Module 5C Explosion and Fire Protection – Combustible Dust Explosions

Last Revised – June 2024

PS Bootcamp Modules

- ✓ Module 1: Introduction
- ✓ Module 2: Hazard Identification
- ✓ Module 3: Risk Matrix
- ✓ Module 4: Safeguard Concepts
- ✓ Module 5: Explosion/Fire Protection
- ❑ Module 6: Management of Change
- ❑ Module 7: Incident Investigation
- ❑ Module 8: Facility Siting

Module 5: Explosion and Fire Protection Agenda

- ✓ **5A – Fire, Combustion and Electrical Area Classification**
- ✓ **5B – Flammable Gas and Vapor Explosions**
- ✓ **5C - Combustible Dust Explosions**

Objectives

Develop awareness level understanding of:

What is a Dust Explosion?

- Conditions needed
- Explosible range
- Minimum ignition energy

Difference between Gas/Vapor and Dust Explosions

Regulations, References and Process Safety Data

Identification and Control of Dust Hazards

What is a Dust Explosion?

Past Dust Explosion Incidents

Jahn Foundry, Springfield, MA

February 26, 1999

Three deaths, Nine injuries

Phenolic Resin Dust

Past Dust Explosion Incidents

West Pharmaceutical Services, Kinston, NC

January 29, 2003

Six deaths, dozens injuries, hundreds of jobs

Facility produced rubber stoppers and other medical use products

Fine plastic powder accumulated above suspended ceiling ignited

Past Dust Explosion Incidents

West Pharmaceutical facility destroyed by polyethylene dust

Past Dust Explosion Incidents

CTA Acoustics, Corbin, KY

February 02, 2003

Seven deaths

Facility produced fiberglass insulation for automotive industry

Resin dust accumulated in production area, likely ignited from manufacturing oven

Past Dust Explosion Incidents

Imperial Sugar Company, Port Wentworth, GA

February 07, 2008

Fourteen deaths, Thirty-eight injuries

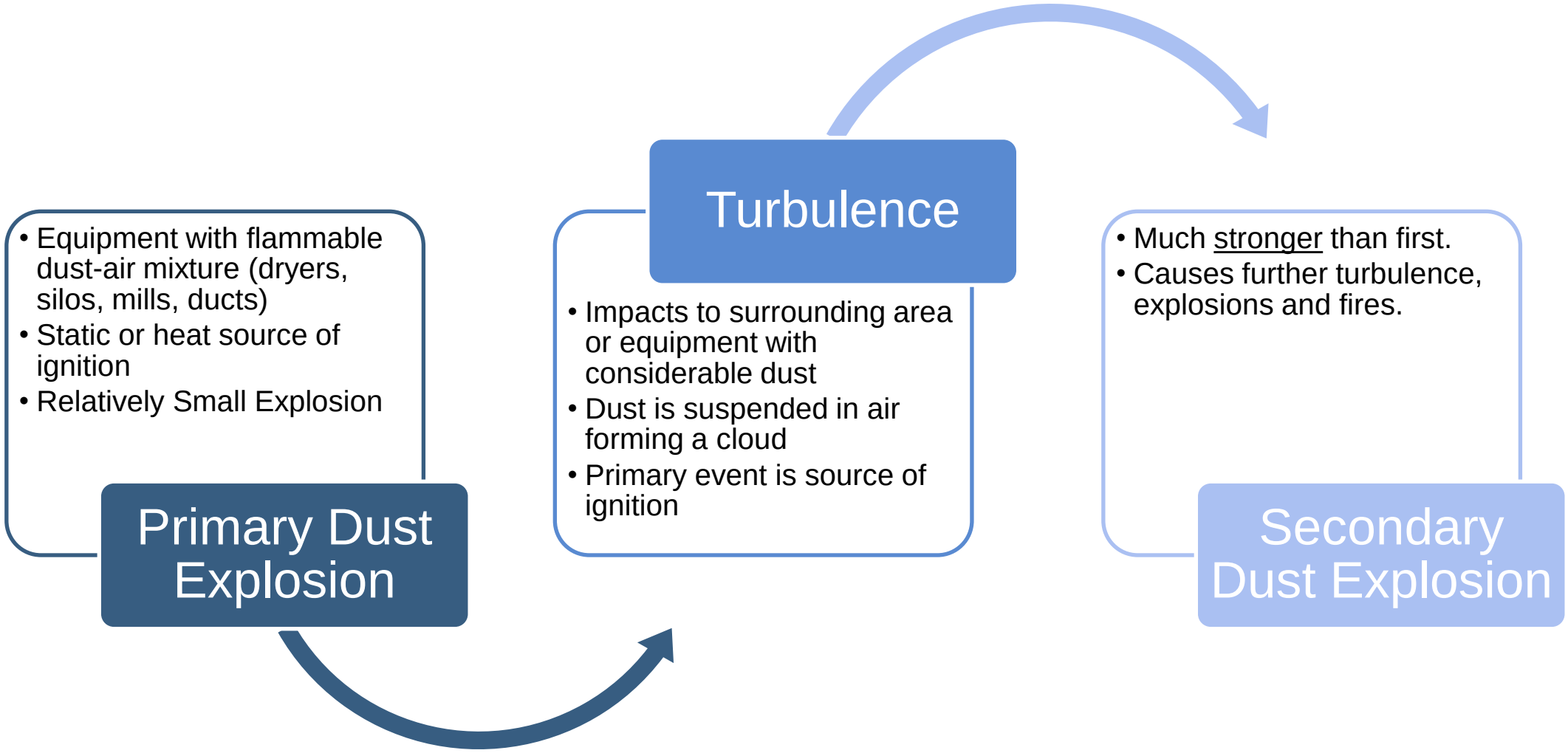
Explosion fueled by massive accumulation of combustible sugar dust throughout packaging building

