I. Introduction

Presentation Goal

Increase the participant's awareness and understanding of Diffuse Fuel Explosions in order to more effectively implement an assessment and control strategy.

Presentation Scope

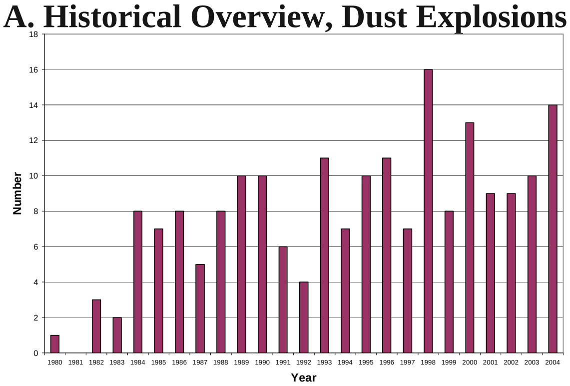
Emphasis will be placed on Dust Explosions, but a brief discussion including all diffuse fuels will be included as these events can also have catastrophic results.

Presentation Objectives

Upon completion of this presentation the participant will be able to:

1. Define and explain key terminology associated with diffuse phase fuel explosions
2. Identify the 5 components required to have a dust or other diffuse phase fuel explosion.
3. Identify hazards conditions that may be in the workplace that will contribute to a dust or other diffuse fuel explosion.
4. Identify control and prevention methodologies for the hazards identified.

A. Historical Overview, Dust Explosions



Source: US Chemical Safety and Hazard Investigation Board

A. Historical Overview

Dust Explosion Incidents
US Chemical Safety Board (CSB)

197 Incidents since 1980
109 Fatalities
592 Injuries

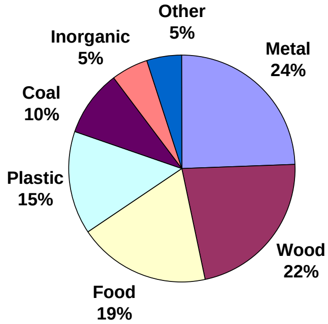
Does not include:

- **Grain handling facilities**
- **Coal mining incidents**
- **Fuel Gas Explosions**
- **Incidents in non-manufacturing sectors (universities, hospitals, military, retail)**
- **Transportation related incidents**
- **Incidents occurring outside the U.S.**

Non-Reported Incidents

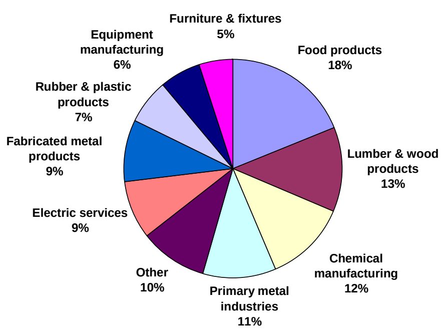
Minor Damage
No Injuries or Fatalities
No Emergency Response

Materials Involved in Incidents



Source: US Chemical Safety and Hazard Investigation Board

Industries



Source: US Chemical Safety and Hazard Investigation Board

CTA Acoustics

Corbin, KY

- February 20, 2003
- Phenolic Resin

CTA Acoustics

7 dead, 37 injured
Widespread facility damage
Fuel was Phenolic Resin
- Lofted by cleaning
- Ignited by flames from open door of curing oven
- Secondary explosions traversed facility

Imperial Sugar Plant

- 14 worker fatalities
- Eight workers died at the scene
- Six others eventually succumbed to their injuries
- Thirty six workers were treated for serious burns and injuries—some caused permanent, life altering conditions.
- Explosions and subsequent fires destroyed the sugar packing buildings, palletizer room, and silos, and severely damaged the bulk train car loading area and parts of the sugar refining process areas.

B. Terminology

1. Combustible Dust

Combustible Dust. A combustible particulate solid that presents a fire or deflagration hazard when suspended in air or some other oxidizing medium over a range of concentrations, regardless of particle size or shape.

Combustible Particulate Solid. Any combustible solid material, composed of distinct particles or pieces, regardless of size, shape, or chemical composition.

Hybrid Mixture. A mixture of a flammable gas with either a combustible dust or a combustible mist.

