Dust Explosions

EPSC Pharma and Food Working Group

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Contents

- What is a dust explosion
- Hazardous Unit Operations in Food/Pharma
- 4 Recent Industry Incidents
- Dust Explosivity Data – what it tells us
- Protection Concepts & Dust Fundamentals
- Key Learnings

Imperial Sugar 2008, Port Wentworth, Georgia

Why are dust explosions so deadly?

1kg of custard powder

15,000kJ/kg heat of combustion

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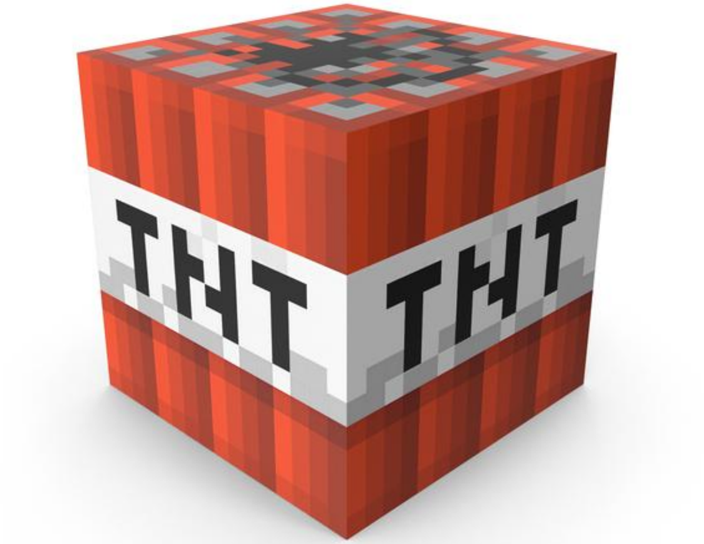


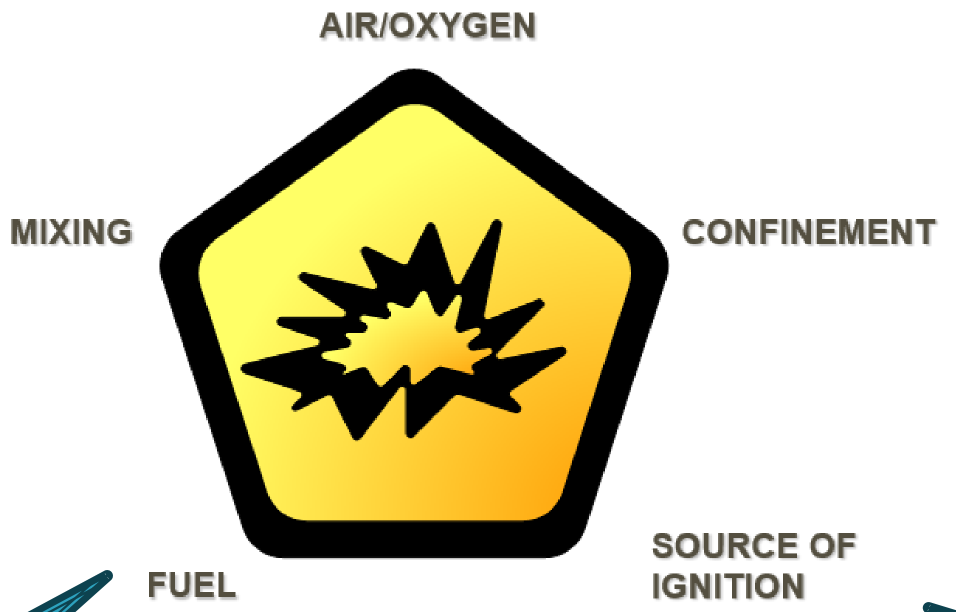
1kg of TNT
15,000kJ/kg heat of combustion

TNT explosions are detonations arising from bonds breaking releasing a great deal of energy. Different mechanism to combustion and much faster release of heat and pressure hence more damage…

Conditions for a Dust Explosion

Most foods and pharma drug products are handled in air. Nitrogen more common for API manufacturing.

Dispersion in air e.g. mills, granulators, pneumatic conveyors.

