Dust Explosion in Malaysia : A Review

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CONTENT OF PRESENTATION

- Introduction to Dust Explosion
- Dust Explosion Review : USA & Malaysia
- Causes of Dust Explosion
- Prevention and Mitigation of Dust Explosion
- Dust Explosion R&D Work at UMP

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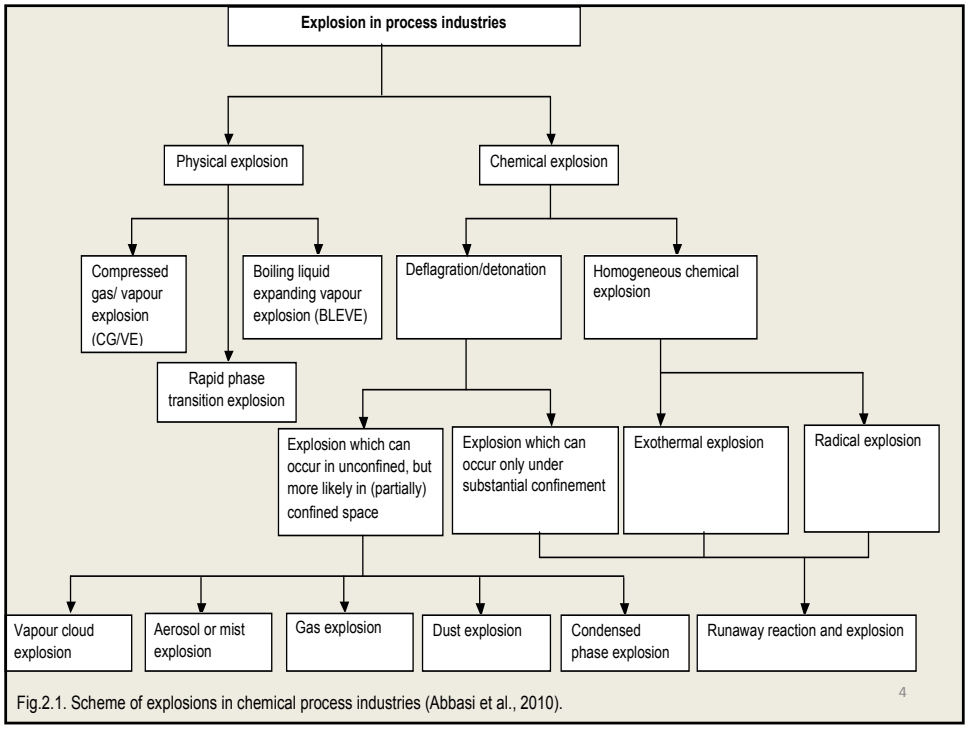

Fig.2.1. Scheme of explosions in chemical process industries (Abbasi et al., 2010).

DEFINITION OF DUST

Dust are fine solid airborne particles which capable to passing a standard sieve.

The National Fire Protection Association (NFPA) defines dust as any finely divided solid, 420 µm or less in diameter that passed through a U.S. No 40 standard sieve (Amyotte and Eckhoff, 2010).

According to British Standard Institute code BS2955:1958, dust are particles less than 76 µm in diameter (Abbasi and Abbasi, 2007).

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Charateristics of Dust Explosion

[www.dustexplosion.info]

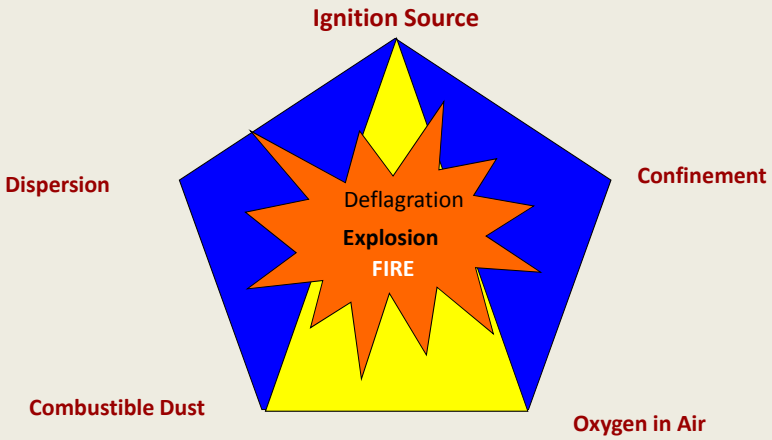
When a mass of solid flammable material is heated it burns away slowly owing to the limited surface area exposed to the oxygen of the air.

The energy produced is liberated gradually and harmlessly because it is dissipated as quickly as it is released.

The result is quite different if the same mass of material is ground to a fine powder and intimately mixed with air in the form of a dust cloud.

