Explosive Dust in Pellet Manufacturing Plants

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Housekeeping in wood manufacturing facilities such as pellet manufacturing plants traditionally has not had the priority it deserves for a number or reasons. The issue of cleaning has a connotation of lesser significance than keeping a plant operating and producing revenue generating products. Cleaning of floors is a nuisance since the generation of dust never stops but it is as important as regular maintenance of machinery. This document describes a methodology for evaluating how much dust on floors, girders and beams is acceptable in order to stay within reasonable margins of safety. Several guidelines are published on this subject but are not necessarily accessible without substantial effort. Also, these guidelines are not always adapted to the characteristics of the type of dust encountered in pellet plants. Based on lab testing of a couple of fundamental parametric values related to the specific characteristics of the dust the method described will allow the operator of a pellet plant to evaluate the necessary safety precautions which needs to be taken as it relates to housekeeping.

Anatomy of dust explosions

Dust explosions typically have two phases, a primary explosion cased by ignition from a mechanical spark or electrostatic discharge, overheated rotating device (ball bearing, idler, guide roller etc.) or bead from hot work or similar, followed by a secondary explosion. The secondary explosion is caused by deflagration of dust lodged on the floor, beams, girders, railings etc becoming airborne as result of the pressure wave from the primary explosion. In a dusty environment there is usually also very fine dust suspended in the air for a long period of time[1] which also contributes to propagation of a deflagration throughout a building. The conversion of dust from a layer to a dust cloud changes the dynamics radically since the dust becomes oxygenated and fluid. If there is a secondary explosion it is often far more damaging since it extends the explosion to much larger spaces where people may be working. Precautions to take for limitation of primary explosions are well documented and consist of a combination of prudent design

[1] Testing of Explosibilty and Flammability of Airborne Dust from Wood Pellets, S. Melin, Wood Pellets Association of Canada, November 2, 2008.

of facilities and machinery and proper maintenance, including cleaning of specific equipment. Precautions to take for limitation of secondary explosions are recommended by NFPA[2] and OSHA[3] in North America and consists primarily of maximum thickness of dust layers. Table 4.0 (see foot note 1) summarizes the explosibility characteristics of dust from pellets produced in British Columbia (white dust) and pellets produced in Nova Scotia (bark dust).

Table 4.0 Results from testing dust from white pellets and bark pellets

Test Mode	Test Parameter (dust <63 µm)		Measure	White Dust	Bark Dust	Coal Dust	Lycopodium Spores	Testing Standards
Dust cloud	Auto-ignition Temp (Godbert-Greenwald)	T_c	°C	450	450	585	430	ASTM E1491
	Min Ignition Energy	MIE	mJoule	17	17	110	17	ASTM E2019
	Max Explosion Pressure	P_{max}	bar	8.1	8.4	7.3	7.4	ASTM E1226
	Max Explosion Pressure Rate	dP/dt_{max}	bar/sec	537	595	426	511	ASTM E1226
	Deflagration Index	K_{St}	bar.m/sec	146	162	124	139	ASTM E1226
	Min Explosible Concentration	MEC	g/m^3	70	70	65	30	ASTM E1515
	Limiting Oxygen Concentration	LOC	%	10.5	10.5	12.5	14	ASTM E1515 mod
Dust Layer	Hot Surface Ignition Temp (5 mm)	T_s	°C	300	310			ASTM E2021
	Hot Surface Ignition Temp (19 mm)	T_s	°C	260	250			ASTM E2021
	Auto-ignition Temp	T_L	°C	225	215			USBM (Bureau of Mines) RI 5624
	Dust Class (>0 to 200 bar.m/sec)			St 1	St 1	St 1	St 1	ASTM E1226
	Dust Class (Explosion Severity (ES > 0.5)			Class II	Class II			OSHA CPL 03-00-06

Calculation of Maximum Dust Layer Thickness

NFPA[4] 664 focuses on dust in the wood working industry, Chapter 11 and Annex A, paragraph 6.4.2.2 or NFPA 499[5], Chapter 5 are stipulating a dust layer thickness of more than 1/8" (3.2 mm) is considered unsafe if the dust is covering a certain percentage of floor or other flat surfaces in a facility. The bulk density of wood dust is around 250 - 550 kg/m^3. A procedure for estimation of dust concentration in a space volume as a result of a secondary explosion is illustrated below. The result is evaluated in view of the Minimum Explosible Concentration (MEC) in Table 4.0 above based on some assumptions regarding the space volume in a building.

