CE 400 / CE 500

Process Safety Management

Lecture 15 Combustible Dust and Deflagration Indices

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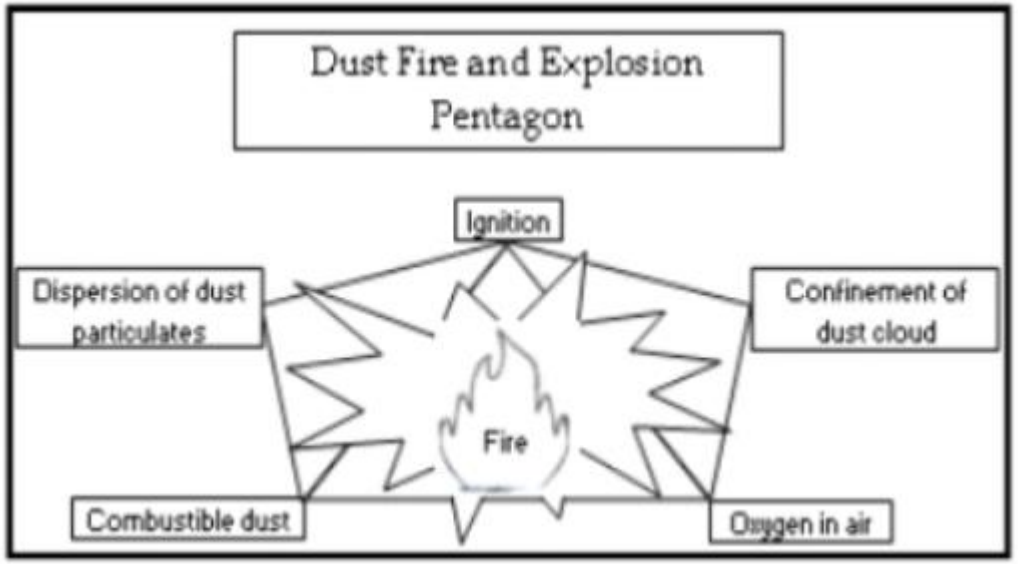
More than just the Fire Triangle

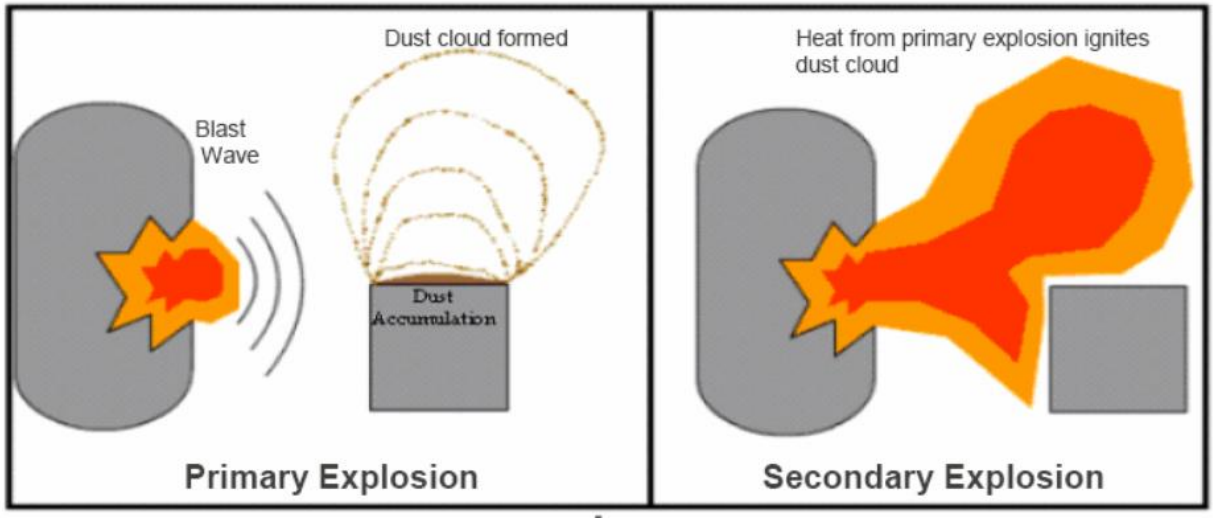
- A pile of combustible dust will not be likely to burn
- It must be dispersed in air as a cloud of dust and have some confinement if it is to cause an explosion



- https://www.osha.gov/dts/shib/shib073105.html

Secondary Explosions

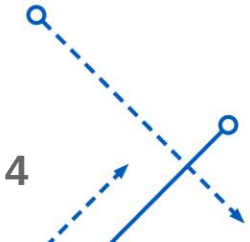
- A primary explosion (may be a vapor cloud explosion) creates a pressure wave which disperses piles of dust into a dust cloud
- These dust clouds find ignition sources – may be heat from primary explosion
  - Can create a chain of explosions