Combustible Dust Video

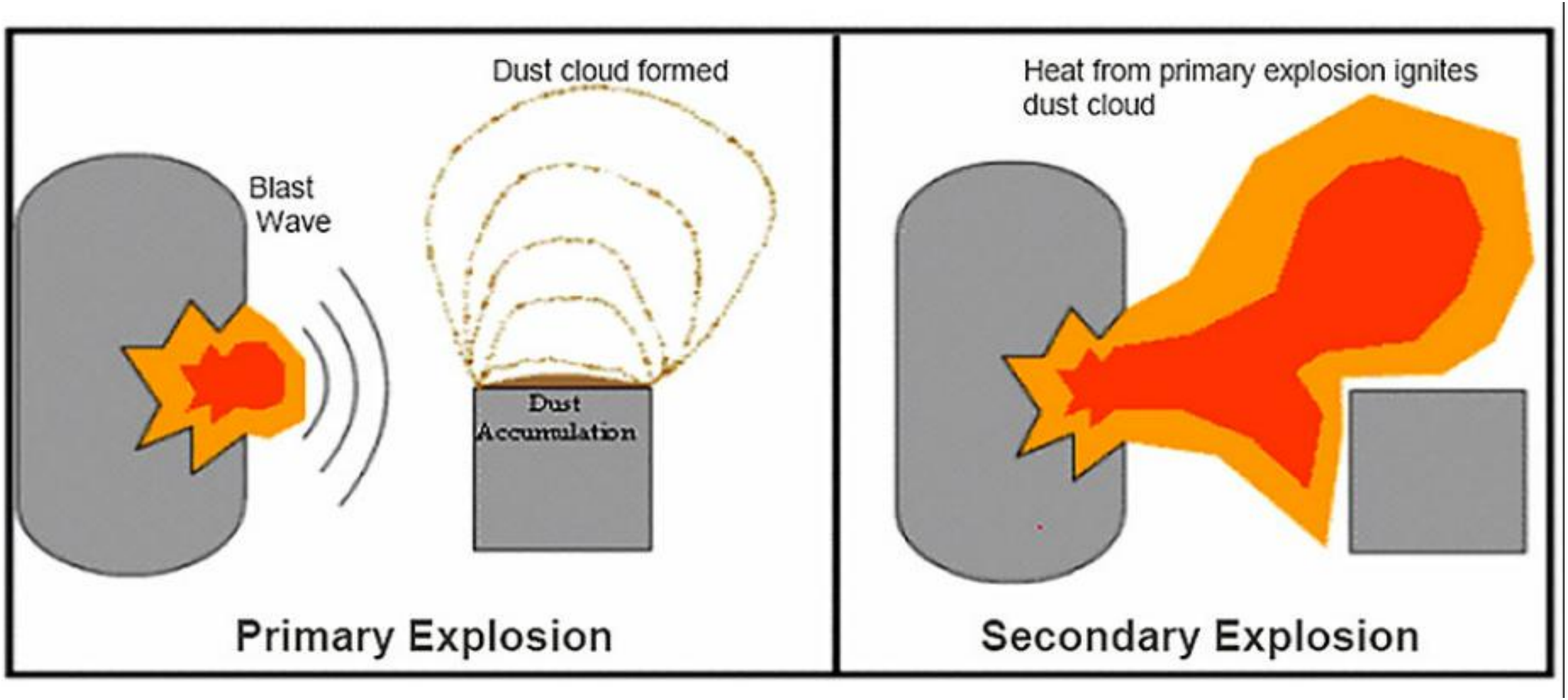
- https://www.youtube.com/watch?v=3d37Ca3E4fA

