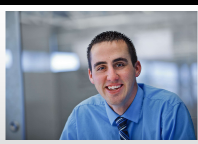
COMBUSTIBLE DUST

What does it mean to me?

September 30, 2019

CRAIG VESELY, PE, CET



Alliant Energy

- Fire Protection Program Manager
- Licensed Fire Protection Engineer in 2 States
- Professional Member of SFPE
- ...apter

WISCONSIN 1848

SFPE Engineering A Fire Safe World PROFESSIONAL MEMBER

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DEFINITION

OSHA defines combustible dust as:
"A solid material composed of distinct particles or pieces, regardless of size, shape, or chemical composition, which presents a fire or deflagration hazard when suspended in air or some other oxidizing medium over a range of concentrations."

What is combustibl

WARNING COMBUSTIBLE DUST

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COMMON TYPES OF COMBUSTIBLE DUST

1. **Solid organic materials:**
   A. **Sugar**
   B. **Flour**
   C. **Grain**
   D. **Wood**




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COMMON TYPES OF COMBUSTIBLE DUST

2. **Metals:**
   A. **Aluminum**
   B. **Titanium**


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COMMON TYPES OF COMBUSTIBLE DUST

3. **Nonmetallic Inorganic Materials:**
   A. **Fiberglass**
   B. **Carbon**
   C. **Graphite**



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OSHA COMBUSTIBLE DUST LIST

Agricultural Products
Egg white
Milk, powdered
Milk, nonfat, dry
Soy flour
Starch, corn
Starch, rice
Starch, wheat
Sugar
Sugar, milk
Sugar, beet
Tapioca
Whey
Wood flour

Agricultural Dusts
Alfalfa
Apple
Beet root
Carrageen
Carrot
Cocoa bean dust
Cocoa powder
Coconut shell dust
Coffee dust
Corn meal
Cornstarch
Cotton
Cottonseed
Garlic powder
Gluten
Grass dust
Green coffee
Hops (malted)
Lemon peel dust
Lemon pulp
Linseed
Locust bean gum
Malt
Oat flour
Oat grain dust
Olive pellets
Onion powder
Parsley (dehydrated)
Peach
Peanut meal and skins
Peat
Potato
Potato flour
Potato starch
Raw yucca seed dust
Rice dust
Rice flour
Rice starch
Rye flour
Semolina
Soybean dust
Spice dust
Spice powder
Sugar (10x)
Sunflower
Sunflower seed dust
Tea
Tobacco blend
Tomato
Walnut dust
Wheat flour
Wheat grain dust
Wheat starch
Xanthan gum

Carbonaceous Dusts
Charcoal, activated
Charcoal, wood
Coal, bituminous
Coke, petroleum
Lampblack
Lignite
Peat, 22%H_2O
Soot, pine
Cellulose
Cellulose pulp
Cork
Corn

Chemical Dusts
Adipic acid
Anthraquinone
Ascorbic acid
Calcium acetate
Calcium stearate
Carboxy-methylcellulose
Dextrin
Lactose
Lead stearate
Methyl-cellulose
Paraformaldehyde
Sodium ascorbate
Sodium stearate
Sulfur

Metal Dusts
Aluminum
Bronze
Iron carbonyl
Magnesium
Zinc

Plastic Dusts
(poly) Acrylamide
(poly) Acrylonitrile
(poly) Ethylene (low-pressure process)
Epoxy resin
Melamine resin
Melamine, molded (phenol-cellulose)
Melamine, molded (wood flour and mineral filled phenol-formaldehyde)
(poly) Methyl acrylate
(poly) Methyl acrylate, emulsion polymer
Phenolic resin
(poly) Propylene
Terpene-phenol resin
Urea-formaldehyde/ cellulose, molded
(poly) Vinyl acetate/ ethylene copolymer
(poly) Vinyl alcohol
(poly) Vinyl butyral
(poly) Vinyl chloride/ ethylene/vinyl acetylene suspension copolymer
(poly) Vinyl chloride/ vinyl acetylene emulsion copolymer

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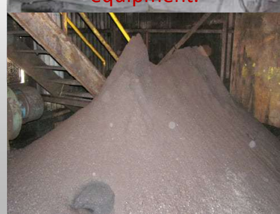
EXAMPLES OF DUST