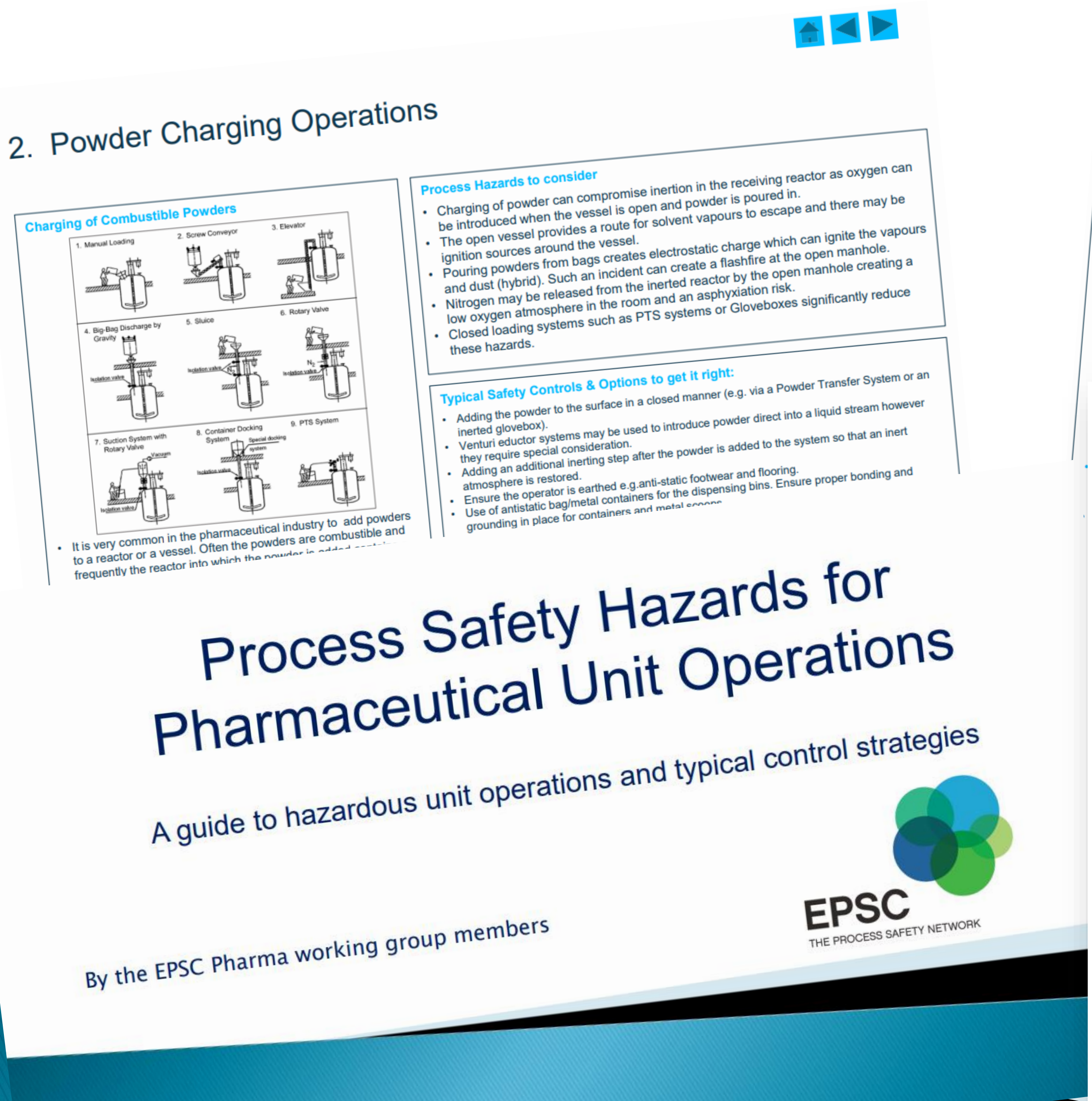


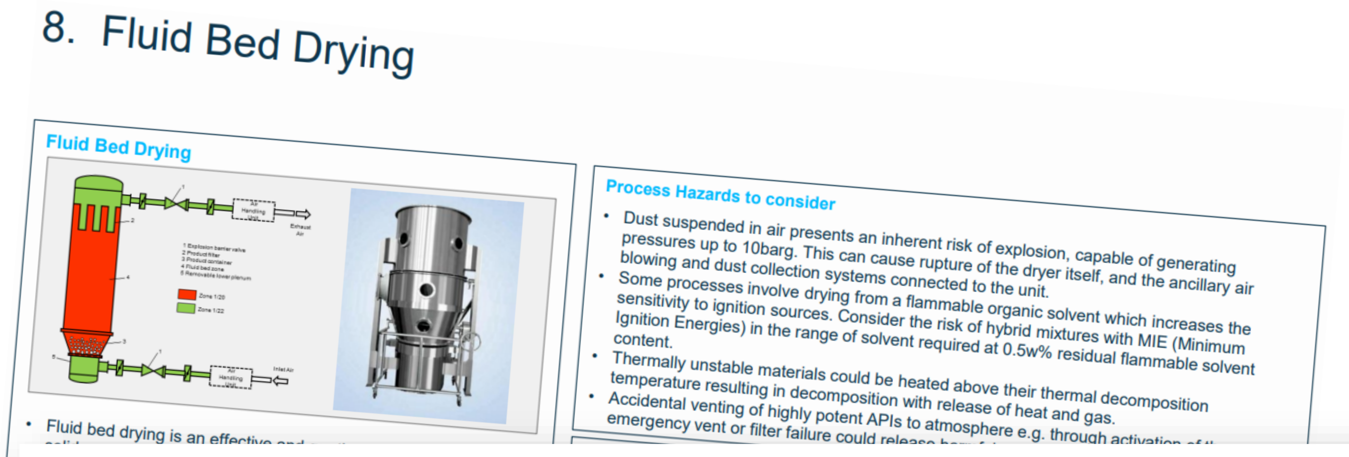
Explosive pressure waves develop if the materials are confined.
Equipment is typically not pressure rated.

Most organic materials are combustible dusts.
APIs tend to have very low minimum ignition energies

Mechanical Equipment,
Electrostatic ignition sources,
Hot work etc.

