention Strategies:
Spark Detection

- Spark Detection (and downstream extinguishing) provides both dust explosion and fire protection

Hot particles in the air flow are detected by UV/IR sensors.

Downstream water spray extinguishes the hot spots before reaching the next point in the process where ignition might occur.

Alternative downstream actions can include a diverter valve to move the temporary hot spots out of the process flow.
Conclusions

• Identify the risk
• Understand the risk
• Manage the risk (apply technology or delete the risk)
• Manage change
• Conduct regular inspection of safety systems (nothing is ‘fit and forget’)

Protected >>>> Productive!