In these conditions the surface area exposed to the air is very great and if ignition now occurs the whole of the material will burn with great rapidity; the energy, which in the case of the mass was liberated gradually and harmlessly, is now released suddenly with the evolution of large quantities of heat and, as a rule, gaseous reaction products

Dust Explosions



Require 5 Elements Simultaneously

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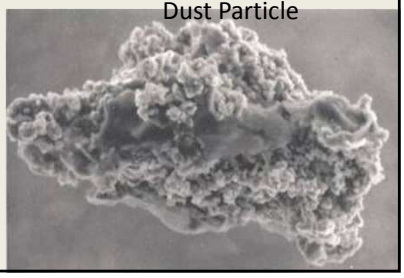
Dust Explosions Factors

- The dust must be combustible and fine enough to be airborne.
- The dust cloud must beat the Minimum Explosive Concentration (MEC) for that particular dust.
- There must be sufficient oxygen in the atmosphere to support and sustain combustion.
- There must be a source of ignition.
- The dust must be confined.
- The dust must be dry.



PROCESSES INVOLVED

1. The milling industries where these materials are converted into powders, flours, meals or dusts;
2. The industries that use such powders, flours, meals or dusts;
3. The industries in which metal castings, or articles of wood, cork, plastics, or other materials are smoothed or polished on abrasive wheels, polishing mops or bands, the dust being produced as an unwanted by-product.

The potential industries with dust explosions hazard (Abbasi and Abbasi, 2007; Amyotte and Eckhoff, 2010)

1) **Wood processing and storage including paper products;**
2) **Grain and foodstuffs material and equipments such as grain dust, flour and feed mills, elevator, bins and silos; metal manufacturing, fabrication and storage of metals powders and dusts;**
3) **Power generation which deals with pulverized coal, wood and peat;**
4) **Chemical production and process industries such as pesticides, dyes and paints; plastic or polymer production and processing;**
5) **Food production, processing and storage including sweetener products, starch, candies and spices;**
6) **Rubber processing and production;**
7) **Textile manufacturing and processing such as wool, linen flax and cotton; and**
8) **Pharmaceutical processing plants.**

The Frequency of Dust

Examples of materials that have historically caused dust explosions include:

- Cosmetics
- Coal
- Dyes
- Grain and other dry foods
- Metal
- Pharmaceuticals
- Plastic and rubber
- Printer toner
- Soaps
- Textiles, Wood and Paper

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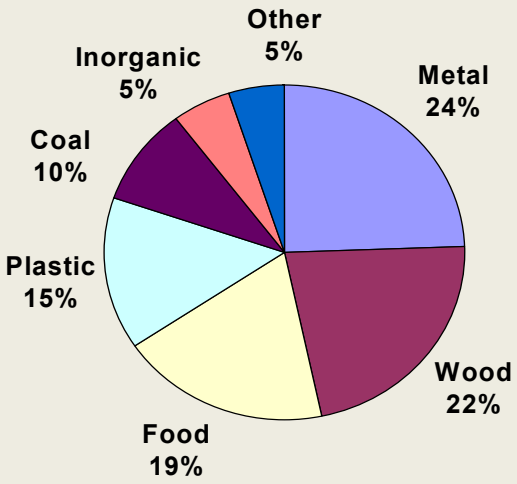
Typical Materials involved in incidents in USA 1980-2005 [CSB 2006]



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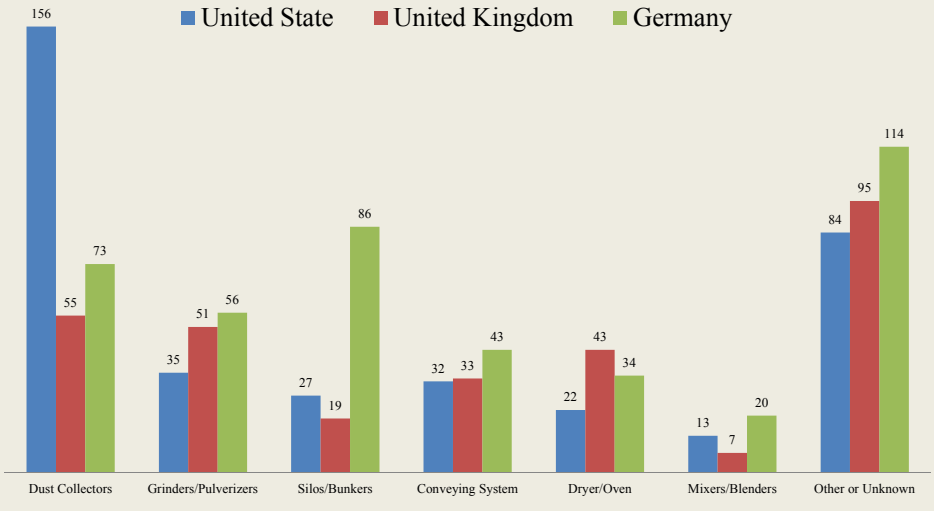
Equipment involved in dust explosions. [Zalosh et al. 2005]