Example

Area selected = 15 m * 25 m = 375 m^2
Dust layer thickness = 1/8" = 3.2 mm
Bulk density = 500 kg/m^3 @ moisture content 5%
Floor area covered with dust = 5%
Total amount of dust in the selected area = 375 * 0.0032 * 500 *5/100 = 30 kg

[2] National Fire prevention Association.
[3] Occupational Safety and Health Administration.
[4] NFPA 664, Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities, 2007 edition.
[5] NFPA 499, Recommended Practice fir the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas, 2004 edition.

Height of the selected area = 4 m
Total space volume in the selected area = 375 * 4 = 1500 m^3
Concentration of dust in the space volume = 30/1500 = 0.020 kg/ m^3 = 20 gram/m^3

The 20 gram/m^3 compared to 70 gram/m^3 (as per Table 4.0) provides a good safety margin of 71%. If the area covered with dust is 30% the calculation looks as follows;

> Dust in the layer = 375 * 0.0032 * 500 * 30/100 = 180 kg
> Concentration = 180/1500 = 0.120 kg/m^3 = 120 gram/m^3

The 120 gram/m^3 is unsafe and would easily sustain a deflagration if a primary explosion were to happen.

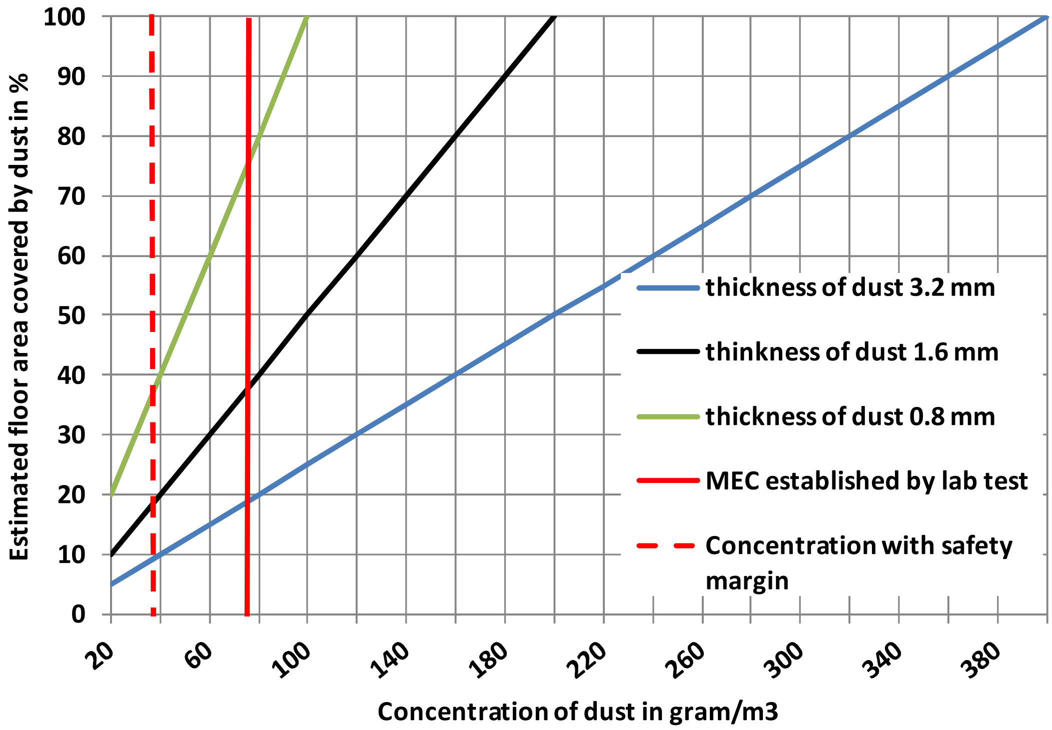
Due to the violent turbulation of the dust when dislodged by a pressure wave the concentration of the dust in most cases can be assumed to be spread evenly within a space volume. The larger the area is covered by a layer of dust the more critical the condition becomes. A spreadsheet model[6] has been developed which can be used for evaluating safety margin for explosions based on the following parameters;

