Fire and Explosion Hazards in the Handling of Combustible Wood Dusts

The Global Experts in Explosion & Process Safety
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- With Chilworth Technology, Inc. – 2002 - Present
- 20 Years as Process Safety Specialist
- FMC Corporation - 1974 – 2000
  Process Engineering, Project Engineering, Plant Operations, PSM on site and Corporate PSM Engineer.
- B.S.Ch.E. – The Pennsylvania State University
- Member - AIChE, NFPA
Prince George Wood Mill Explosion - April 2012
What is a Wood Dust Explosion?

A wood dust explosion is a propagating (moving) combustion process in which an ignited dust particle ignites nearby particles and the flame proceeds from the ignition source through the premixed dust/air atmosphere.

The result is heat, light, combustion gases and pressure.
5 Conditions for Dust Explosions

- Oxidant
- Confinement
- Ignition Source
- Suspension
- Fuel (Combustible Dust)
Illustration of how the combustion rate of a given mass of combustible solid increases with increasing sub-division

(a) slow combustion
   (fixed flame-front)

(b) fast combustion
   (fixed flame-front)

(c) Flash-Fire or Explosion
   (Moving Flame-Front)
### Wood Dust Literature Data:

<table>
<thead>
<tr>
<th>Property</th>
<th>Dry Wood Dust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Ignition Energy, MIE</td>
<td>7 to 250 mJ</td>
</tr>
<tr>
<td>Minimum Cloud Ignition Temperature</td>
<td>490 °C (914 °F)</td>
</tr>
<tr>
<td>Minimum Layer Ignition Temperature</td>
<td>310 - 320 °C (590 - 608 °F)</td>
</tr>
<tr>
<td>Minimum Explosible Concentration, MEC</td>
<td>40 - 60 g/m³</td>
</tr>
<tr>
<td>Maximum Pressure, $P_{\text{Max}}$</td>
<td>9.2 barg (133 psig)</td>
</tr>
<tr>
<td>Deflagration Index, $K_{\text{St}}$</td>
<td>100 to 150 bar•m/sec</td>
</tr>
<tr>
<td>Moisture Content</td>
<td>Less than 5 %</td>
</tr>
<tr>
<td>Particle Size</td>
<td>less than 100 μ</td>
</tr>
<tr>
<td>Dust Explosion Class (some wood dust is St-2)</td>
<td>St-1</td>
</tr>
</tbody>
</table>
Clumping nature of some wood process materials
Wood Dust Released From The Process
Conditions for a Dust Explosion

- Dust must be suspended in air.
- Dust particles must be small
- Dust concentration must be within the “Explosible Range”.
- There must be enough oxygen (or other oxidant).
- There must be an ignition source having enough energy to initiate flame propagation.
- The dust cloud must be in a closed or partially enclosed space to create pressure effects.
Range of explosible dust concentrations in air at normal temperature and atmospheric pressure for a typical natural organic dust (maize starch), compared with typical range of maximum permissible dust concentrations in the context of industrial hygiene, and a typical density of deposits of natural organic dusts (Eckhoff)

**Industrial Hygiene**

**Explosible Range**

**Dust Deposits**

**Mass of Powder/Dust per Unit Volume (g/m³)**

10⁻³  10⁻²  10⁻¹  1  10  10²  10³  10⁴  10⁵  10⁶
A cloud of 40g/m³ of coal dust in air is so dense that a glowing 25W light bulb can hardly be seen through a dust cloud of 2m (~6.6 ft) thickness (Eckhoff).
**Explosion Severity**

Deflagration Pressure/Time Curve

- Maximum Pressure, $P_{\text{max}}$ [barg]
- Maximum Rate of pressure Rise, $(dP/dt)_{\text{max}}$ [bar/s]
- Deflagration Index, $K_g$ or $K_{St}$ [bar m/s]

Note: 1 bar = 14.504 psi
Illustration of how the blast wave from a primary explosion entrains and disperses a dust layer, which is subsequently ignited by the primary dust flame (*Eckhoff*)
Secondary Dust Explosion Video
A Three Pronged Approach to Management of the Dust Explosion Risk

● Reduce/Eliminate Dust Generation
  - Engineering Controls, i.e., dust collection and suppression
  - Keep equipment tight
  - Close inspection doors, maintain integrity of seals, gaskets, etc.