- https://www.osha.gov/dts/shib/shib073105.html

Imperial Sugar Company Explosion

- February 7, 2008 in Fort Wentworth, GA
- 14 fatalities, 36 non-fatal injuries
- Sugar dust is actually a very combustible material
  - It's pure fuel!
- https://www.youtube.com/watch?v=fI-jlNqpCQ8

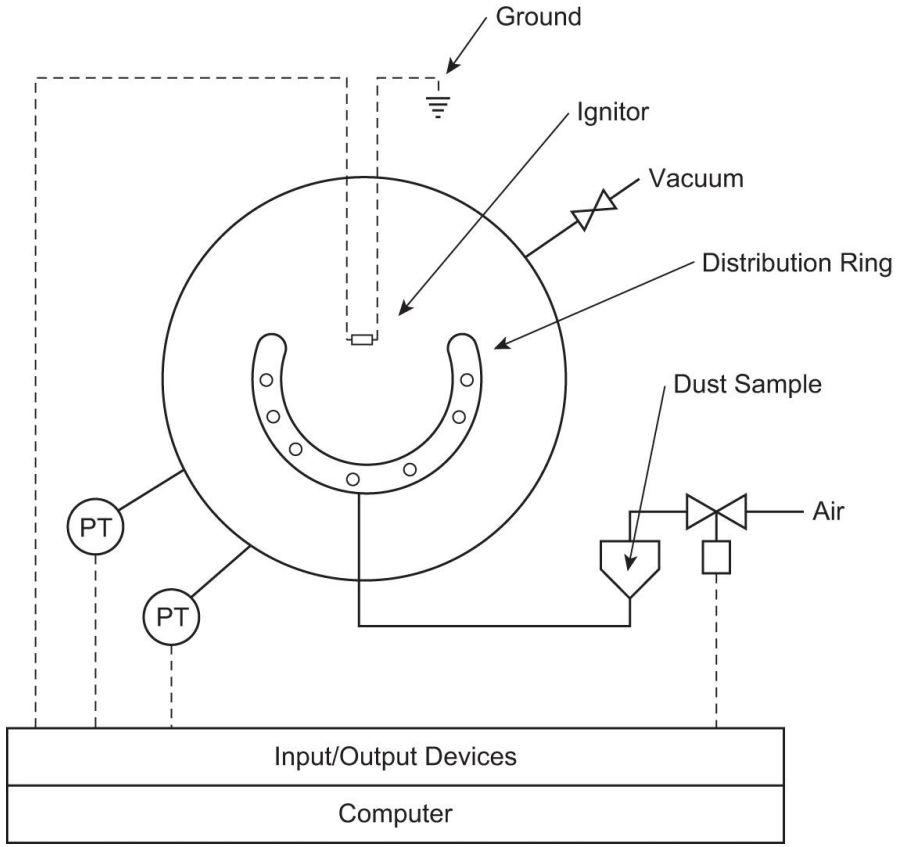


What is a Combustible Dust?

- Typically an organic solid
  - Carbon based particles participate in classic combustion reaction
  - Some metals (for example, Fe and Al) can rapidly oxidize when occurring as fine particles are combustible
    - Not the combustion reaction we typically think of, but a rapid oxidation leading to explosive release of energy
- There is no universal answer to the question “Is such and such a material a combustible dust”
  - It is absolutely dependent on the particle size distribution
    - A material that is not combustible at a given particle size will eventually become combustible if the particle size becomes small enough
      - Assuming that it chemically can participate in a combustion/oxidation reaction
  - You NEED samples from your actual production process to actually answer the question of whether or not you are dealing with combustible dust in your plant

Determining if a Sample is Combustible

- Samples are collected anywhere that dust is found in your plant
- Sample is blown into the chamber via the distribution ring to create a uniform dust cloud
- Ignitor introduces spark of a specific energy
- Pressure transmitters monitor the rise in pressure
- Very similar apparatus is used to measure vapor/air mixtures
  - Distribution ring and air supply not required for vapor testing