Dust Hazards in Pharma / Food Operations





Process Hazards & Recommended Safety Controls

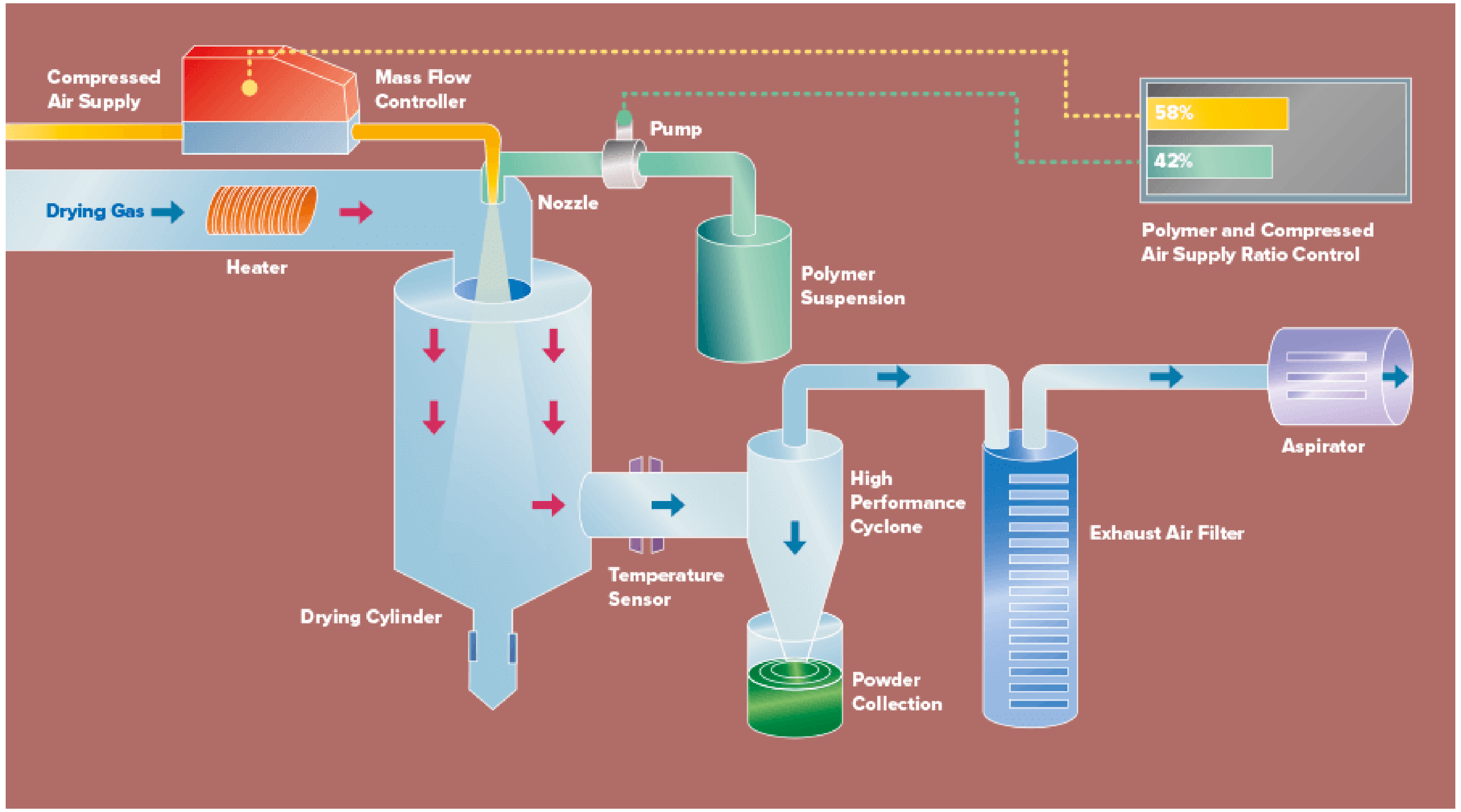
No	Unit Operation	No	Unit Operation
1	Drum handling (unloading a drum by drum pumps)	9	Dust Collectors
2	Manual charging of powder	10	Solvent Tablet Coating (Solvent))
3	API chemical synthesis (semi-batch reactor)	11	Big Bag Unloading
4	Extraction and Separation	12	Powder Transfer Systems
5	Spray Drying	13	Centrifugation
6	Solvent recovery (rectification)	14	Utilities – Thermal Oil Systems
7	Size reduction (Milling, Micronization).	15	Utilities – Ammonia Refrigeration Systems
8	Fluid Bed Drying	16	Utilities – Asphyxiant Gases (Nitrogen etc)

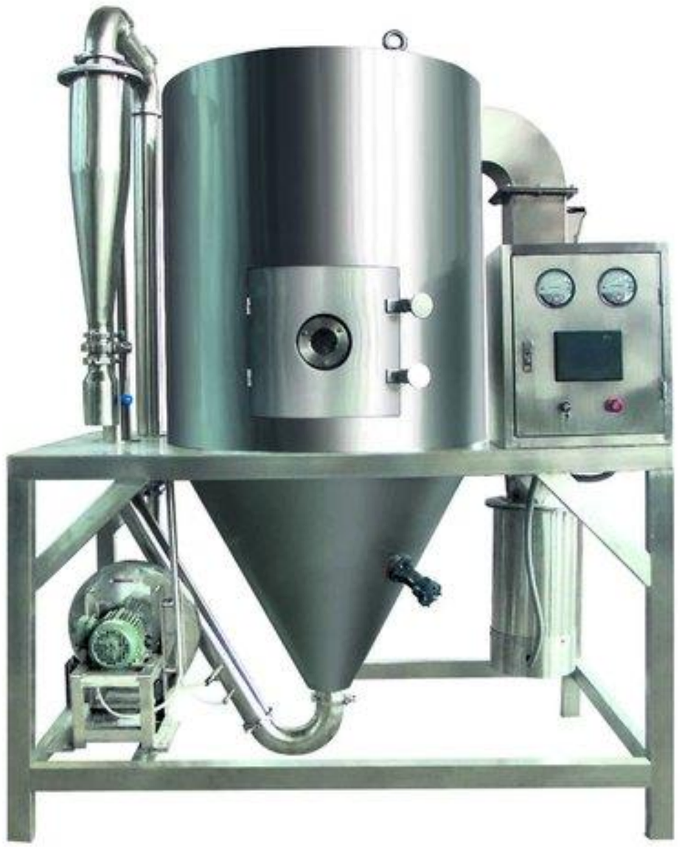
Sigachi Industries Pharma Plant Explosion near Hyderabad

- June 30th. 54 fatalities and 8 missing. Many more were injured in tragic accident.
- Approx 150 workers were on the premises.
- Latest information suggests massive temperature buildup in Microcrystalline Cellulose (MCC) spray dryer unit.
- Blast resulted in the building structure collapsing causing many injuries.
- Some reports suggest temperatures reached 700degC in the dryer.
- Investigation report not yet available – cannot be clear on the root cause.