- Imperial Sugar Company Dust Explosion and Fire | CSB

Propagation of a Dust Explosion



Secondary Explosions

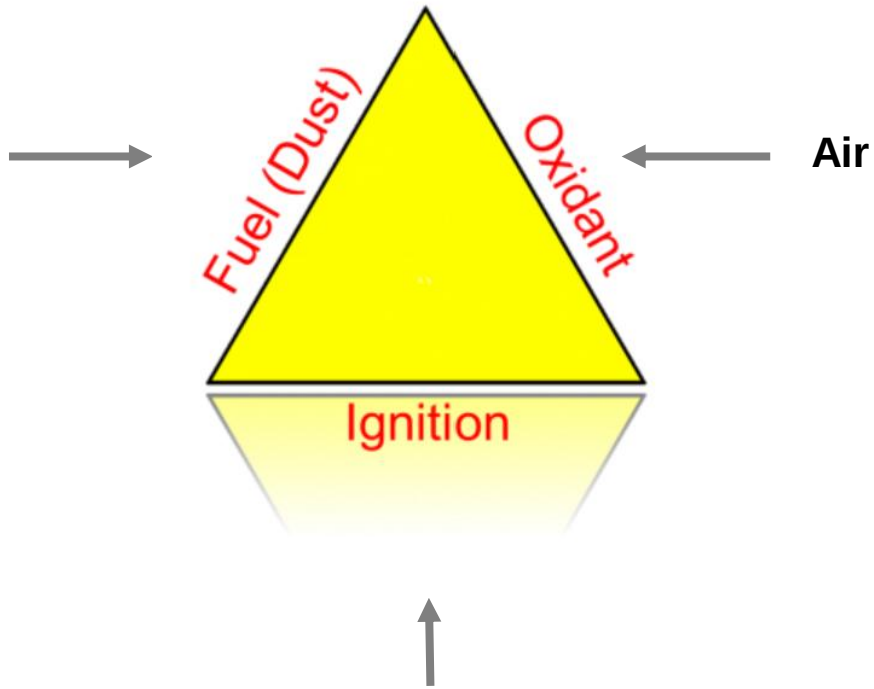


Difference Between Gas/Vapor and Dust Explosions

Fire Triangle

DUST

- **Sieving**
- **Drying**
- **Filtering**
- **Conveying/Transport/Transfer**
- **Grinding**
- **Classification**

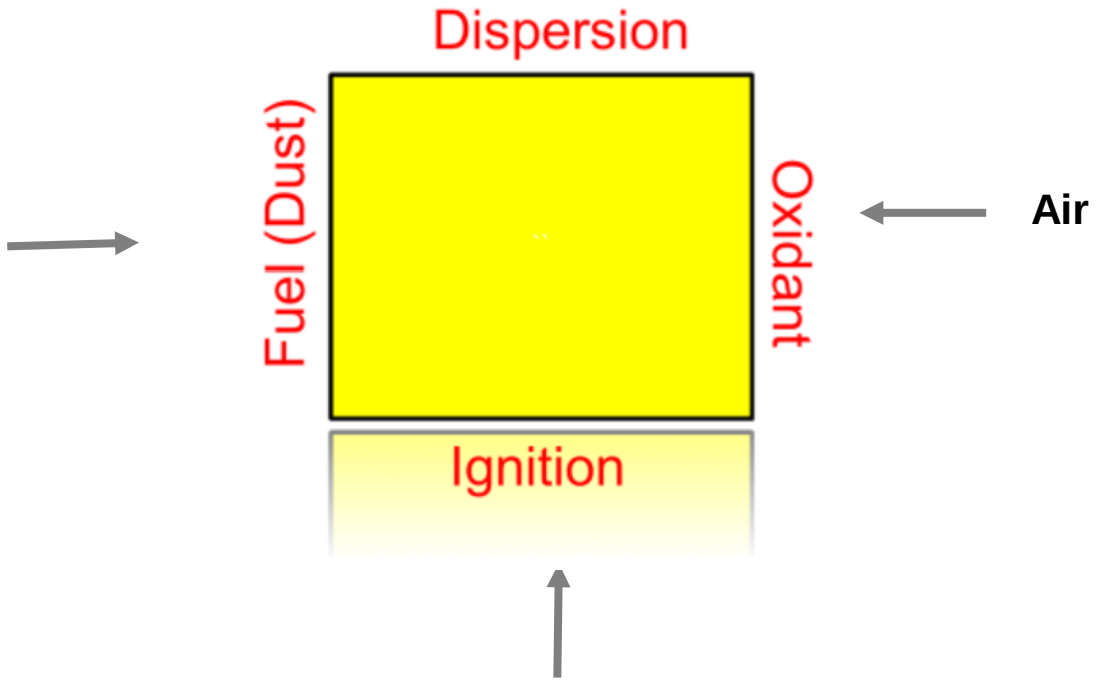


- **Static Electricity**
- **Self Heating**
- **Mechanical Sparks**
- **Open Flames**
- **Hot Surfaces**

Flash-Fire Square

DUST

- **Sieving**
- **Drying**
- **Filtering**
- **Conveying/Transport/Transfer**
- **Grinding**
- **Classification**



- **Static Electricity**
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Dust Explosion Pentagon