● Limit/Restrict Dust Migration
  - Partitioning/enclosing off areas where dust is being generated
  - Positive pressure ventilation of rooms/areas plenums above ceiling, Motor Control Rooms

● Remove/Clean Dust Accumulation
  - Housekeeping policies, procedures, practices
  - Promptly clean-up or report leaks and spills
Control the Fuel Source: Minimize Emission of Combustibles Equipment Design & Use

Good equipment design:

*RAGAGEP*

Good practice of use.
Effective maintenance.

*Sawdust screening operation product discharge*

*Recognized and generally accepted good engineering practices*
Dust Management Methods

**Dilution/room Ventilation:** reduces background concentration of the flammable atmosphere in the working area, but ineffective/incapable of controlling vapor/dust concentration.

**Local Exhaust Ventilation, LEV:** intercepts the flammable solid at the source of release and directs it into a system of ducting connected to an extraction fan.

Most Practicable and Most Effective for Dusts
General features of a Local Exhaust Ventilation ‘LEV’ System

- Explosion Relief Vent
- Cartridge Filter
- Header
- Hood
- Isolation Valve
- Branch Line
- Extraction Fan
- Vent
- Sifter
- Hand Scooping
LEV in action
But….LEV can be less than effective
Where does it come from?
One Obvious Source

Release Point?
Housekeeping

- Reduce secondary explosion hazard.
- Relatively small initiating event can lead to much larger disastrous event.
- Dust layers as thin as 1 mm can create explosible dust/air clouds to a height of 5 meter in a room.
Housekeeping

• Plants and equipment should be sealed as much as possible.
• Dust accumulations should be minimized by dust collection.
• If there are dust accumulations the accumulated dusts should be removed using methods that do not disperse the deposited dusts in air.
• Compressed air should not be used to “clean” dusts on surfaces.
Housekeeping Do’s and Don’ts Combustible Particulate Solids

**Do**

- Use water to clean up wherever practical
- Perform regular cleaning on horizontal surfaces, floor, and walls such as equipment, ducts, pipes, hoods, ledges, beams, stair rails, and above suspended ceilings and other concealed surfaces.
- Clean floors and work areas at least weekly
- Use a vacuum cleaner that is listed for use in Class II hazardous locations or a fixed-pipe system with a remotely located exhauster and dust collector
Don’t:

Allow dust layers to accumulate more than the limits allowed in NFPA 664 or 3 mm (1/8 inch) of wood dust

- A dust layer is capable of creating a hazardous condition if it exceeds 5% of the building’s floor area.
- Dust accumulations on ledges, overhead beams and joists can contribute significantly to the secondary dust cloud.
Housekeeping Do’s and Don’ts

Combustible Particulate Solids

**Don’t**

Use compressed air or steam to blow down surfaces unless:

- There is no other practical method
- The area and equipment has been vacuumed prior to blowdown.
- Electrical equipment not suitable for Class II locations and other sources of ignition (hot surfaces or flames capable of igniting a dust cloud) are removed from the area.
- Low-pressure steam or compressed air, not exceeding a gauge pressure of 30 psig is used
Typical Ignition Sources
[in approximate descending order of importance]

- Hot work [welding; cutting; grinding; soldering; brazing]
- Open flames [torches; heaters]
- Electrical arcs [sparks at motor brushes, switches, and receptacles; power tools]
- Electrostatic discharges
- Mechanical friction [bearings]
- Hot surfaces and equipment [motors]
- Thermal decomposition
Electro-Static Charge Can

- Produce electric shocks
- Cause plugging of powder flow
- Ignite gas/vapor in air
- Ignite dust cloud in air
## TYPES of ELECTROSTATIC DISCHARGES

<table>
<thead>
<tr>
<th>Discharge Type</th>
<th>Origin</th>
<th>Potential Energy</th>
<th>Incendivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spark</td>
<td>Isolated Conductors</td>
<td>As high as 10J $E = \frac{1}{2} C V^2$</td>
<td>Vapors, Gases and Dusts</td>
</tr>
<tr>
<td>Brush</td>
<td>Solid Insulator</td>
<td>Less Than 4 mJ</td>
<td>Vapors, Gases and some Sensitive Dusts</td>
</tr>
<tr>
<td>Cone (Bulk)</td>
<td>Bulking Powder</td>
<td>10 to 25 mJ</td>
<td>Vapors, Gases and some Sensitive Dusts</td>
</tr>
<tr>
<td>Propagating Brush</td>
<td>Insulator with metal backing</td>
<td>Less Than 2 J</td>
<td>Vapors, Gases and Dusts</td>
</tr>
<tr>
<td>Corona</td>
<td>Conductor or Insulator</td>
<td>Very Low Less than 0.1 mJ</td>
<td>Unknown (stoichiometric hydrogen?)</td>
</tr>
</tbody>
</table>
Incorrectly specified and/or installed electrical equipment is a potent ignition source for dusts:

- **Sparks**: brushes or switches in motors
- **Overloaded (hot) motors**
- **General-purpose plugs and receptacles**
- **General-purpose equipment**

In facilities handling combustible or flammable materials, electrical equipment must be suitable for the environment in which it is to be used:

- **Class II, Group G** for many dusts
- **Division 1** for frequent dust clouds
- **Division 2** for very-infrequent dust clouds

Control: Classification map; conformance to standards
Methods of Controlling Ignition Hazards of Electrical Equipment

- Classification is required where:
  - Visible dust clouds, or
  - “routine” deposits in excess of 3 mm (1/8 inch)
- Ignition hazards of electrical equipment must be controlled by equipment design.
- Electrical equipment that can cause ignition hazards must be separated from flammable material/atmosphere.
Electrical Area Classifications – N. America

**Class I:** Gases and vapors (liquids)
- **Division 1:** Having flammable atmosphere under normal conditions
- **Division 2:** Having flammable atmosphere under abnormal conditions

**Class II:** Combustible powders
- **Division 1:** Having flammable atmosphere under normal conditions
- **Division 2:** Having flammable atmosphere under abnormal conditions

**Class III:** Combustible fibers
- **Division 1:** Easily ignitable fibers are manufactured or used
- **Division 2:** Easily ignitable fibers are stored or handled
Area Classifications – IEC in Europe

Class II, Zone 20:
Ignitable concentrations of combustible dusts, or fibers or flyings are present continuously, or for long periods of time.

Class II, Zone 21:
Ignitable concentrations of combustible dusts, or fibers or flyings are likely to exist: under normal operating conditions; frequently because of repair or maintenance operations or because of leakage; other similar conditions.

Class II, Zone 22:
Ignitable concentrations of combustible dusts, or fibers or flyings are likely to exist for a short period of time under abnormal conditions.
Recent Combustible Dust Findings of the US Occupational Safety and Health Administration’s Inspections under the National Emphasis Program [NEP]
Some Combustible Dust NEP Findings

1. Hazardous levels of dust accumulations in the workplaces due to poor housekeeping practices.

2. Electrical equipment and Powered Industrial Trucks not approved for locations handling combustible dusts.

3. Dust collectors were located inside buildings without proper explosion protection systems, such as explosion venting or explosion suppression systems, or explosion vents would discharge into buildings.

4. Deflagration isolation systems were not provided to prevent deflagration propagation from dust handling equipment to other parts of the plant.
Some Combustible Dust NEP Findings

5. The horizontal surfaces such as beams, ledges, and screw conveyors at elevated surfaces were not minimized to prevent accumulation of dust on surfaces.

6. Air from dust collectors was recycled through duct work back into the work area without the protection of a listed spark detection system, high speed abort gate, and/or a functioning extinguishing system.

7. Magnetic separators and tramp metal separators were not installed or not functioning to prevent foreign material entering into process stream and potentially cause a spark.

8. Explosion vents on bucket elevator(s) and dust collectors were directed into work areas and not vented to a safe, outside location away from platforms, means of egress, or other potentially occupied areas.
Some Combustible Dust NEP Findings

9. Equipment (such as grinders and shakers) were not designed and maintained to minimize escape of dust into the surrounding work area.

10. Ductwork used in transporting combustible dust were not constructed of metal (conductive) and were not bonded or grounded to minimize generation and accumulation of static electricity.

11. Hot work (open flame or sparks from welding, cutting, grinding) was performed in the combustible dust handling areas without hot work procedures.

12. Silos and legs of bucket elevators were not equipped with explosion relief venting.
Some Combustible Dust NEP Findings

13. Enclosureless systems were allowed indoors where they were not emptied at least daily; where they were located in areas routinely occupied by personnel; and where they were not separated by at least 20 feet.

14. Compressed air was periodically used to clean up the combustible dust accumulation in the presence of ignition sources.