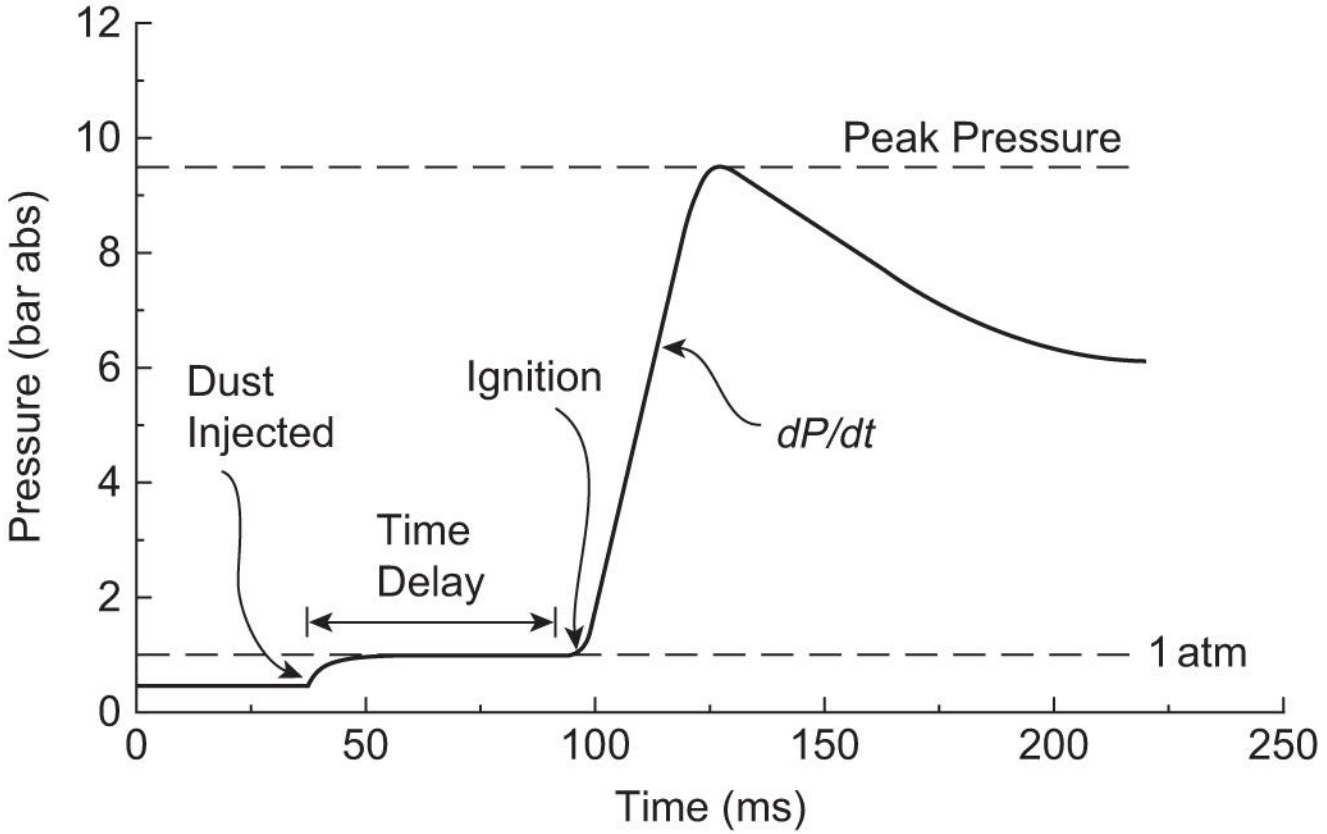


Test apparatus for acquiring dust explosion data.

Combustible Dusts and Deflagration Indices

Explosion Data

- The range of concentrations that are explosive can be determined
- The maximum rate of pressure increase indicates the robustness of an explosion
- Can be run at different ignition energies for screening purposes
- Note the extremely short time frame!



Pressure data from dust explosion device.

Deflagration Indices

- Create log-log plot of Maximum rate of Pressure Rise vs Volume of Test Vessel
- Frequently results in a straight line with slope = -1/3
- This leads to relationship:

$$\left(dP/dt\right)_{max} V^{1/3} = Constant$$

- The constant is known as the deflagration index for that sample
- For a vapor the constant is K_G
- For a dust the constant is K_{St}
- These values are sensitive to the experimental configuration and conditions
  - For example – mixing and distribution

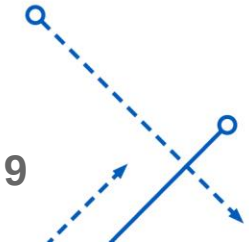
Extrapolating Data

- If one knows the deflagration index then they can predict the maximum rate of pressure rise of an explosion in a production vessel

$$\left[\left({}^{dP}/_{dt}\right)_{max} V^{1/3}\right]_{in\ vessel} = K_{St}\ or\ K_G$$

- "In vessel" could refer to a process vessel or a room

- Note that maximum pressure achieved is highly dependent on initial pressure of vessel