DUST

- **Sieving**
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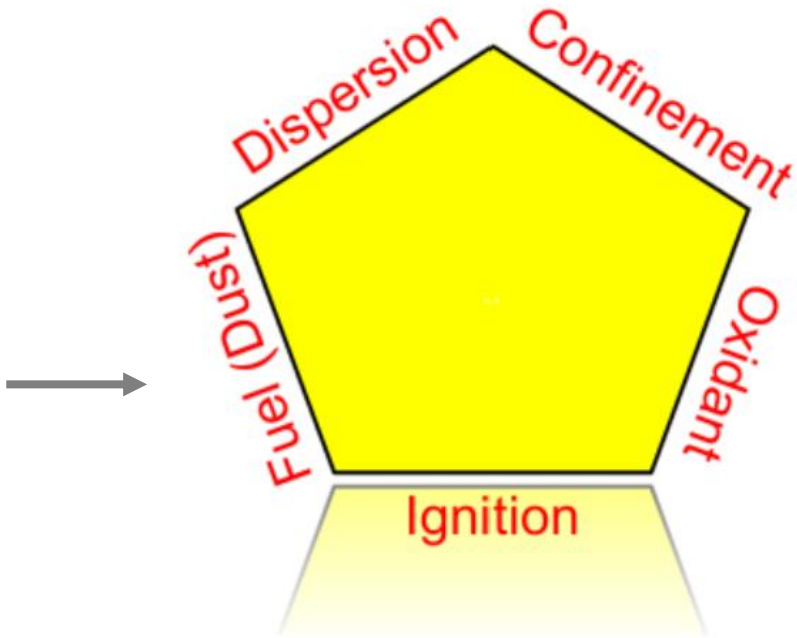


Air

- **Static Electricity**
- **Self Heating**
- **Mechanical Sparks**
- **Open Flames**
- **Hot Surfaces**

When can a dust cloud explosion occur?

Only when:

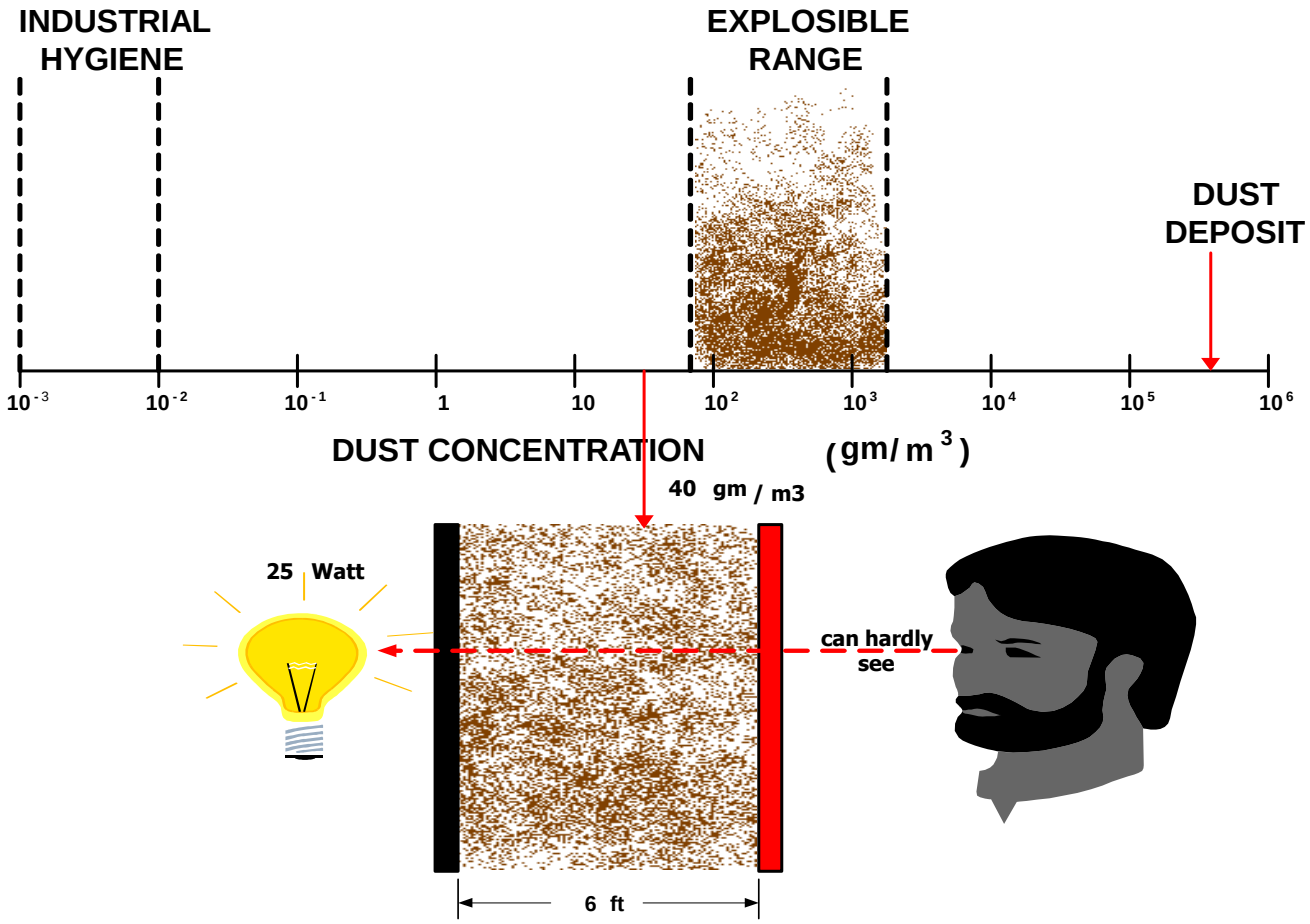
Fuel, oxygen, and an ignition source exist at the same place at the same time AND