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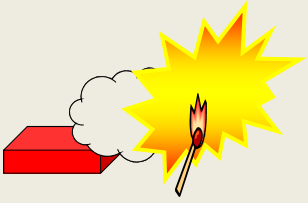
Dust explosion in a work area

Dust settles on flat surfaces

Some event disturbs the settled dust into a cloud

Adapted from CSB



Dust cloud is ignited and explodes

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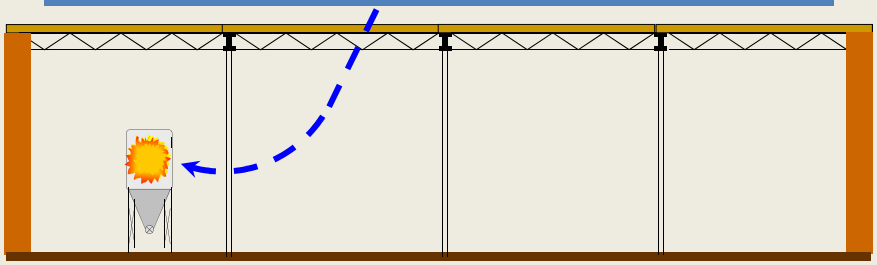
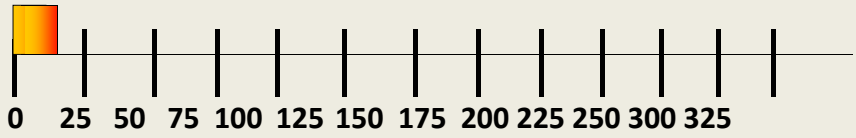
The "Typical" Explosion Event

Primary deflagration inside process equipment





Time, msec.
(Timing of actual events may vary)

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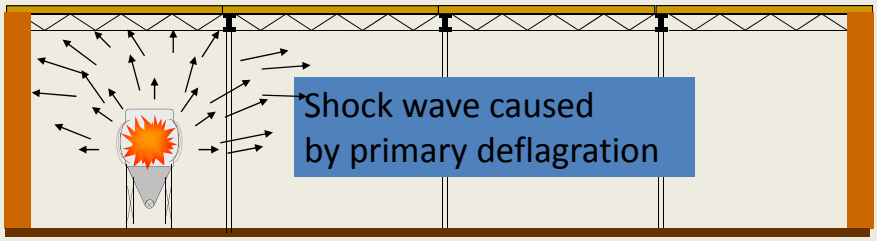
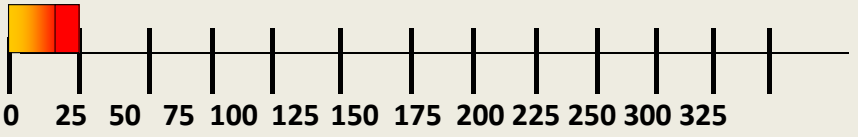
The "Typical" Explosion Event



Shock wave caused
by primary deflagration



Time, msec.

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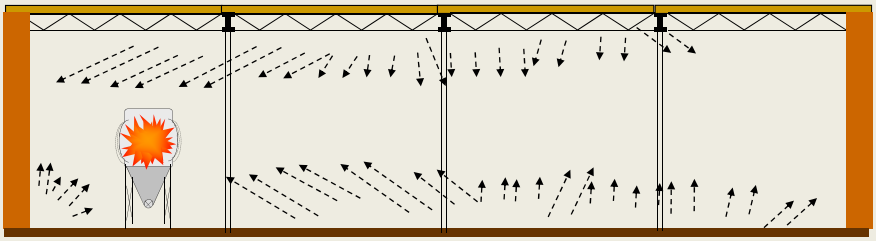
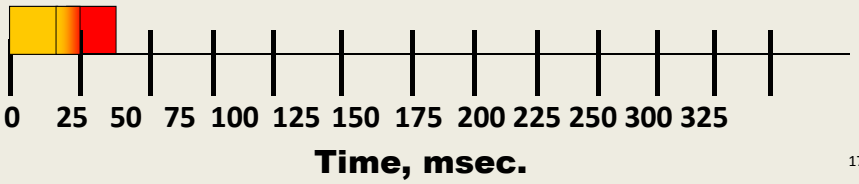
The "Typical" Explosion Event

Shock waves reflected by surfaces within the building cause accumulated dust to go into suspension





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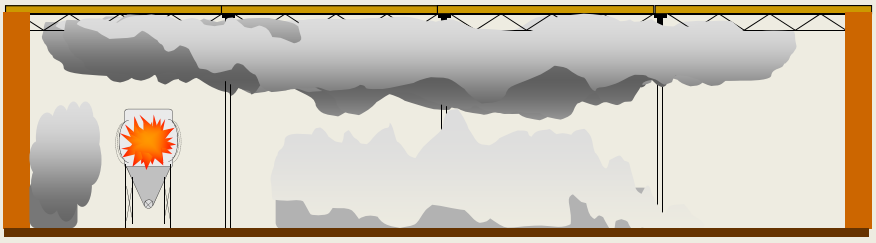
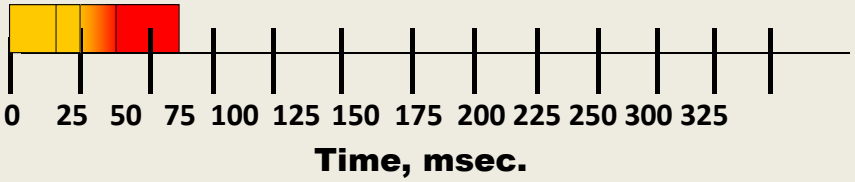
The "Typical" Explosion Event