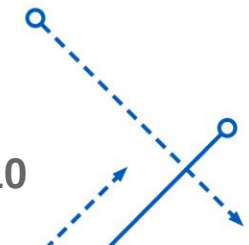


St Classes for Combustible Dusts

- Various ranges of K_{St} indicate different design requirements from NFPA standards

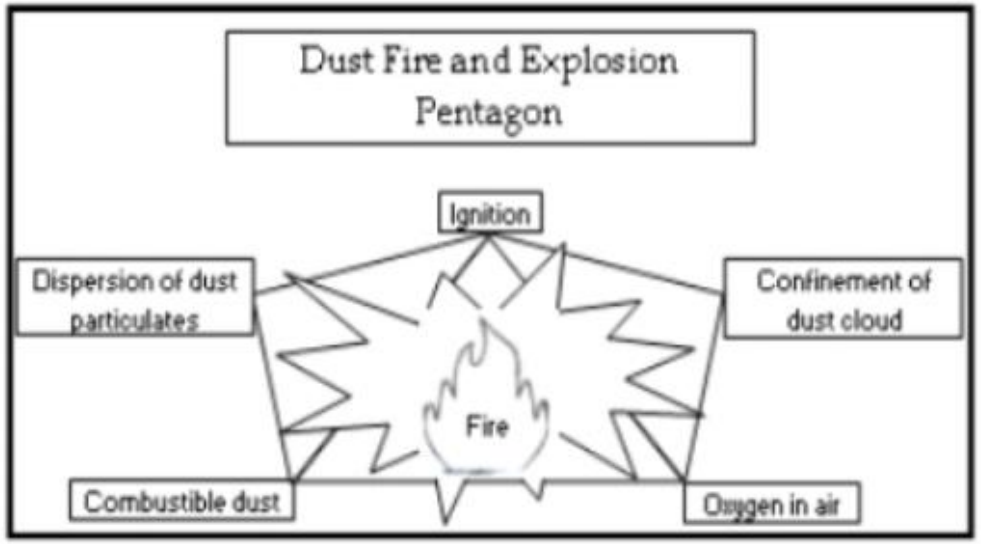
K_{St} (bar m/s)	St Class
0	St-0
1-200	St-1
200-300	St-2
>300	St-3

- Data in textbook (Table 6-8) for various materials depends massively on the particle size distribution
  - They quote median particle size but the range of fines is also very important



Back to the Beginning

- Just like for vapors there is a range of concentrations where dust cloud is combustible – you need the proper mix of fuel to oxygen
- The dust must be of a material that can participate in a combustion/oxidation reaction and the particles must be small enough
- The dust must be dispersed into a cloud and contained
- An ignition source is needed, the MIE is typically much higher than that of a vapor cloud explosion

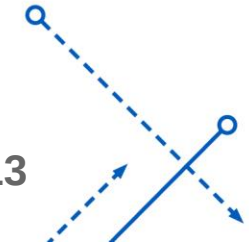


Combustible Dust Program

- Assessment
  - Do you handle solids?
  - If so can they participate in a combustion reaction?
    - Organic (Contain Carbon and Hydrogen) - yes
    - Certain metals – yes
    - Rocks/Minerals - no
- Survey your plant
  - Collect samples
    - Inside equipment
    - Fugitive dust that has escaped the equipment and is collecting around the plant
      - Collect samples from the highest surfaces – it will have the smallest particle size distribution and be the most likely to be combustible

Combustible Dust Program

- Have the samples tested to determine the deflagration index of various samples
- Consult NFPA design standards for design requirements
  - May need to add:
    - Inerting
    - Non-sparking equipment with explosion-proof housings
    - Relief panels
    - Explosion/Fire suppression systems



Combustible Dust Program

- **CONTROL** – If at all possible modify process to eliminate production of combustible dust
  - Change composition of material
  - Change processing to increase particle size distribution
- **CONTAIN** – Seal up process equipment to eliminate dust from escaping
  - Process equipment still needs to be designed for combustible dust
- **CAPTURE** – Use dust collection equipment to capture and remove dust that has escaped from process equipment
  - Dust collection system must be designed for combustible dust
- **CLEAN** – Institute and monitor a program to clean up any dust that has collected on surfaces in your plant

Combustible Dust Program - Cleaning

- Cleaning must be done in a manner which does not disperse collected dust into clouds
  - Do not use compressed air to blow off equipment!
- Vacuum equipment must be rated for combustible dust
- After initial cleaning you need to monitor the rate of accumulation to determine required frequencies for cleaning
- Rule of thumb – if you cannot see what color the paint is, then the layer of dust is too thick
  - Due to large surface areas a thin layer can create a large cloud of dust in the combustible range