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Code Requirements

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APPLICABLE CODES

- 2015 International Fire Code (IFC)
  - Chapter 22 – Combustible Dust-Producing Operations
- National Fire Protection Association
  - NFPA 652 – Standard on Fundamentals of Combustible Dust
  - NFPA 654 – Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids
  - NFPA 61 – Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities
  - NFPA 484 – Standard for Combustible Metals
  - NFPA 655 – Standard for the Prevention of Sulfur Fire and Explosions
  - NFPA 664 – Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities

NFPA 652

NFPA 652

- NFPA 652 – *Standard on the Fundamentals of Combustible Dust*
- Section 1.1 – Scope:
  - "This standard shall provide the basic principles of and requirements for identifying and managing the fire and explosion hazards of combustible dusts and particulate solids."
- Section 5.2.1
  - Determination of combustibility or explosibility shall be based upon either:
    - Historical facility data or published data deemed represen materials and conditions.
    - Analysis of representative samples.

NFPA 652

- NFPA 652 – *Standard on the Fundamentals of Combustible Dust*
- Dust Hazards Analysis (DHA) Requirements
- Section 7.1.1.1:
  - "A DHA shall be completed for all new processes and facility compartments."
- Section 7.1.1.2:
  - "For existing processes and facility compartments, a DHA shall be completed by **September 7, 2020**."
- Section 7.1.1.3:
  - "The owner/operator shall demonstrate reasonable progress each year in completing DHAs prior to the deadline set in 7.1.1.2."

NFPA 652

- Section 7.1.2:
  - "The **owner/operator** of a facility where materials determined to be combustible or explosible in accordance with Chapter 5 are present in an enclosure **shall be responsible** to ensure a DHA is completed in accordance with the requirements of this chapter."
- Section 7.1.3:
  - "The absence of previous incidents shall not be used as the basis for not performing a DHA."
- Section 7.1.4:
  - "The DHA shall be reviewed and updated at least every 5 years."

Properties of Dust

DUST TESTS

- Maximum Pressure Developed by the Deflagration (P_{max})
- Maximum Rate of Pressure Rise $(dP/dt)_{max}$
  - Volume Normalized Rate of Pressure Increase (K_{St})
- Minimum Explosible Concentration (MEC)
- Minimum Ignition Energy (MIE)

MEASUREMENT	DESCRIPTION
KST	[illegible]
MIE	Minimum ignition energy, the smallest amount of heat or energy that can cause your dust to ignite
MEC	Minimum explosive concentration, the smallest amount of dust in the air that will ignite to cause an explosion
PMAX	Maximum pressure, the greatest amount of pressure and maximum amount of damage that your dust can cause in an enclosed space

PARTICULATE SIZE

- Rate of combustion depends on particle size.
- The smaller the average particle size:
  - The greater the rate of combustion.
  - The more hazardous the particulate.
- Rarely are all particles the same size.
  - Usually shown as a distribution.
- The generally accepted size criterion for flame propagation is 500µ (passing U.S. #35 sieve).

CONCENTRATION

- Deflagration hazard when dust cloud concentration ranges between:
  - Greater than or equal to the lower explosive limit (LEL)
  - Less than or equal to the upper explosive limit (UEL) – rarely available figure
- Laboratory tests will determine the Minimum Explosible Concentration (MEC)
  - This figure is measured in grams/cubic meter (g/m^3).
  - Typically decreases with decreasing particle size (i.e. the smaller the particle, the lower the concentration needed for explosibility).
  - Variations occur - MEC is lowered as the diameter of particles decreases.

MOISTURE CONTENT

- Moisture in particles raises minimum ignition temperature (MIT).
  - Increases agglomeration of particles.
  - Heat is absorbed during heating and vaporization of the moisture.
- Direct relationship between moisture content and:
  - Minimum ignition energy (MIE)
  - Minimum explosible concentration (MEC)
  - Maximum pressure developed by deflagration (P_{max})
  - Maximum rate of pressure rise $(dP/dt)_{max}$

MAXIMUM DEFLAGRATION PRESSURE

- Maximum Pressure Developed by the Deflagration (P_{max})
  - The maximum pressure produced during a deflagration
  - P_{max} is determined in accordance with ASTM E 1226, *Standard Test Method for Explosibility of Dust Clouds*
  - Demonstrates the power of the dust particles under ideal conditions

RATE OF PRESSURE INCREASE

- Volume-Normalized Rated of Pressure Increase (K_{St})
  - Also referred to as the Deflagration Index
  - The maximum rate of pressure increase normalized to the volume in which the rate was measured.