What went wrong in the deadly Telangana factory blast on June 30? – Source The New Indian Express

Sigachi Industries Pharma Plant Explosion near Hyderabad





- Reports suggest the incident initiated in a Spray Dryer unit, no solvents on site.
- Could the Minimum Ignition Temperatures for MCC have been exceeded?
- Could a static spark have ignited the powder?
- Could a frictional spark have ignited the dust in the extraction system?
- Or something else?.....

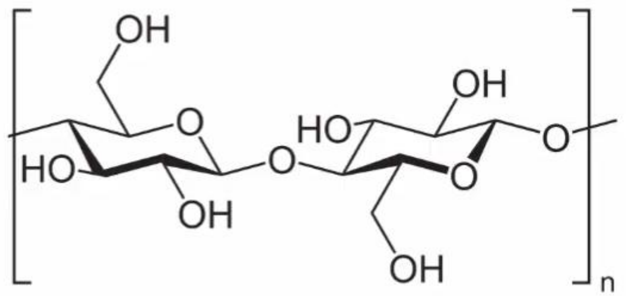
Sigachi Industries Pharma Plant Explosion near Hyderabad

- MCC – it is a depolymerised cellulose widely used in pharma and cosmetics as a 'filler and binder'
- Variety of methods to convert pulp cellulose to MCC – extrusion, hydrolysis (enzyme/acid) and steam.

- Particle size ranges from ~50micron to 200micron.
- Relatively high minimum ignition energy.
- Relatively high dust cloud and layer ignition temperatures.
- Fast charge relaxation time.

Warning Flags

- Train fire (flammable solid)
- Melting point ~236degC.



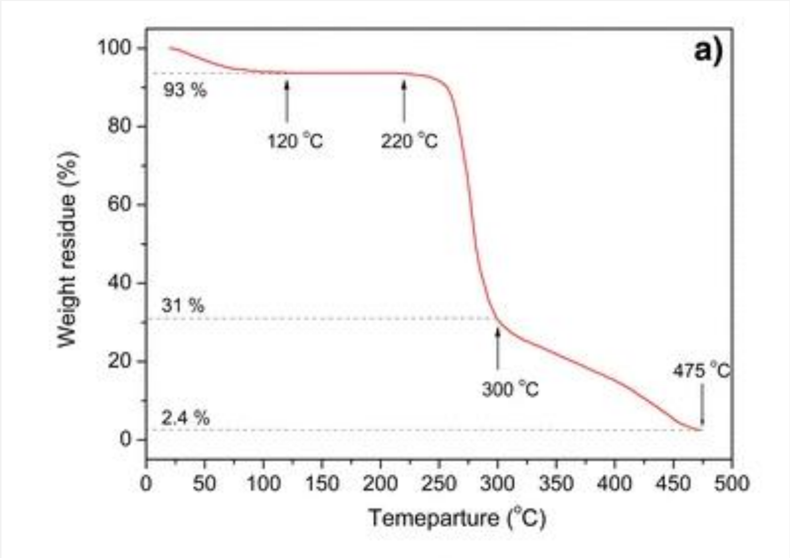
GSK Data for Avicel® 102 microcrystalline cellulose (MCC) is a purified, partially depolymerized alphacellulose excipient made by acid hydrolysis of specialty wood pulp.

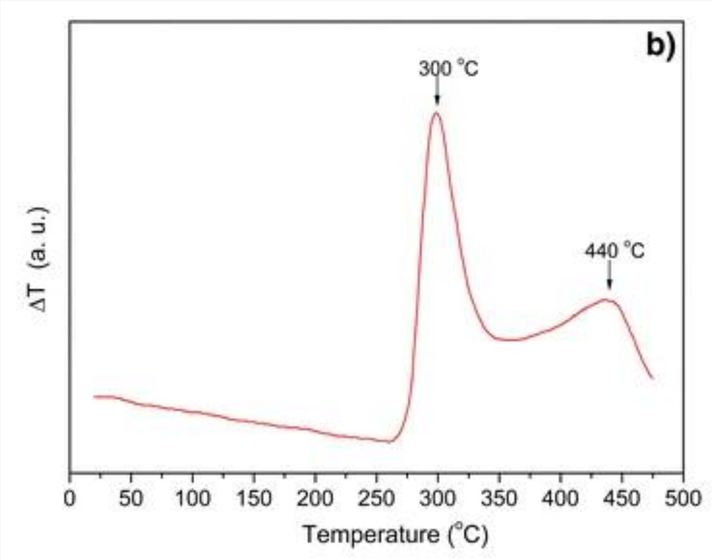
6. TEST RESULTS

DUST EXPLOSIVITY	
Group:	A
Maximum Explosion Pressure:	7.2 bar
Maximum Rate of Pressure Rise:	236 bar/s
Kst:	64 bar.m/s
St Class:	1
Limiting Oxygen Concentration:	13 % v/v
MINIMUM IGNITION ENERGY:	400 to 500 mJ
MINIMUM IGNITION TEMPERATURE	
Dust Cloud:	400 °C
Powder Layer:	340 °C
RESISTIVITY	
Ambient Humidity (41%):	9.34E09 ohm.m.
Low Humidity (3%):	1.43E13 ohm.m.
CHARGE RELAXATION TIME	
Ambient Humidity (41%):	8 s
Low Humidity (3%):	1859 s
TRAIN FIRE (10cm burn):	232 to 276 s
MELTING POINT: Decomposition onset	237 to 238 °C
pH (10% suspension.):	6.1