The fuel/oxygen mixture is in the flammable region. For dusts, the material must be finely divided (particle size <0.5mm) and dispersed and suspended in the air AND

The ignition source is energetic enough to produce a self-sustained propagating flame front AND

There is a degree of confinement to enable the rise in pressure

Explosive Concentration



Question

How many of these energies are large enough to ignite a flammable mixture of a combustible dust dispersed in the air?


A. 1000 mJ


B. 100 mJ


C. 10 mJ


D. 1 mJ


E. 0.1 mJ

F. None of the above

Minimum Ignition Energy (MIE)

Selected dusts in mixture with air.

MIEs depend on the particle size distribution* and sample humidity & are thus not generally valid.

Fuel	MIE [mJ]
corn starch	30
rice	50
sugar	30
wheat flour	50
acetyl cellulose	
hard rubber	
nylon	
polyethylene	
polypropylene	30
polystyrene	15
polyvinyl chloride	1500

Fu	MIE [mJ]
sulphur	15
	20
	150
	20
	250
	200
onium	5

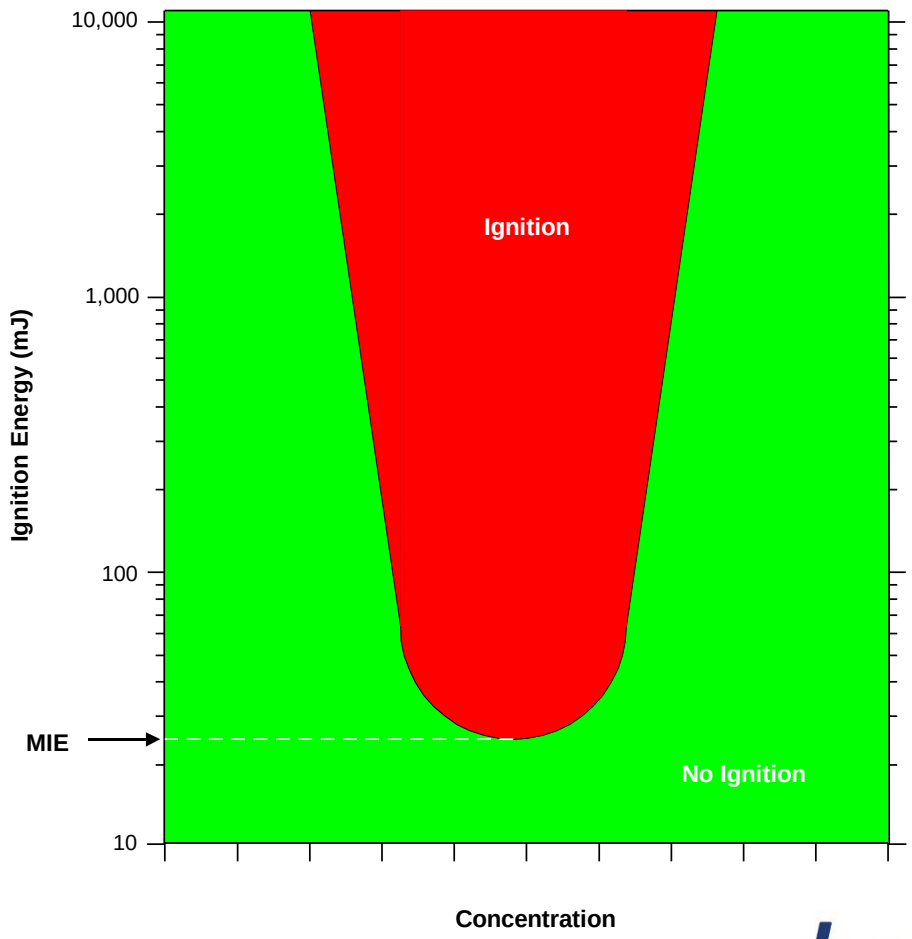
Do we want to include CPET chemicals?