Examples of K_{st} Values for Different Types of Dusts

Dust explosion class*	K_{st} (bar.m/s)*	Characteristic*	Typical material**
St 0	0	No explosion	Silica
St 1	>0 and ≤ 200	Weak explosion	Powdered milk, charcoal, sulfur, sugar and zinc
St 2	>200 and ≤ 300	Strong explosion	Cellulose, wood flour, and poly methyl acrylate
St 3	>300	Very strong explosion	Anthraquinone, aluminum, and magnesium

The actual class is sample specific and will depend on varying characteristics of the material such as particle size or moisture.

* OSHA CPL 03-00-008 - *Combustible Dust National Emphasis Program.*

** NFPA 68, *Standard on Explosion Prevention by Deflagration Venting.*

Fire & Explosion Hazards

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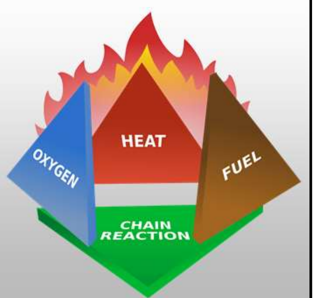
FIRE TETRAHEDRON

- Fire comprises 4 parts:
  - Fuel (something that will burn)
  - Heat (enough to make it burn)
  - Oxygen
  - Chain Reaction



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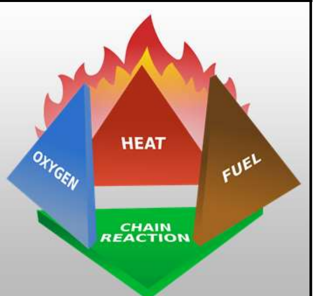
FLASH FIRE

NFPA 652 defines as:
“A fire that spreads by means of a flame front rapidly through a diffuse fuel, such as dust, gas, or the vapors of an ignitable liquid, without the production of damaging pressure.”



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DEFLAGRATION

NFPA 652 defines as: “Propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium.”

This can be thought of as an expanding ball of flame that is rapidly consuming a cloud of dust.

Usually deflagrations rapidly produce large increases in pressure when they occur within a confining enclosure.

DEFLAGRATION

- 4 Conditions Necessary for Dust Deflagration:
  - Combustible particulate of sufficiently small particle size to be deflagrable (i.e. explosible).
  - Deflagrable (i.e. explosible) particulate suspension of sufficiently high concentration.
  - Deflagrable (i.e. explosible) particulate is suspended in air or other oxidizing medium (i.e. sufficient oxygen concentration).
  - Source of ignition is strong enough to ignite where applied to the suspension that is of sufficient concentration for flame propagation.

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DEFLAGRATION

- Liberate large quantities of heat very rapidly.
- Increases the air temperature rapidly.
- Causes the air and combustion product gases to expand rapidly.
- Rapid heating & expansion causes large pressures to develop.
- Pressure increase produces a radiating acoustic wave.
- Pressure increase causes rapid flow of combustion product gases.

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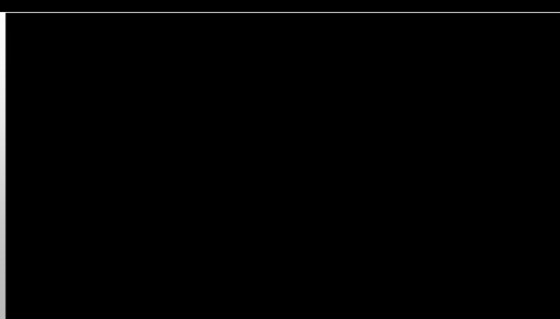
DETONATION

NFPA 68 defines as:
"Propagation of a combustion zone at a velocity greater than the speed of sound in the unreacted medium."

DETONATION



EXPLOSION

NFPA 69 defines as:
"The bursting or rupturing of an enclosure or container due to the development of internal pressure from a deflagration."

The ***explosion*** is the ***result***.

The ***deflagration*** is the ***process*** that causes the result.