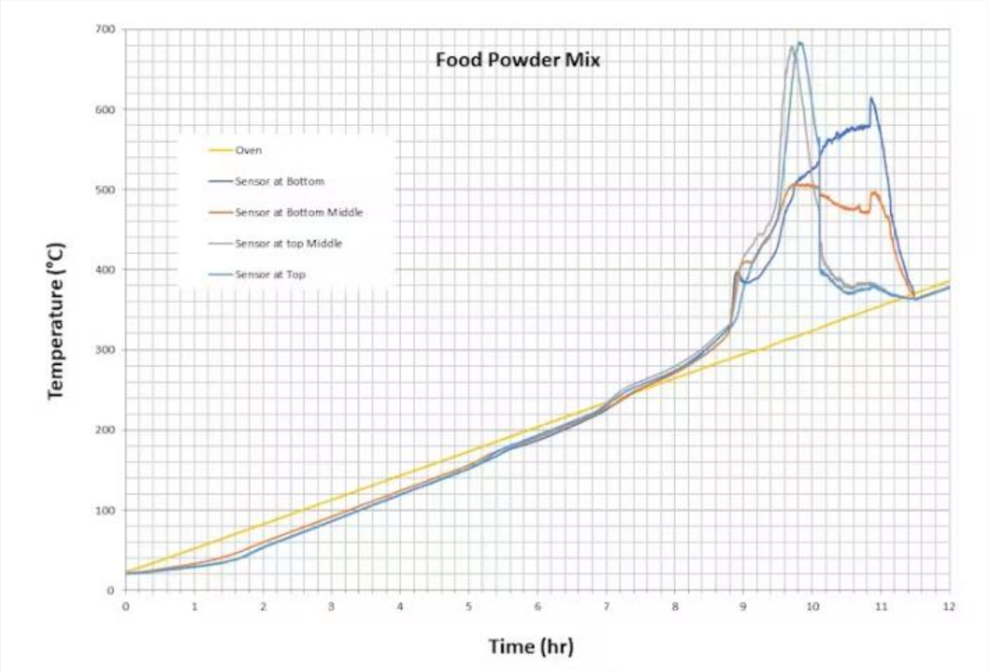
Sigachi Industries Pharma Plant Explosion near Hyderabad

- TGA and DSC data for cellulose suggests thermal decomposition can occur in MCC above 220-300degC.
- An oxidation reaction initiates which is exothermic and can result in smouldering.
- If the powder is blocked / choked in the spray dryer then it is possible smouldering could have occurred in the bulk.
- Material may not be classified as a self-heating solid under UN DG but could still be a risk during processing conditions.





[Glass transition temperature and thermal decomposition of cellulose powder | Cellulose]



Sakarya Pasta Factory, Turkey

- Sept 15, 2024 - 5 fatalities – multiple injured
- Fire and grain dust explosion in the mill section of the plant, due to electrical failure / short circuit
- “It is concluded that a spark caused by a short circuit in the energy room ignited the flour dust present, leading to the explosion.”
- According to the report:
  - Risk analysis inadequate – not addressing all risks
  - Heavy dust accumulation observed in mill area
  - Explosion Protection Document inadequate
  - Integrity and design of electrical systems inadequate
  - Electrical panels open and dust accumulated inside
  - Lack of implementation of corrective/preventative measures
  - Safety Culture – incident reporting & follow-up, fatigue

Source:
Expert report on deadly Sakarya pasta factory explosion finds neglect – BIANET

Sakarya Pasta Factory, Turkey

Company chair named responsible

The report identified Mehmet Musa Özgüçlü, Chairman of the Board of Oba Makarna, as primarily responsible for the explosion due to "violations of employer obligations."

I.B., who prepared the Explosion Protection Document (EPD), was held primarily responsible for the explosion. The report stated that I.B. did not allocate sufficient time to inspect the facility while preparing the document, failed to adequately evaluate its scientific foundations, and overlooked the need for technological protective measures in areas with the highest risk of dust explosions, thereby preventing the recognition of potential hazards.

Occupational safety specialist D.T. was identified as secondarily responsible. According to the report, D.T. prepared the mandatory risk analysis, Explosion Protection Document, and periodic machine and equipment inspections without considering the dusty working environment. D.T. also failed to fulfill their responsibility to guide the implementation of

Source:
Expert report on deadly Sakarya pasta factory explosion finds neglect – BIANET

JSC AsiaAgroFood, Almaty Kazakhstan

- May 23rd 2025. Four fatalities.
- Powerful explosion of flour dust at feed mill facility.
- Emergency Department “Dust-Air mixture of grain waste on the first floor of the second elevator’s nine-story building”.
- Fire covered 1400m^2
- >100 emergency responders and 31 firefighting units.