*At T = 20 C and P = 1 bar abs. By reducing the grain size by a factor of 10 the MIE drops by a factor of 1000)

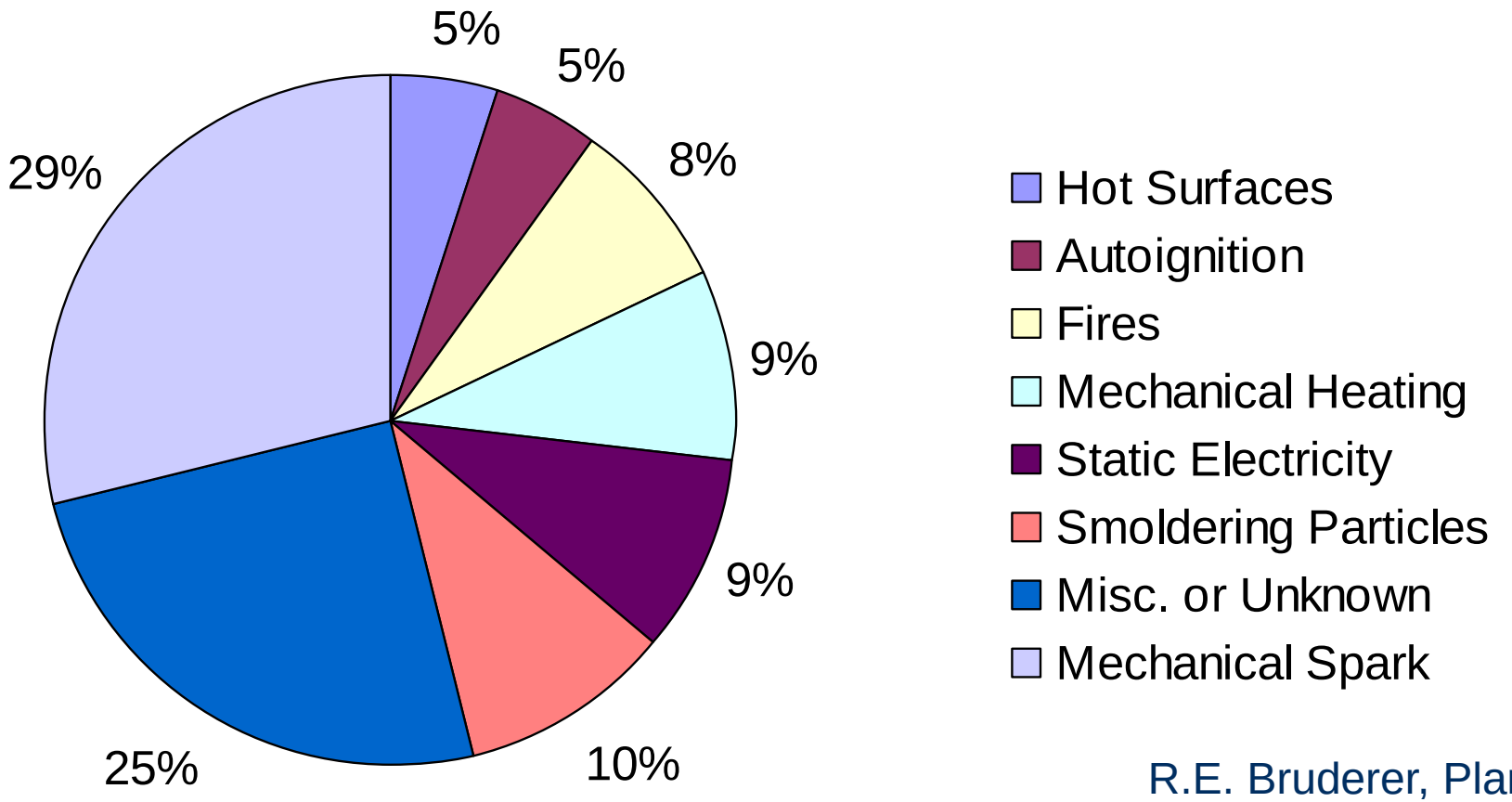
Dust Cloud Ignition Energy as a function of Dust Concentration