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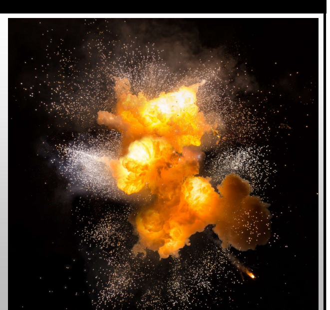


FLASH FIRE VS. DEFLAGRATION VS. EXPLOSION

FM GLOBAL DUST EXPLOSION TEST

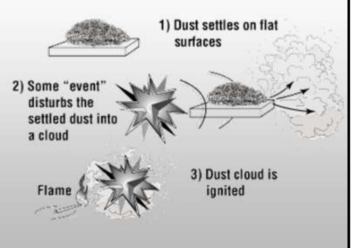
SECONDARY EXPLOSION

Dust deflagration in process equipment causes failure.

Produces a strong disturbance in the form of a blast wave and associated air motion.

Disturbance causes settled dust into suspension and forms a combustible dust cloud.

Cloud often ignited by the flame that has emerged from the equipment.



Hazard Management

DUST LAYER DEPTH

- NFPA 654 Layer Depth Criterion is 1/32" (0.8 mm)
- Dust explosion or flash-fire hazard exists if:
  - Total area of nonseparated dust accumulations exceeding the layer depth criterion is greater than 5% of the footprint area.
  - Area of any single nonseparated dust accumulation exceeding the layer depth criterion is greater than 1000 ft^2.
  - Total volume of nonseparated dust accumulations is greater than the layer depth criterion multiplied by 5% of the footprint area.
  - Total volume of any single nonseparated dust accumulations is greater than the layer depth criterion multiplied by 1000 ft^2.
- Mass Method A
- Mass Method B
- Risk Assessment Method

HAZARD MANAGEMENT

- Control of Ignition Sources
- Control of Concentration
- Explosion Protection

CONTROL OF IGNITION

- Mechanical Sparks & Friction
- Electrical Equipment per NFPA 70
- Static Electricity
- Cartridge-Actuated Tools
- Hot Work
- Process & Comfort Heating Equipment
- Hot Surfaces

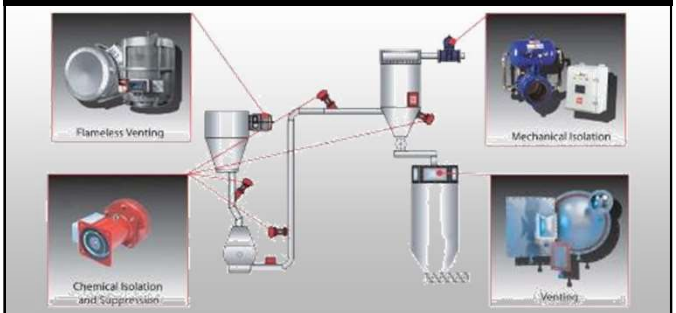
CONTROL OF CONCENTRATION

- Control of Oxidant Concentration
- Control of Fuel
- Housekeeping

EXPLOSION PROTECTION

- Explosion Venting
- Deflagration Isolati
- Deflagration Suppr
- Return Air Diversio

EXPLOSION PROTECTION



Case Studies

IMPERIAL SUGAR

- February 7, 2008
- Port Wentworth, GA
- Sugar Dust
- 14 Deaths
  - 8 at the scene
  - 6 at the burn center
- 38 Injured

WEST PHARMACEUTICAL SERVICES

- January 29, 2003
- Kinston, NC
- Fine Plastic Powder
- 6 Deaths
- 36 Injured

CTA ACOUSTICS

- February 20, 2003
- Corbin, Kentucky
- Resin Dust
  - Resin was a phenolic binder used to produce fiberglass mats
- 7 Deaths
- 37 Injured

DIDION MILLING

- May 31, 2017
- Cambria, Wisconsin
- Corn Dust
- 5 Deaths
- 14 Injured

Owner Responsibilities

OWNER RESPONSIBILITIES

- Determine combustibility and explosibility hazard of materials.
- Conduct a Dust Hazard Analysis (DHA)
  - A systematic review to identify and evaluate the potential fire, flash fire, or explosion hazards.
- Manage identified fire, flash-fire, and explosion hazards.
  - A prescriptive approach.
  - A performance-based approach.
- Communicate hazards to affected personnel.
- Establish written Safety Management System.

FINAL REMINDER

Questions?

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COMBUSTIBLE DUST

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