- Estimated average thickness of a dust layer
- Bulk density of the dust (from lab test)
- Minimum Explosible Concentration (MEC) of the dust (from lab test)
- Size of floor space
- Ceiling height
- Horizontal surface area within the space volume of beams, girders, railings etc.
- Estimated percentage of floor covered by dust
- Estimated amount of lofted dust in space volume
- Average dust concentration in space volume
- Selected safety margin to measured MEC

The model is iterative and lends itself for estimation of the risk level in selected areas. Example of the output from this model is illustrated in Graphs 1. This particular graph is valid for dust with MEC 70 gram/m^3 and a bulk density of 500 kg/m^3.

[6] Delta Research Corporation drc@dccnet.com

Graph 1. Calculated Concentration of dust in gram/m3



The concentration of dust Cd is inversely proportional to the space volume V. This means that a space volume twice as large would produce the same dust concentration

$$C_d = (d_{th} * 1000 * A * (A_d/100) * d_b) / V$$

where

C_d = concentration of dust in space volume	gram/m^3
d_{th} =dust layer thickness	mm
A = floor area in	m^2
d_b = dust bulk density in	kg/m^3
A_d = floor area covered by dust	%
V = Space volume	m^3

From Graph 1 it can be concluded that a dust layer with thickness of 3.2 mm (1/8th inch) covering 20% of the floor the concentration of dust is estimated to 75 gram/m^3. With an MEC of 70 gram/m^3 for dust generated in BC pellet plants deflagration could be propagated throughout a building as a result of a primary explosion. A safety margin of 50% to the MEC (50% of 70 gram/m^3 = 35 gram/m^3 from Table 4.0) as established by lab test is recommended. If 10% of the floor area is covered by a 3.2 mm layer of dust the estimated dust concentration is 40 gram/m^3 which is less than the MEC for the dust on Table 1 and provides a safety margin of 43%. This safety margin may be sufficient although 50% safety margin should be the target. A housekeeping guideline stipulating a maximum thickness of a dust layer of 1.6 mm would provide a safety margin of 50% or better even if the dust layer is covering approximately 20% of the floor. Alternatively, a thickness of the dust layer of 3.2 mm covering less than 5% of the floor would also be within the 50% safety margin. This illustrates the importance of keeping as large areas as possible clean.

The MEC is a measure related to the characteristics of the dust. Characteristics such as MIE, LOC, deflagration index and particle size is implicit in the value of the MEC (see reference 1 for more details). The NFPA 499 and NFPA 664 are not necessarily accounting for the explosibility characteristics as measured by lab test for a particular dust in question.

Considerations for Determination of Safety Margin

With MEC established at 70 gram/m^3 for the material as per Table 1 and a safety margin of 50% the maximum allowed dust concentration should be less than 35 gram/m^3. The MEC as well as the bulk density of the dust are essential parameters when determining guidelines for housekeeping to keep a manufacturing plant safe. Without those values the guidelines becomes a gamble and the housekeeping may not achieve what it is supposed to achieve – as safe working environment as possible.

The speed of a deflagration is subsonic which means the burning dust is propagating at up to 343 m/sec at a temperature of +20^{o}C. The burnout time for many particles would be several seconds. This means that particles in a deflagration wave penetrating objects in its way in a contained building will continue to burn at temperatures above +250^{o}C for several seconds which is sufficient to initiate fires in combustible materials and cause severe burn injuries if a person is exposed to the ignited dust storm. Spaces inside buildings may have constrictions such as hall ways which may magnify the propagation of the deflagration speed. The average distribution of dust as calculated in a model does not tell the entire story since the dust is unevenly spread due to eddies behind walls etc. With a high speed deflagration wave sweeping through a building a deflagration may propagate between clusters of high concentrations of dust. In an environment where dust layers are forming on floord and flat surfaces there is always dust aloft in the air. The airborne concentration is very much depending on the distance to the source of the dust, air movement and the particle size of the dust. The following diagram illustrates the sedimentation time as a function of particle size (for more details see reference 1) for particles in still air.