[Four die after grain dust explosion in Kazakhstan | World Grain]

Photo: MoES RK

Combustible Wood Dust Explosion at Horizon Biofuels, Fremont, NE, USA

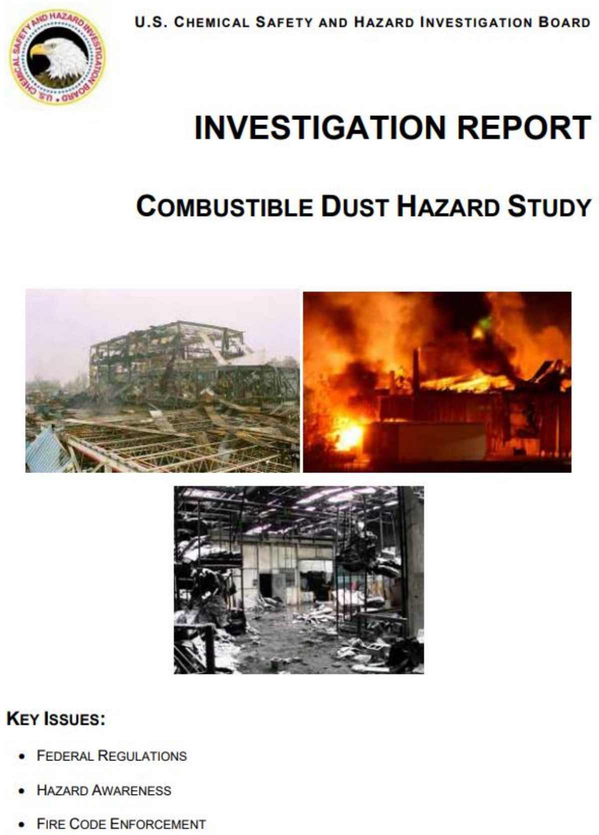
- July 29, 2025 - 3 fatalities (incl 2 children).
- Only 5 people on site.
- Facility produced wood pellets for use a heating fuel and animal bedding.
- Initial report states the plant had equipment for
  - Grinding/milling scrap wood
  - Conveying equipment
  - Pellet mill (exit temperature >90degC)
  - Silo's/ Storage bins
  - Dust collection system located on top floor of building.

- Investigation in progress CSB update Sept-25
- CCTV indicates explosion started in top of building (location of DCU)
- Softwoods (pine spruce) typically MIE 10-30mJ for fine dust.

horizon_biofuels_investigation_update_2025-09-17_final_public1.pdf

CSB Combustible Dust Hazard Study

- CSB Combustible Dust Hazard Study Published 2006
- Following 119 fatalities and 718 injuries in US 1980 to 2005
- NFPA654 Combustible Dusts
- OSHA “Emphasis Programme”