Dust clouds thrown in the air by the shock waves





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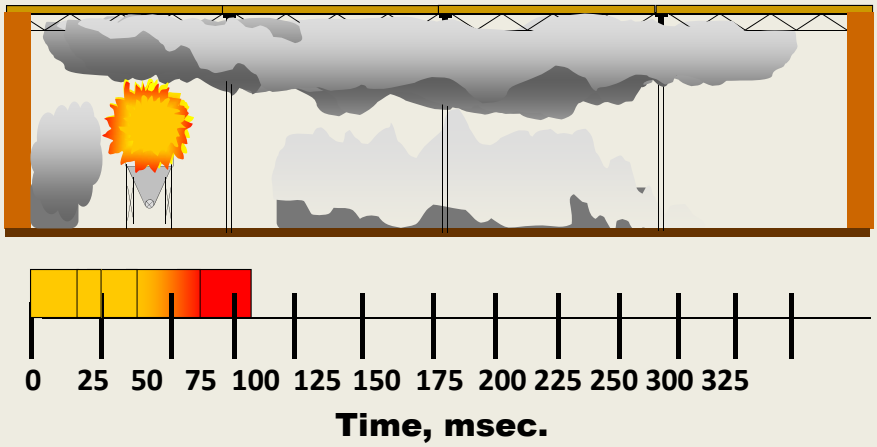
The "Typical" Explosion Event

Primary deflagration breaks out of the equipment enclosure - creating a source of ignition



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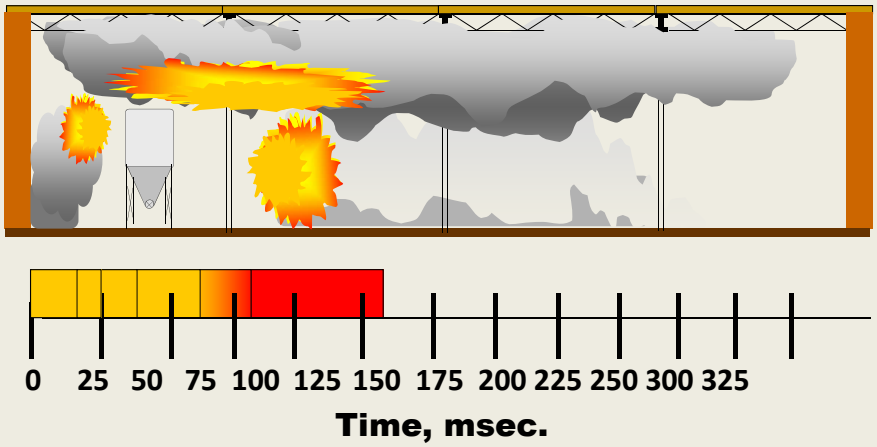
The "Typical" Explosion Event

Secondary deflagration ignited



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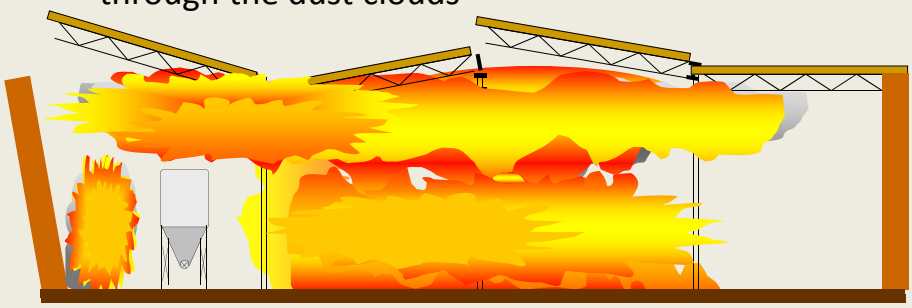
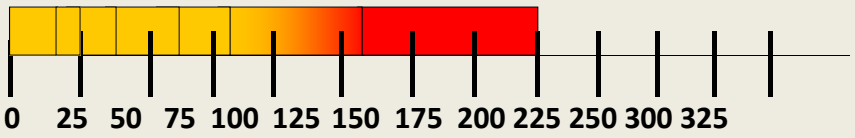
The "Typical" Explosion Event