Source: NFPA 654 Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids
2006 Edition

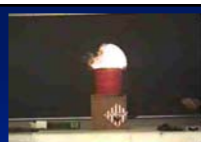
2. Diffuse and Condensed Phase Fuel Explosions

Diffuse Phase Fuel, Gases and Vapors

A general category of combustion explosions that occur as a result of the ignition of fuel gases (i.e. Natural Gas, LPG), Industrial Gases, Sewer Gases, and vapors of pooled liquids (i.e. gasoline vapors, lacquer thinner, MEK).

Dust Explosion

Ignition of solid materials such as dusts and fines.



Non-Seated Explosion

Those explosions where there is no physical evidence of a single location where the explosion originated.

Diffuse Phase Fuel

Condensed Phase Fuel

An explosive material in the form of a solid or liquid rather than a gas or vapor.

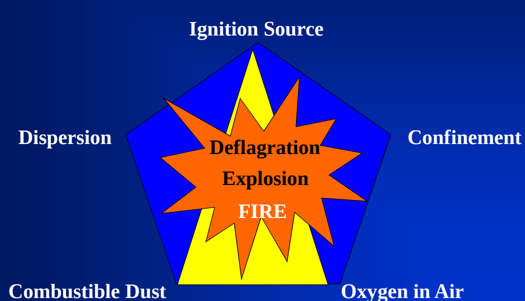
Mechanical Explosion

BLEVE

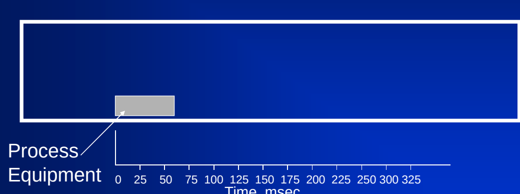
- Boiling
- Liquid
- Expanding
- Vapor
- Explosion

II. Dynamics of Dust or other Diffuse Fuel Explosion

A. 5 Elements Required for a Dust or other Diffuse Fuel Explosion



B. The "Typical" Explosion Event



1. Dust Explosions

a. Finely divided solids as fuels

- Suspended
- Layered


1. Dust Explosion

1. Dust Explosion




2. Wide variety of materials

Combustible and Non-Combustible

Dust Explosions, Continued

3. Particle size

a. Rates of combustion related to surface area

b. Violence of explosion is inversely proportional to particle size

c. 840 microns (0.033") diameter or less for explosion hazard

Dust Explosions, Continued

4. Concentration

a. Effect upon ignitability and violence of blast pressure wave

b. Minimum concentrations exist for specific materials

c. Minimum concentrations for most materials are from 0.015 to 2.0 oz./cu.ft.

d. Most common concentrations are less than 1.0 oz./cu.ft.

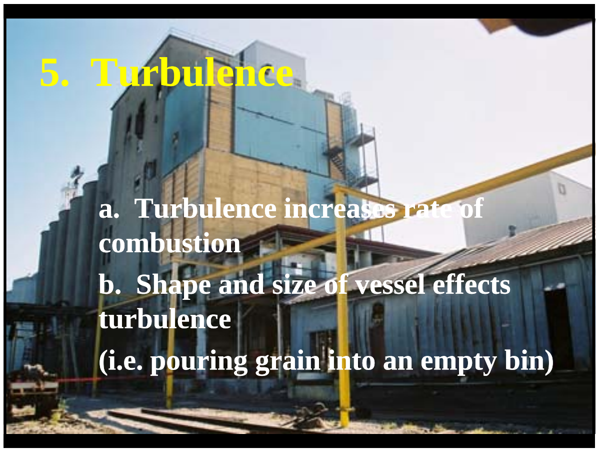
Concentration, Continued

LEL

e. Generally no upper concentration limit

f. Reaction more controlled by surface area to air ratio than by a maximum concentration

g. Rate of pressure rise and maximum pressures increase with concentration to stoichiometric and decrease in higher concentrations