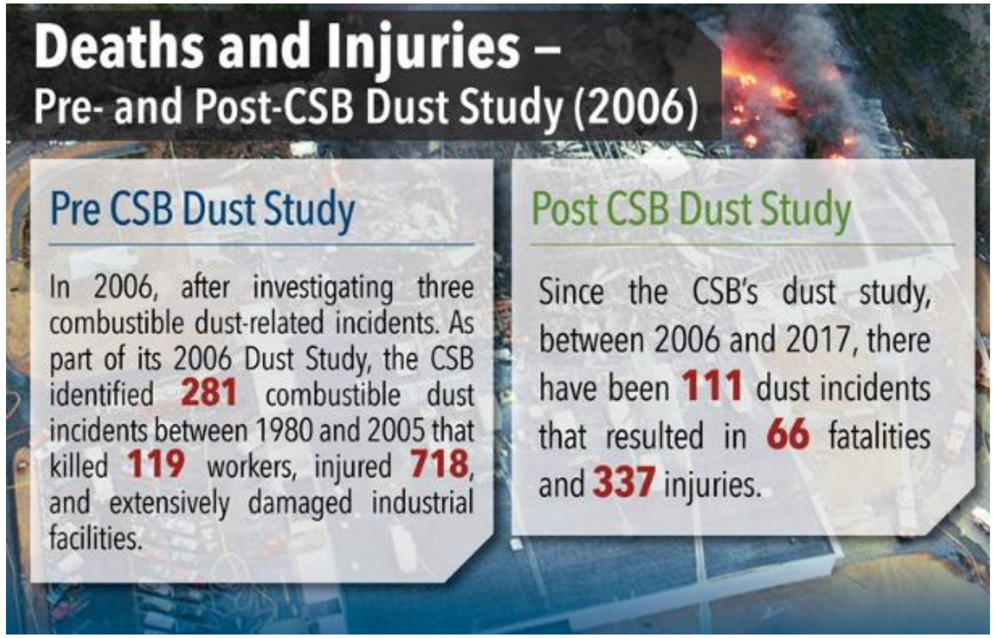

U.S. Chemical Safety and Hazard Investigation Board

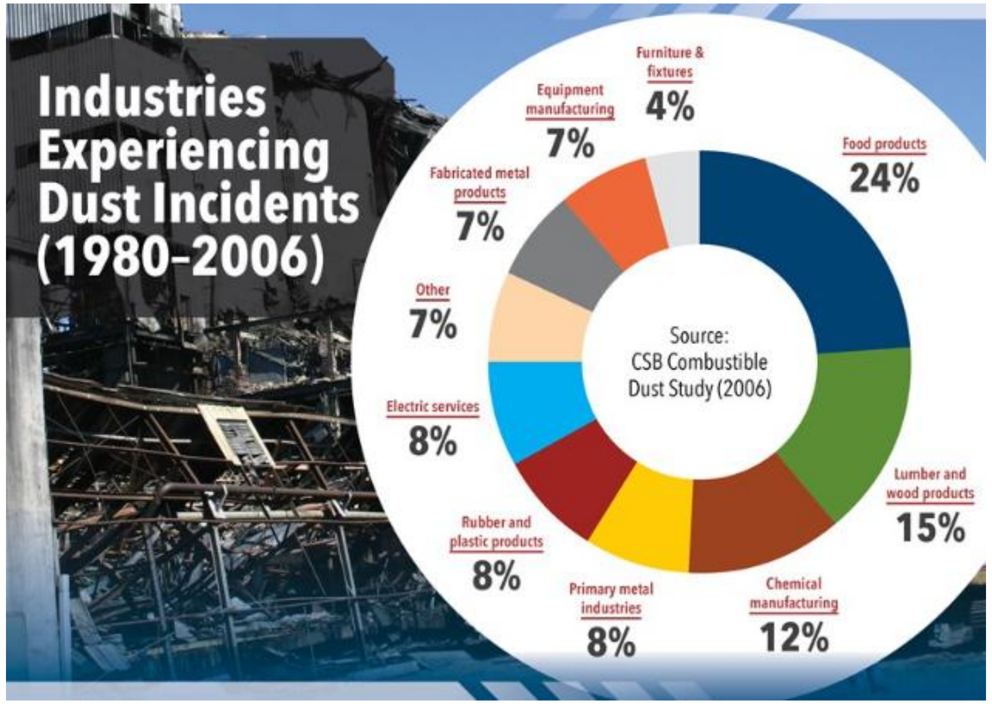
INVESTIGATION REPORT

Combustible Dust Hazard Study

Key Issues:

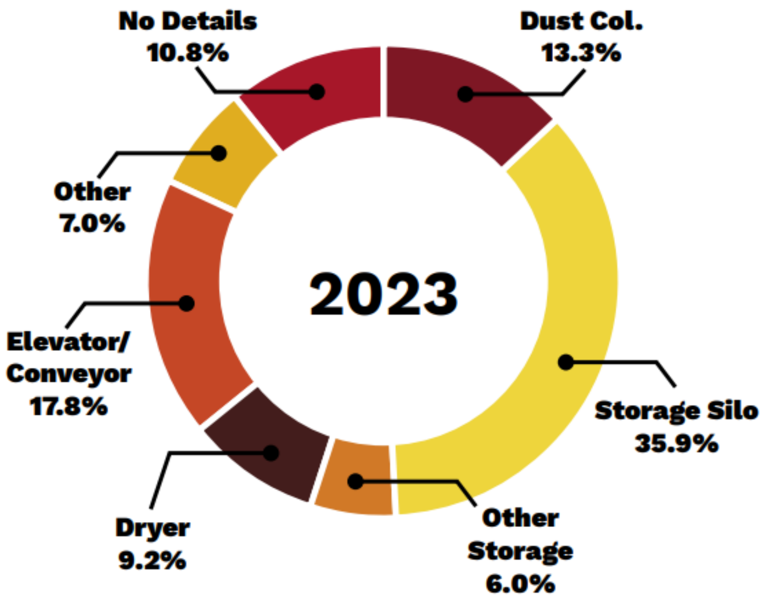
- Federal Regulations
- Hazard Awareness
- Fire Code Enforcement





Dust Safety Science

- Dust Safety Science (Dr Chris Cloney) publishes annual report incorporating US, Can and International data.
- International reporting on the increase.