Secondary Deflagration is propagated through the dust clouds





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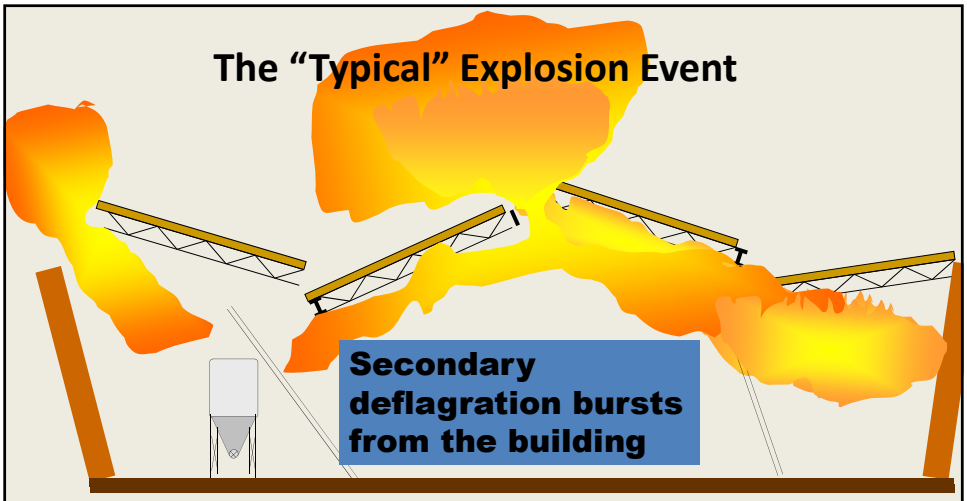
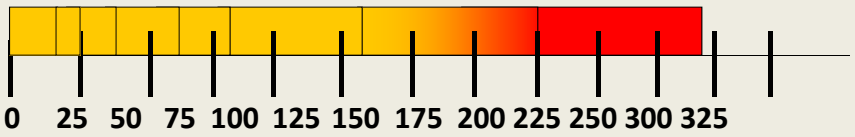
The "Typical" Explosion Event





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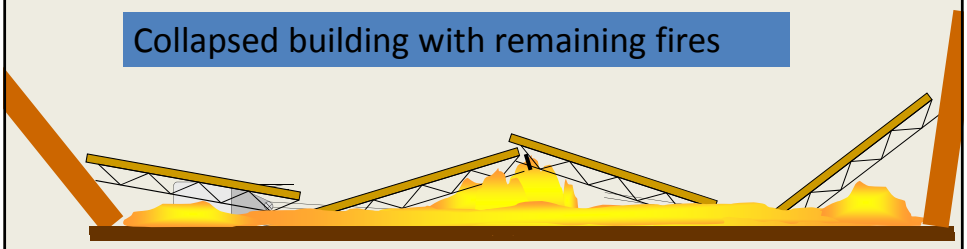
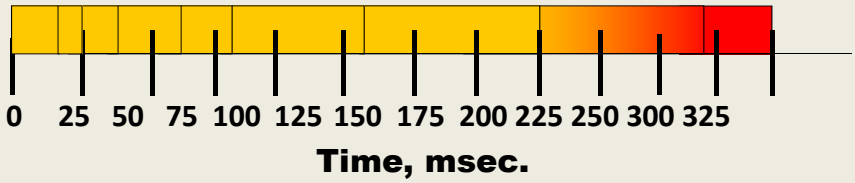
The "Typical" Explosion Event

Collapsed building with remaining fires





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Overview - USA

In US, dust explosion is a major industrial hazard.

According to CSB, over the last 30 years there have been approximately 3,500 combustible dust explosions, 281 of these have been major incidents resulting in the deaths of 119 workers and another 718 workers sustained injuries.

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US Ink facility, East Rutherford , NJ
September 10, 2012
Explosion and fire → 7 injured

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Hoeganaes facility in Gallatin, TN
January 31, 2011; March 29, 2011; May 27, 2011
Metal Dust Flash Fires and Hydrogen Explosion
5 Killed, 3 Injured

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New Cumberland A.L. Solutions titanium plant in West Virginia
December 9, 2010
Fueled by titanium powder → 3 Killed

27

Imperial Sugar Company, Port Wentworth GA.
Feb. 7, 2008
Explosion and Fire → 13 Dead and Numerous serious injuries

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West Pharmaceutical Services plant in Kinston, North Carolina.
January 29, 2003
Fueled by fine plastic powder
6 deaths, dozens of injuries, and hundreds of job losses

29

CTA Acoustics manufacturing plant in Corbin, Kentucky.
February 20, 2003
Fueled by resin dust → 7 killed, 37 injured

30

Hayes Lemmerz manufacturing plant in Huntington, Indiana
October 29, 2003
Fueled by accumulated aluminum dust, a flammable byproduct of the wheel production process.
1 killed, 6 injured

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Overview - MALAYSIA

According to DOSH Malaysia, from March 2008 to August 2013, there have been 5 combustible dust explosion incidents resulting 7 fatalities and 12 injuries. However, only 3 incidents were published in the website.