7. Minimum Ignition Energy (MIE)

a. Ignition temperatures generally 572-1112 F

b. Layered dusts have lower ignition temperatures than the same dusts in suspension

c. Minimum ignition energies are higher than for gases and vapors

d. 10-40 millijoules

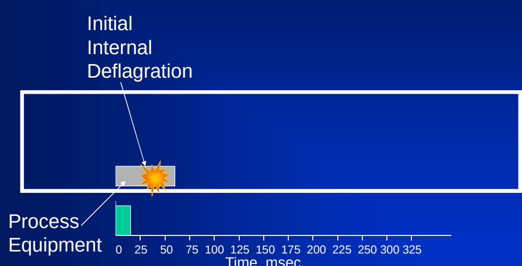
8. Progression of Dust Explosions

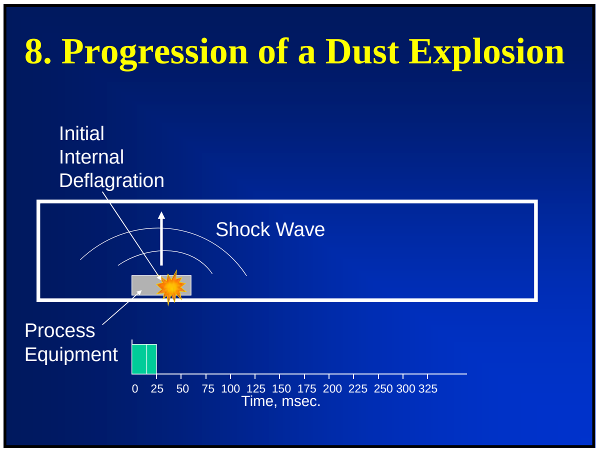
a. Usually occur in series

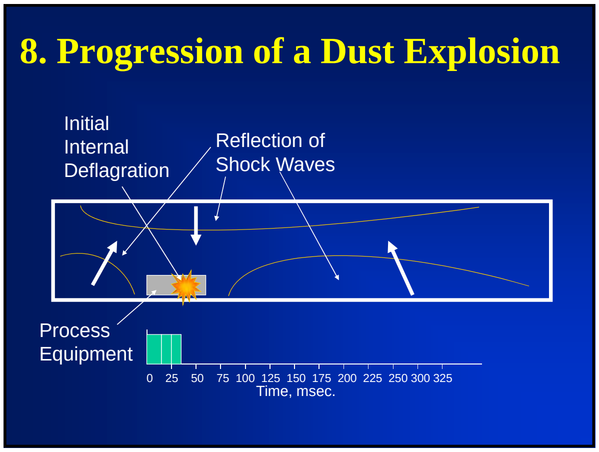
b. Initial explosions usually less violent than subsequent

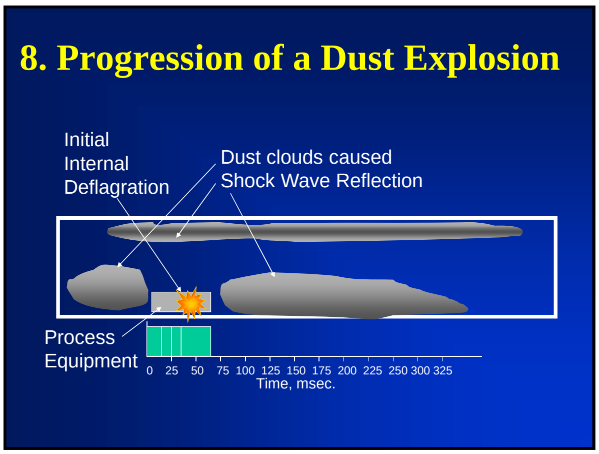
c. Subsequent explosions are fueled by additional dust put into suspension