MIE_{DUSTS} is typically >20 mJ, but can be much less

$MIE_{VAPORS,GASES}$ < 1 mJ

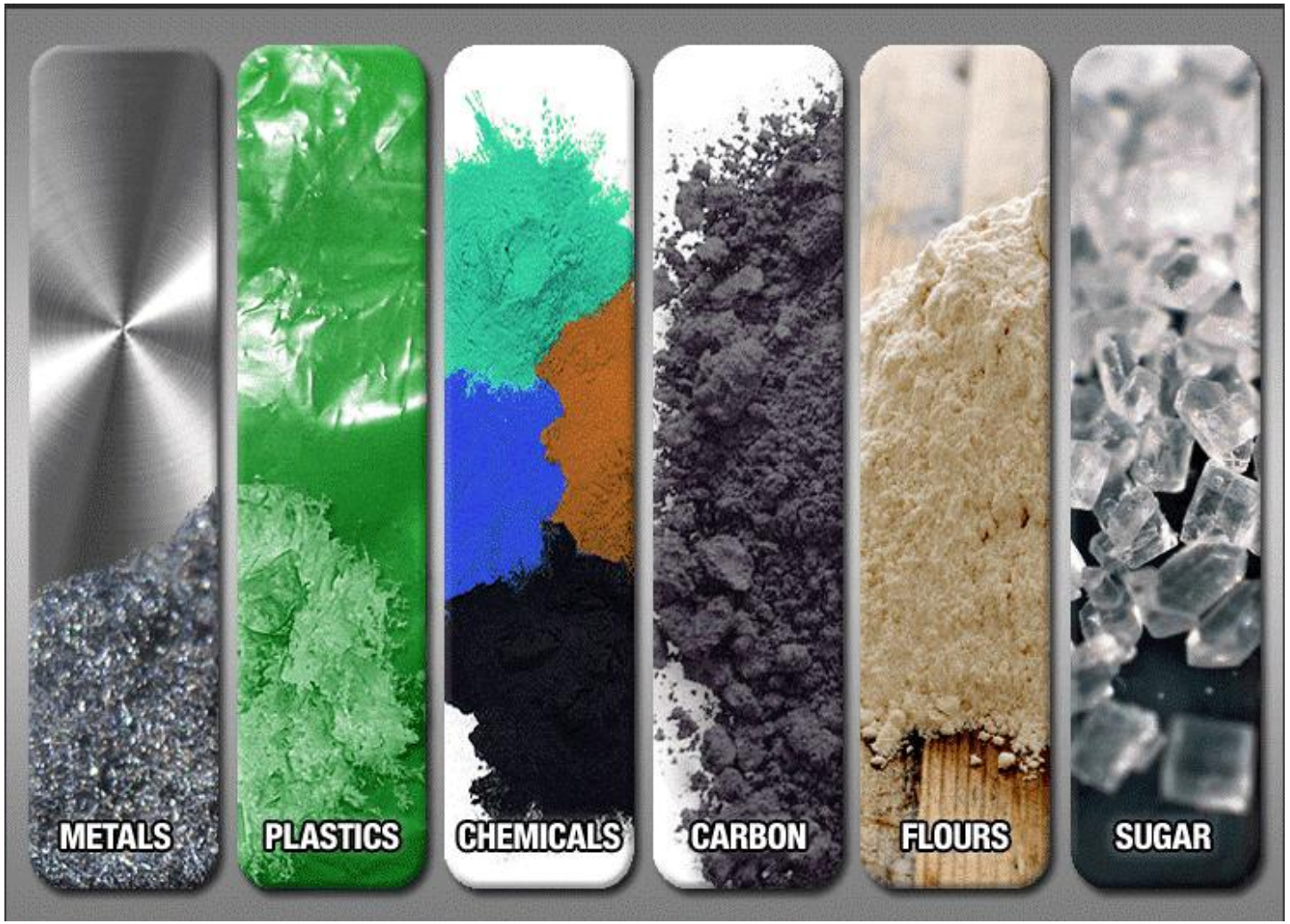


Ignition Sources for 357 Dust Explosions



R.E. Bruderer, Plant/Operations Progress (Vol. 8, No. 3)

Combustible Dust – Many Forms



Hybrid Mixtures

A mixture of combustible dust and flammable vapor or gas is known as a “hybrid mixture”.

Hybrid mixtures behave differently than combustible dust clouds

The presence of the flammable gas or vapor reduces the MIE of the mixture.

Thus, hybrid mixtures are more easily ignited than simple combustible dust clouds.

If flammable gas or vapors can be present, even at low concentrations, extra care must be taken to eliminate ignition sources.

Regulations, References and Process Safety Data

Regulations and RAGAGEP

US OSHA Regulations

CPL 03-00-008 – Combustible Dust National Emphasis Program

29CFR1910.22 – Housekeeping

29CFR1910.176(c) – Housekeeping in Storage Areas

29CFR1910.272 – Combustible Dusts in grain handling facilities

29CFR 1910.307 – Hazardous (Classified) Locations

Consensus Standards

NFPA 652 (2019), Standard on the Fundamentals of Combustible Dust. General requirements with appropriate reference to NFPA 61, 484, 499, 654, 655, 664

Dust Hazard Analysis (DHA) by Sept. 7, 2020

References

IVL EHSG-403-09, Dust Explosion Hazard Assessment

Guidelines for Combustible Dust Hazard Analysis, CCPS, ISBN – 1119010160

NFPA 652: Standard on the Fundamentals of Combustible Dust

Safe handling of combustible dusts: Precautions against explosions - HSG103 (hse.gov.uk)

Combustible Dust: An Explosion Hazard - Overview | Occupational Safety and Health Administration (osha.gov)

Process Safety Data for Dust Hazards

Property	Definition	ASTM Test Method	Application
K_{St}	Dust deflagration index	ASTM E 1226	Measures the relative explosion severity compared to other dusts.
P_{max}	Maximum explosion overpressure generated in the test chamber	ASTM E 1226	Used to design enclosures and predict the severity of the consequence.
$(dp/dt)_{max}$	Maximum rate of pressure rise	ASTM E 1226	Predicts the violence of an explosion. Used to calculate K_{St}.
MIE	Minimum Ignition energy	ASTM E 2019	Predicts the ease and likelihood of ignition of a dispersed dust cloud.