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Incidents in Malaysia

Grain storage and milling plant, Lumut, Perak
March 17, 2008
Grain dust explosion
4 Dead, 2 injured

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Incidents in Malaysia

Motorcycle rim manufacturing factory, Pulau Pinang
March, 2010
Aluminum dust explosion
8 injured and cause damaged the building, manufacturing plant, dust collector system and broke the windows of nearby factories.

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Incidents in Malaysia

Medicine and cosmetic processing plant
(Exact place was not stated)
Stearate based chemical explosion
2013 (Exact date was not stated)
2 dead and 2 severely injured.

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NFPA USA STANDARD

NFPA Number	Title	Edition
61	Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities	2002
68	Guide for Venting of Deflagrations	2002
69	Standard on Explosion Prevention Systems	2002
70	National Electrical Code	2005
77	Recommended Practice on Static Electricity	2000
85	Boiler and Combustion Systems Hazards Code	2007
86	Standard for Ovens and Furnaces	
91	Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids	2007 2004
484	Standard for Combustible Metals	
499	Recommended Practice for the Classification off Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas	2006 2004
654	Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling off Combustible Particulate Solids	2006 2007 2007
655	Standard for Prevention of Sulfur Fires and Explosions	
664	Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities	

Source: Abuswer 2012

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DUST EXPLOSION EUROPEAN STANDARD

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Causal Factors for Dust Explosions

- Lack of hazard awareness
- Inadequate hazard evaluation
- Failure to comply with standards
- Poor housekeeping
- Inadequate change management
- Failure to investigate and respond to previous incidents

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Awareness of the Hazard

- MSDSs do not convey the explosion hazard
- Employees not trained about dust explosion prevention
- Third-party inspections with no recognition of the hazard

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Hazard Evaluation

- Often, no hazard analysis performed
- Focus on exposure hazards but not facility process safety issues

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Housekeeping

- The worst damage from a dust explosion is often the result of one or more secondary explosions.

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Change Management

- Major modifications performed without adequate design review, hazard analysis or documentation

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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

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MEANS OF PREVENTING & MITIGATING

- **PREVENTION - Preventing ignition sources**
  - Smouldering combustion in dust, dust fire
  - Other type of open flames – hot work
  - Hot surfaces (electrically, thermically or mechanically heated)
  - Heat from mechanical impact (metal sparks or hot spots)
  - Electric sparks and arcs. Electrostatic discharges

R.K. Eckhoff 2005

MEANS OF PREVENTING & MITIGATING

- **PREVENTION – preventing explosive dust clouds**
  - Inerting of dust clouds by N2, CO2 and rare gases
  - Intrinsic inerting of dust clouds by combustion gases
  - Inerting dust clouds by adding inert dust
  - Keeping dust concentration outside explosive range

R.K. Eckhoff 2005

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MEANS OF PREVENTING & MITIGATING

- **MITIGATION**
  - Explosion–pressure resistant construction
  - Explosion isolation (sectioning)
  - Explosion venting
  - Automatic explosion suppression
  - Partial inerting dust cloud by inert gas
  - Good housekeeping (dust removal/cleaning)

R.K. Eckhoff 2005

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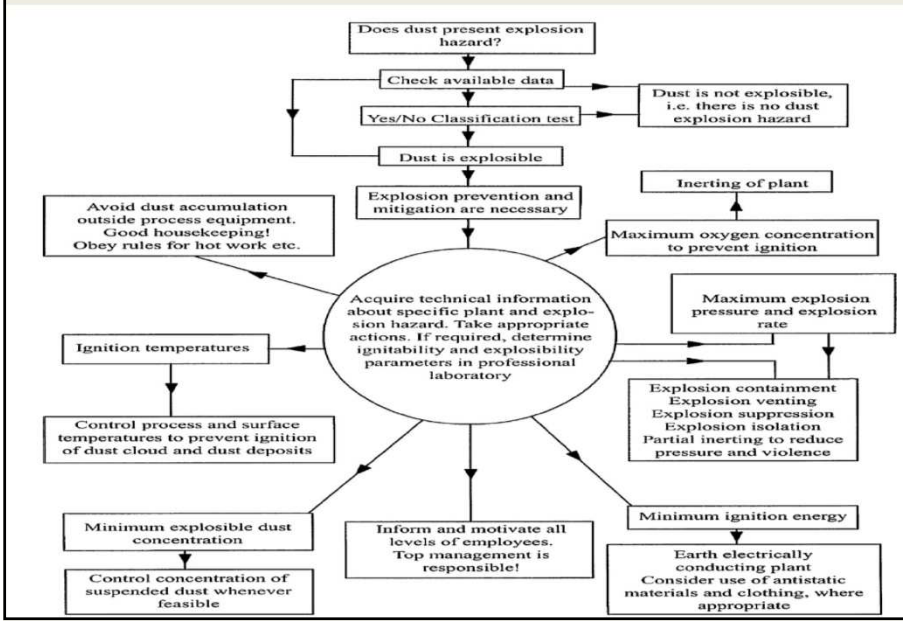
Logic diagram for dust explosion hazard identification and risk reduction [Abuswer 2012]



Keys to Prevention

- **Inherently safe process design**
  - **Process itself be designed in such a way that no explosion hazard exists**
- **Increased hazard awareness**
  - Improved MSDSs
  - Dust explosions taught in undergrad curriculum
  - Access to NFPA standards
- **Applied principles of PSM**
  - Change management; Hazard evaluation; Incident investigation; Hazard communication etc.