15. Portable Vacuum Cleaners were not approved for Class II locations.

16. Process Hazard Analysis was not conducted to determine if explosion protection systems, interlocked rotary valves, deflagration vents, and flame front diverters were needed.
Summary:

- Dry, wood dust is explosible
- Manage the Flammable Atmosphere:
  - Prevent releases of dust
  - Contain as much as is feasible
  - Use effective Local Exhaust Ventilation
- Prevent dust deposits (housekeeping):
  - Do not exceed 3 mm (1/8th inch)
  - Use appropriate Class II vacuums and ESD hoses
- Ensure bonding and grounding of collection components
Summary:

- **Control ignition sources:**
  - Manage hot work
  - Use appropriately rated electrical equipment,
  - Electrostatic Ignitions:
    - Ensure bonding and grounding of all conductive components
    - Ground personnel if MIE of dust cloud is below 50 mJ.

- **Protect where appropriate:**
  - Dust collection systems:
    » Contain, vent or suppress and isolate
Questions?
Thank you!

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GREEN WOOD and NON-DEFLAGRABLE WOOD DUST

Primary Reference:

NFPA 664 – Definitions:

- **3.3.12 Green Material.** Wood particulate that has an average moisture content equal to or **greater than 25 percent** by weight (wet basis).

- **3.3.24.2 Dry Non-Deflagrable Wood Dust.** Wood particulate with a **median diameter greater than 420 microns** (i.e., material that will not pass through a U.S. No. 40 Standard Sieve), having a moisture content of **less than 25 percent** (wet basis).

  - not a good indicator!! Should conduct screening tests. Softwood with 75% -20 + 40 mesh particle size distribution exploded in the 20 l vessel – $K_{st} = 15 \text{ bar}\cdot\text{m/sec}$. 

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8.2.1 Hazard Determination. The hazard associated with the particulate conveying system shall be determined through a hazard analysis.

8.2.1.1 The analysis of the fire and deflagration hazard shall address the moisture content and particle size distribution of the particulate comprising the process stream downstream of each point of material entry to determine whether the material is green, dry non-deflagrable, or deflagrable.
8.2.1.2 The analysis of the fire and deflagration hazard shall identify the minimum explosible concentration (MEC) for all deflagrable material.

8.2.1.3 Fire and deflagration hazards shall be deemed nonexistent where only green material is collected or conveyed and construction of the equipment handling and storing the material is all noncombustible.
NFPA 664 - Chapter 11 Housekeeping:

- **11.1 General Requirements.**

- **11.1.1** This chapter shall apply to the monitoring and removal of combustible waste materials in order to prevent these materials from accumulating outside, on, or around operating equipment or otherwise within the facility in sufficient quantity to create an undue fire hazard. A.11.1.1 These materials include, but are not limited to, bark, chips, scrap lumber, wood dust, and other debris within wood processing and woodworking facilities.
11.1.2* Documented housekeeping and inspection programs shall be developed and maintained.

- A.11.1.2 The facility should implement a weekly housekeeping inspection in the facility's fire prevention and maintenance program. Cleaning schedules for production equipment and the facility in general can be based on the findings of the housekeeping inspection. Typical cleanup routines, as a minimum, should include the following:

- (1) Daily, or per shift, cleanup of personal work areas, walkways, emergency escape routes, and access-ways to fire protection equipment.
NFPA 664 Housekeeping

Typical cleanup routines, as a minimum, should include the following:

(2) Weekly cleanup of floors throughout the facility, and specific cleanup in and around materials-handling equipment or production equipment (e.g., beneath lumber sorting decks, beneath or at the transfer points of belted chip or scrap conveyors, and beneath board presses). Machinery, motors, and hot surfaces should be kept clean of materials such as sawdust, oil, or grease.

(3) Weekly to semiannual cleanup of dust collection on horizontal surfaces (e.g., ducts, hoods, interior mezzanines, or ceilings) and on structural building members, such as ledges, beams, and joists, to minimize dust accumulations. As a rule of thumb, do not exceed 3.2 mm (1/8 in.) in depth. In all cases, consideration should be given to minimizing horizontal surfaces where dust can accumulate. One method of reducing horizontal surfaces on structural building members is to install angled members (angle of repose) or shields to minimize buildup.
NFPA 664 – Housekeeping:

11.1.3* Any waste material or debris found in large enough quantity that the material is heavily coated or is in any way impeding the operation of energized or moving equipment shall be collected and removed immediately.