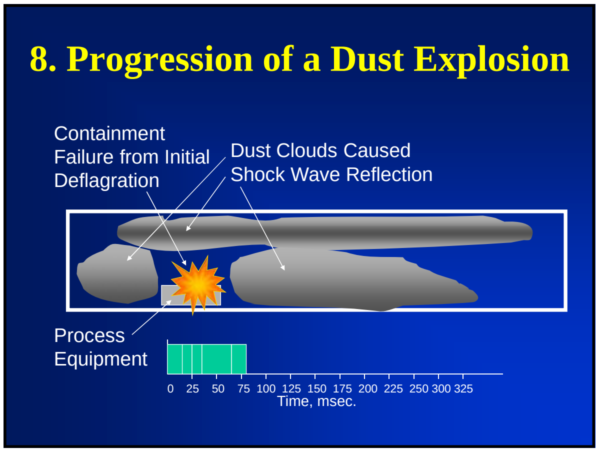
8. Progression of a Dust Explosion

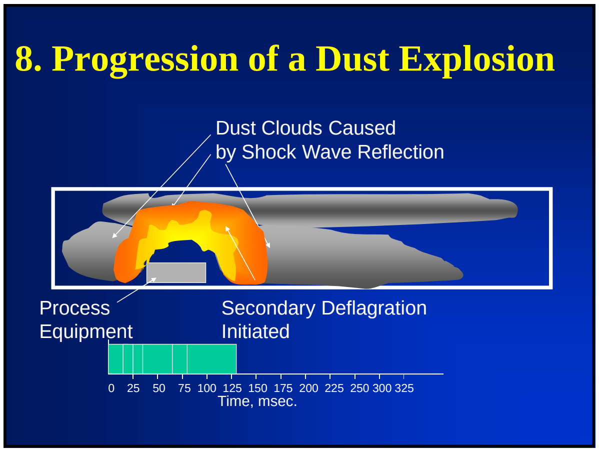


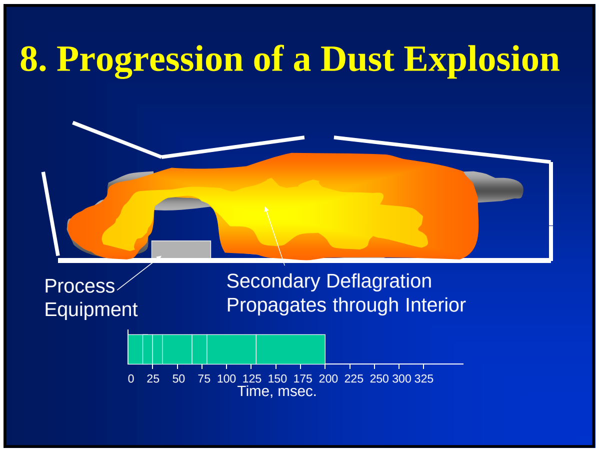

8. Progression of a Dust Explosion
Initial Internal Deflagration
Shock Wave
Process Equipment
0 25 50 75 100 125 150 175 200 225 250 300 325
Time, msec.

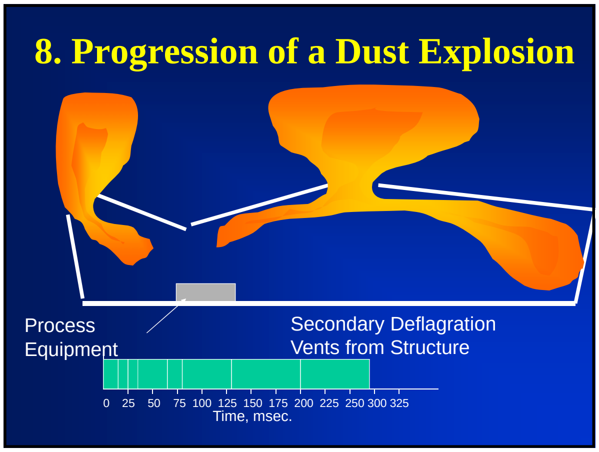

8. Progression of a Dust Explosion
Initial Internal Deflagration
Reflection of Shock Waves
Process Equipment
0 25 50 75 100 125 150 175 200 225 250 300 325
Time, msec.

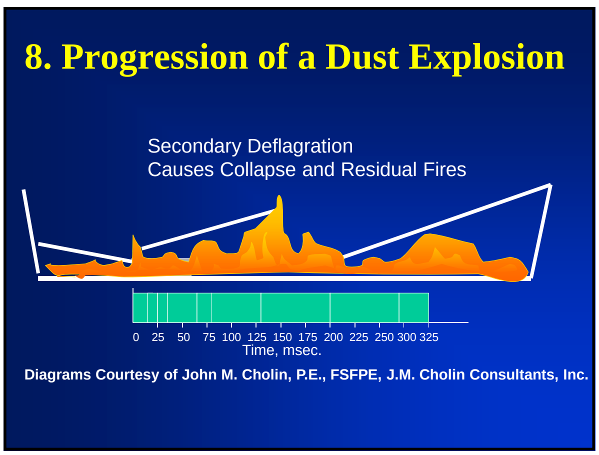

8. Progression of a Dust Explosion
Initial Internal Deflagration
Dust clouds caused Shock Wave Reflection
Process Equipment
0 25 50 75 100 125 150 175 200 225 250 300 325
Time, msec.


8. Progression of a Dust Explosion
Containment Failure from Initial Deflagration
Dust Clouds Caused Shock Wave Reflection
Process Equipment
0 25 50 75 100 125 150 175 200 225 250 300 325
Time, msec.