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R&D : SIMULATION OF DUST EXPLOSION

FACULTY OF CHEMICAL & NATURAL RESOURCES ENGINEERING [FKKSA]

Universiti Malaysia PAHANG
Engineering • Technology • Creativity

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WHY MODELING & SIMULATION?

1. CAPABILITY OF COMPUTING POWER
2. AVAILABILITY OF RELATED SOFTWARE
3. SAFE AND RELIABLE
4. COST-SAVING AND REPEATIBILITY

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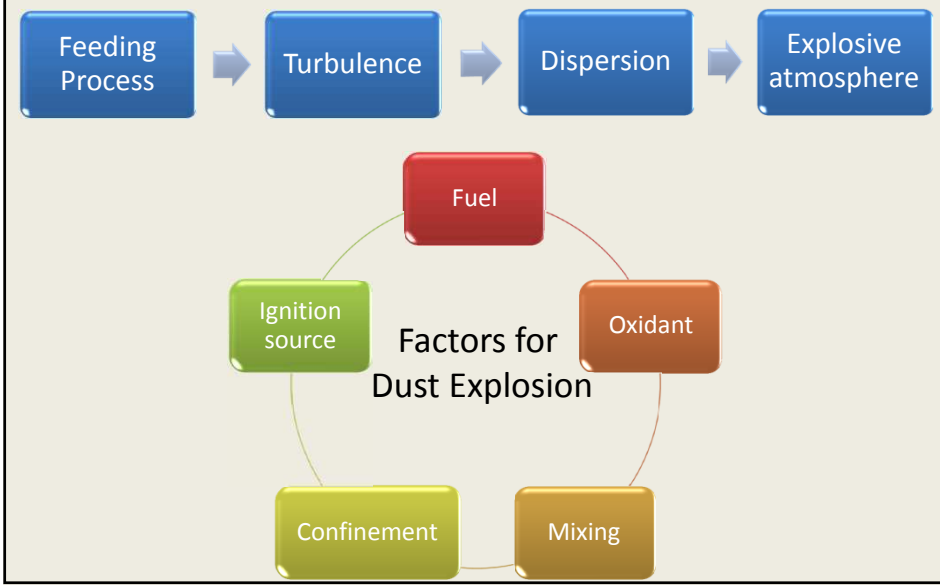
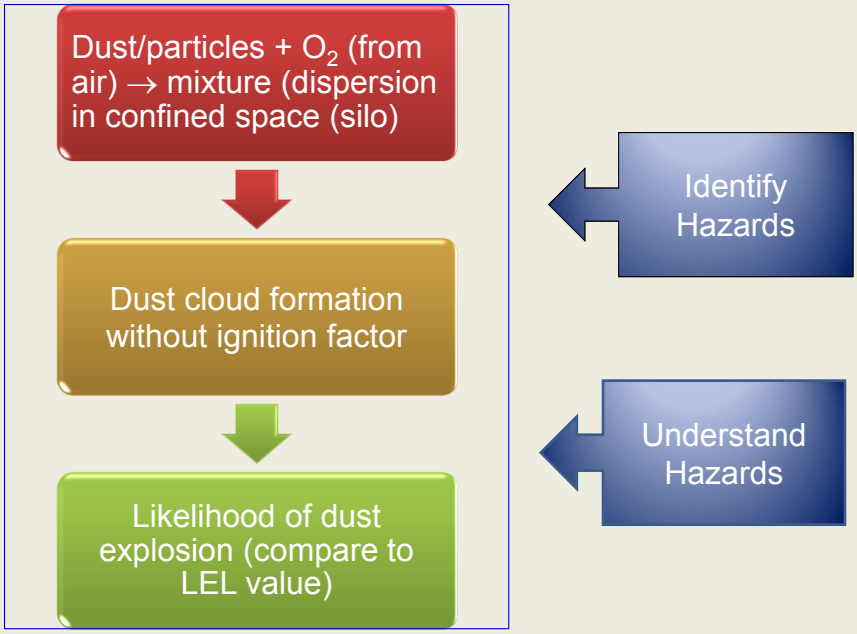
In UMP, we simulate the likelihood for dust explosion in silo using CFD code, FLUENT