Process Safety Data for Dust Hazards

Property	Definition	ASTM Test Method	Application
MEC	Minimum explosible concentration	ASTM E 1515	Measures the minimum amount of dust, dispersed in air, required to spread an explosion. Analogous to the lower flammability limit (LFL) for gas/air mixtures.
LOC	Limiting oxygen concentration	ASTM standard under development	Determines the least amount of oxygen required for explosion propagation through the dust cloud.
ECT	Electrostatic charging tendency	No ASTM standard	Predicts the likelihood of the material to develop and discharge sufficient static electricity to ignite a dispersed dust cloud.

Dust Explosion Class

Explosion class	K_{St} bar.m.sec^{-1}	
St 0	0	No explosion
St 1	> 0 ≤ 200	Increasing severity of explosion
St 2	> 200 ≤ 300	
St 3	> 300 ≤ 600	

HSE, HSG 103

Examples Measurements

Dust tested	Median particle size µm	Minimum explosible concentration g/m³	Maximum explosion overpressure bar	K_{St} valve bar.m/s	St class
Paper tissue	54	30	8.6	52	1
Glucose	30	60	9.2	123	1
Wheat	80	60	9.3	112	1
Polyethylene low density	62	15	8.5	131	1
Polymethyl methacrylate	21	30	9.4	269	2
Calcium stearate	12	30	9.1	132	1
Wood flour- various samples	65	60	7.7-10.5	83-192	1
Magnesium	28	30	17.5	508	3

HSE, HSG 103 – Not to be used for design purposes.

Identification and Control of Dust Explosion Hazards

Dust Hazard Analysis (DHA)

NFPA 652 (2019) Dust Hazard Analysis (DHA) – Sept. 7, 2020 US Deadline

Systematic process to identify hazards that includes:

- Combustible material data (such as Kst, Pmax, MIE, MEC and MIT)
- Identification of areas where the potential for a dust explosion exist
- Credible ignition sources and dust suspension mechanisms
- Safe operating ranges
- Existing protection methods
- Explosion propagation hazards
- Additional protection recommendations and implementation plan

IVL EHSG-403-09 Dust Explosion Hazard Assessment

NFPA 652 – Combustible Dust Management Program

Owner/Operator General Requirements	Hazard Management Mitigation and Prevention	Management Systems
• Determine combustibility and explosibility hazards of materials • Identify and assess any fire, flash fire, and explosion hazards (perform DHA) • Manage identified fire, flash fire, and explosion hazards • Communicate hazards to affected personnel	• Building design • Equipment design • Housekeeping • Ignition source control • Personal Protective Equipment (PPE) • Dust control • Explosion prevention and protection • Fire protection	• Operating procedures and practices • Inspection, testing, and maintenance • Training and hazard awareness • Contractors • Emergency planning and response • Incident investigation • Management of change • Documentation retention • Management systems review

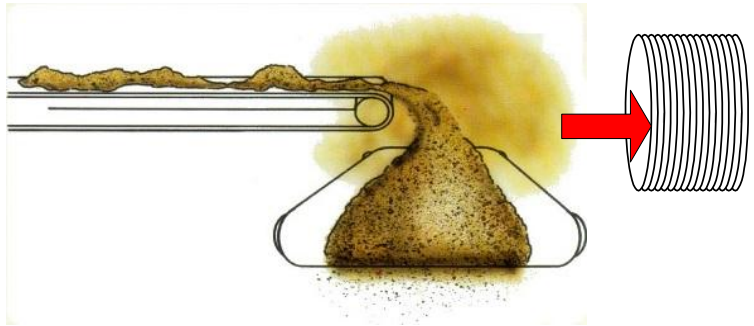
Protecting Against Dust Cloud Explosions

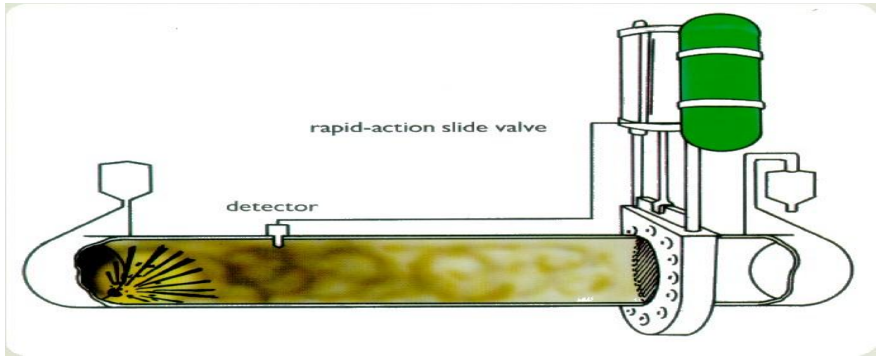
Prevention

- Organizational measures
- Engineering/design measures
- Inerting
- Elimination of ignition sources

Mitigation

- Explosion resistant construction
- Explosion isolation
- Explosion suppression
- Explosion venting





Questions/Comments

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