8. Progression of a Dust Explosion
Dust Clouds Caused by Shock Wave Reflection
Process Equipment
Secondary Deflagration Initiated
0 25 50 75 100 125 150 175 200 225 250 300 325
Time, msec.

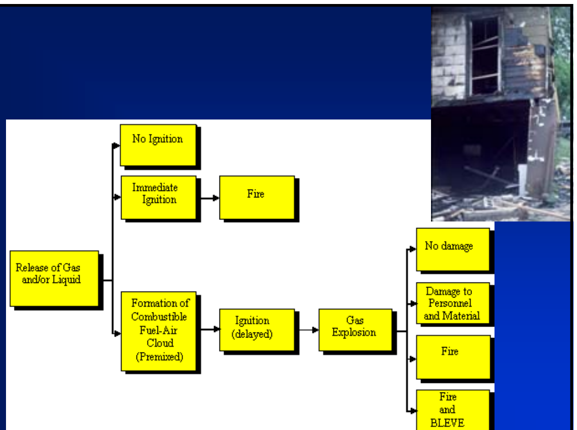

8. Progression of a Dust Explosion
Process Equipment
Secondary Deflagration Propagates through Interior
0 25 50 75 100 125 150 175 200 225 250 300 325
Time, msec.


8. Progression of a Dust Explosion
Process
Equipment
Secondary Deflagration
Vents from Structure
0 25 50 75 100 125 150 175 200 225 250 300 325
Time, msec.


8. Progression of a Dust Explosion
Secondary Deflagration
Causes Collapse and Residual Fires
0 25 50 75 100 125 150 175 200 225 250 300 325
Time, msec.
Diagrams Courtesy of John M. Cholin, P.E., FSFPE, J.M. Cholin Consultants, Inc.


9. CSB Model of the Imperial
Sugar Plant Explosion

C. Progression of a Fuel Gas Explosion, Confined



Gas Migration Ignition Study, Minnesota Chapter IAAI

To much gas(oline)!

Flash fire or unconfined combustion explosion?

III. Prevention Strategies

1. Keys to Prevention

Increased Hazard Awareness

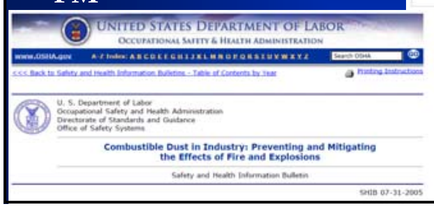
- Improved MSDSs
- Dust explosions taught in undergrad curricula
- Access to NFPA standards

Apply Principles of PSM

- Change management
- Hazard evaluation
- Incident investigation
- Hazard communication

2. Follow Recommended Practices

OSHA
NFPA
FM



3. Incident Investigation

- Precursor events
  - Small deflagrations or fires
  - Events at other facilities
  - "Whew" events (if not for the safety device, this could have been bad)
- Not reported
- Not investigated
- No corrective actions taken
- Findings not communicated to employees

4. Increase Emergency Response Planning

Evacuation in the Event of an Event

III. Hazard Mitigation

- Dust control
- Ignition source control
- Damage control

A. Dust Control

- Design of facility & process equipment
- Contain combustible dust
- Clean fugitive dust
  - Regular program
  - Access to hidden areas
  - Safe cleaning methods
- Maintenance

1. Dust Layer Thickness Guidelines

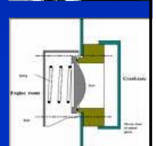
- 1/8” in grain standard
- Rule of thumb in NFPA 654
  - 1/32” over 5% of area
  - Bar joist surface area ~ 5%
  - Max 20,000 SF
- Consider point in cleaning cycle

B. Ignition Source Control

- Electrical equipment
- Static electricity control
- Mechanical sparks & friction
- Open flame control
- Design of heating systems & heated surfaces
- Use of tools, & vehicles
- Maintenance

C. Damage Control Construction

- Detachment (outside or other bldg.)
- Separation (distance with in same room)
- Segregation (barrier)
- Pressure resistant construction
- Pressure relieving construction
- Pressure Venting
- Relief valves
- Maintenance



C. Damage Control Systems

- Specialized detection systems
- Specialized suppression systems
- Explosion prevention systems
- Maintenance

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