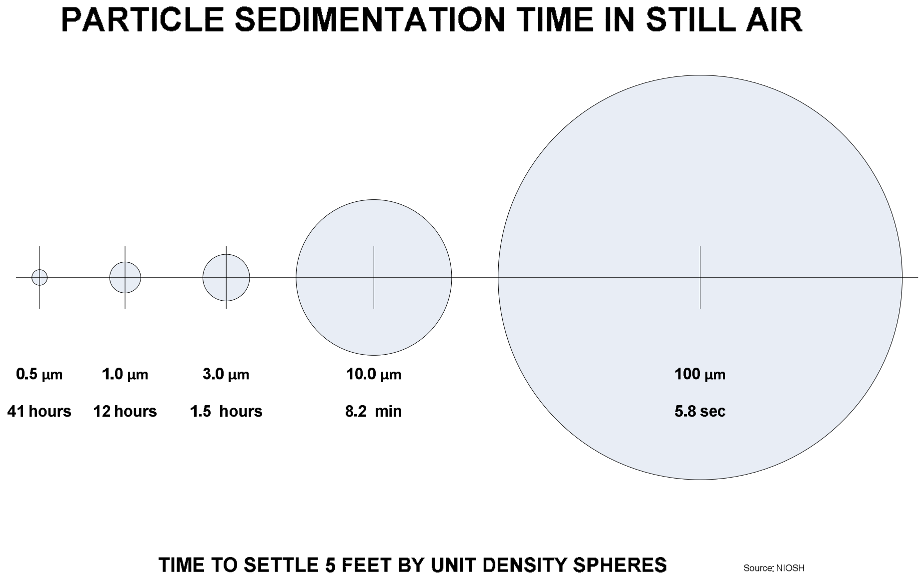


Figure 1.

A substantial portion of the airborne dust in a pellet plant is smaller than 10 micron which means that those particles add to the airborne concentration caused by a secondary explosion. Normal condition in an industrial environment is that the air is in constant turbulence which means that particle sizes less than 100 micron remain lofted.

A safety margin of at least 50% calculated from the MEC established by a lab test is recommended.

Recommendations and Guidelines

The guidelines documented by NFPA are considered the industry standard. Most spaces in a pellet plant should be classified as Class II Division 1 space (see NFPA 499, Chapter 4.1). The dust itself is classified as Group G (see NFPA 70[7], Chapter 500.6).

Buildings were explosions can be expected due to release of dust and difficulty with proper housekeeping shall be designed for explosion protection by deflagration venting as recommended in NFPA 68[8] and 69[9].

Equipment in such areas requires equipment compatible with Temperature Class (T code) in accordance with NFPA 70, Chapter 500.8 depending on the Hot Surface Ignition Temp (19 mm) as established by ASTM[10] E2021.

[7] NFPA 70 National Electrical Code, 2008 edition.
[8] NFPA 68 Standard on Explosion Protection by Deflagration Venting, 2007 edition.
[9] NFPA 69 Standard on Explosion Prevention Systems, 2002 edition.
[10] ASTM E2021-06, Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers, American Society for Testing and Materials.

NFPA 664, Annex A paragraph 6.4.2.2 provide some general guidance regarding dust layer thickness, floor size and bulk density of dust but are not necessarily applicable to the environment in a pellets mill with dust of higher bulk density.

It is recommended that a site specific evaluation is done for any specific area to make sure the guideline for maximum dust layer thickness is established. Such evaluation should be done in areas where dust is easily accumulating and where housekeeping is difficult to maintain.

Each pellet mill should have the MEC established by a certified lab in accordance with testing standards given in Table 4.0. Also the dust bulk density of the dust generated in the plant should be established to make sure the fundamentals for establishing a safe limit for dust layer thickness as well as housekeeping guidelines to keep the floor areas sufficiently clean to not exceed the max dust volume dislodged allowed if a primary explosion were to happen. **Without knowing the MEC and dust bulk density safety rules for a production plant and safety management becomes a guessing game. A safety margin policy of 50% or better should be established for any pellet manufacturing plant.**