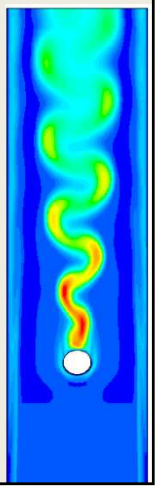
Experiment vs CFD Simulation

Experiment

- Expensive setup & instruments
- High risk
- Time consuming to setup the silo

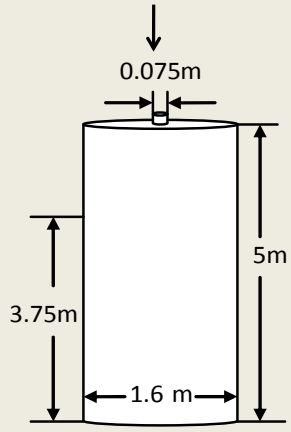
CFD

- Save cost
- No risk
- Provide good prediction
- Provide insight view



Geometry and condition

v_{in} gas (air)
v_{in} solid (particles)
$\dot{m}_{in}$ solid (particles)



Feeding rate = 3 kg/m^3
Conveying velocity = 23 m/s
Particle mean diameter = 15μm

Validated using LDA measurement by Hauert and Vogl (1995)

Modeling Strategy

CFD code, Fluent, 3D, 100% quality hexahedral grid

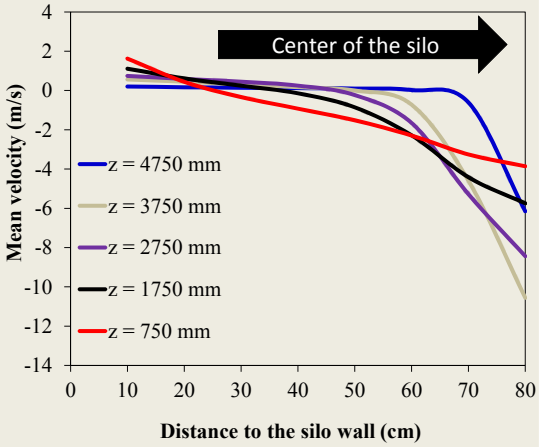
SIMPLE scheme; 1st & 2nd order discretization; standard & PRESTO

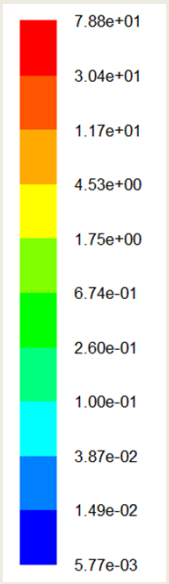
Dust cloud formation in silo

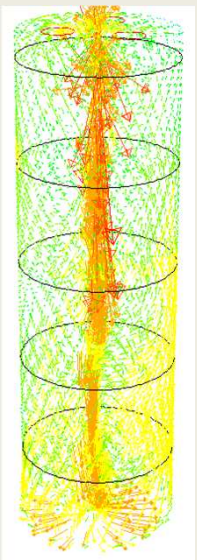
Gas phase: Classical k-epsilon turbulence model

Disperse phase: DPM –Eulerian Langrangian; gravity; Saffman's force & 2 way coupling

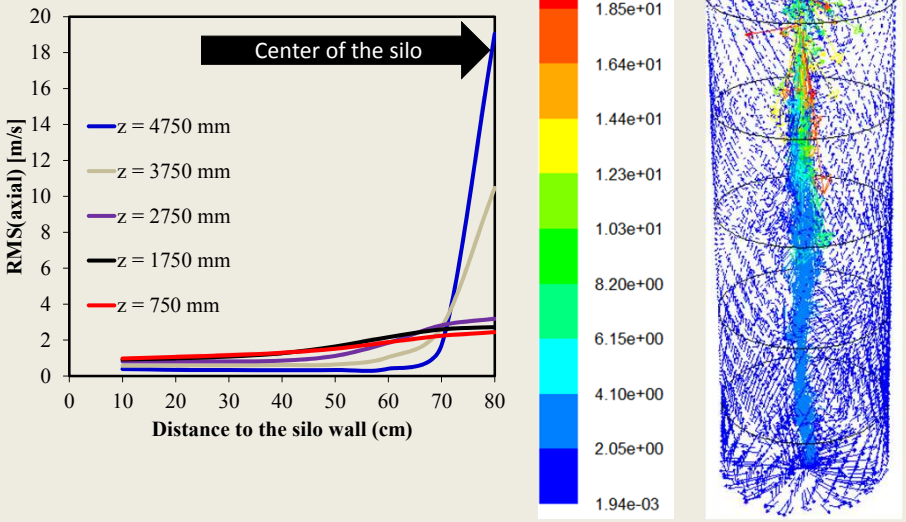
Results - Prediction of mean velocity at various levels







Results - Prediction of turbulence flow at various levels



Conclusion

- The most important factor to prevent dust explosion is by increasing the awareness of Malaysian industries that produce, process, store or use combustible dust.
- Malaysian industries should learn the lessons from the previous incidents occurred around the world.
- Simulation is one of the important and significant tools in understanding and managing dust explosion phenomena.

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