DUST SAFETY SCIENCE

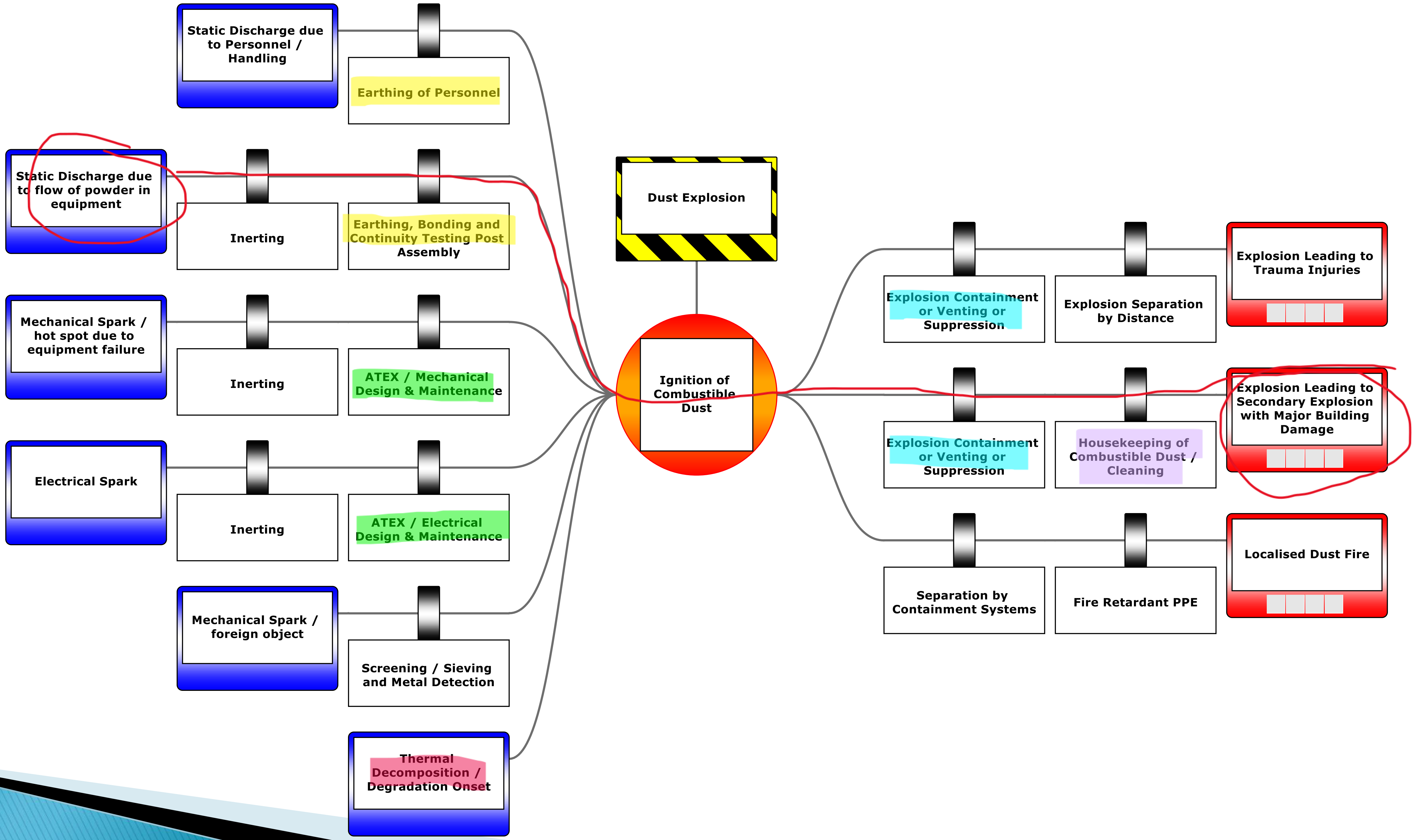
INCIDENT DATA OVERVIEW

	UNITED STATES					CANADA					INTERNATIONAL				
	2019	2020	2021	2022	2023	2019	2020	2021	2022	2023	2019	2020	2021	2022	2023
Fires	175	116	98	79	75	22	14	8	9	14	53	35	57	75	174
Explosions	37	26	19	26	17	1	7	3	0	2	37	27	30	24	34
Injuries	42	35	26	24	21	4	2	9	0	0	72	51	180	65	73
Fatalities	1	1	2	1	0	0	0	3	0	0	7	9	64	48	62

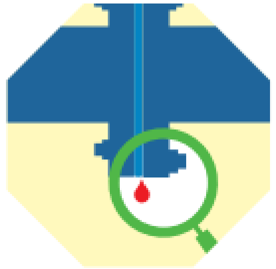
Understanding your Combustible Dusts – some key parameters

Property	Acronym	Nature of Test	Used for
Melting Point Thermal Stability, Decomposition temperatures, Mass effects	DSC ARC Basket Tests	Identify whether a material undergoes exothermic decomposition at different initiation temperatures in storage, normal processing and credible maloperation conditions.	• Inherent Safety • ATEX Temperature Class • Interlocks & Trips • Ignition Risk Assessment
Layer and Cloud ignition temperatures	LIT, MIT-Layer, MIT-cloud	Temperature required to ignite a 5mm layer of powder or dispersed cloud	
Minimum Ignition Energy	MIE (mJ)	Minimum amount of energy required to ignite a dust cloud	• Ignition source risk assessment incl mechanical and electrostatic hazards.
Maximum pressure Max Rate of Pressure Rise and Deflagration index	Pmax dP/dTmax Kst	Explosion severity: Maximum pressure reached by explosion, and the rate of pressure increase which is indicative of the shock forces on the surrounding equipment.	• Design Strength • Vent Panel sizing • Propagation risk
Charge relaxation time & resistivity		Time it takes for an electrostatic charge on a material to dissipate to a certain % of its value & a measure of how strongly a material resists the flow of electric current.	• Electrostatic Risk assessment • Classify materials as conductive/insulating
Moisture Content and particle size		Changes combustion rate, MIE, possibility to form a cloud, conductivity, relaxation time and other electrostatic properties	• Effects of humidity on electrostatic properties

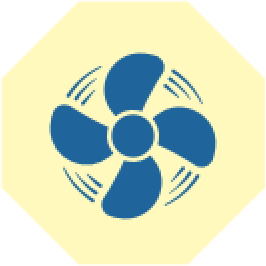
Protection Principles for Food and Pharma



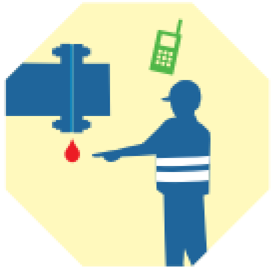
Fundamentals



Verify Leak Tightness after Interventions.



Ventilation in Hazardous Areas



Report Process Safety Incidents

13. ELECTROSTATICS (GROUNDING AND BONDING)

HAZARDS

Most materials in the pharmaceutical and food industry are flammable (including solvents, vapours and dusts).

WHEN IMPORTANT

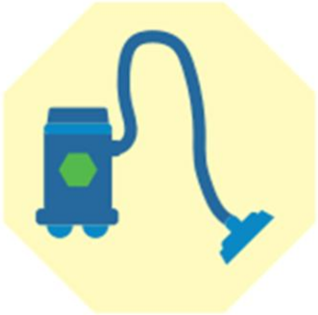
When transferring flammable gases, vapours and dusts. When performing manual handling such as loading powders When spraying flammable liquid.

CHALLENGES IN THE FIELD

- Maintaining continuity of earthing and bonding especially after maintenance/ modification.
- Earthing of mobile equipment including tanks, scoops, vessels.
- Earthing of process operators during open handling of materials.

RECOMMENDED PRACTICES

- Verify continuity of grounding and bonding on a regular basis by both physical inspection and use of a resistance meter.
- Ensure operators and maintenance staff are trained to check continuity after performing interventions.
- Use appropriate (e.g. ATEX rated) equipment in zoned area's.
- Hazardous area equipment for handling flammable materials and follow the correct maintenance and inspection regime.
- People can accumulate static electricity - use static dissipative footwear and flooring where handling operations take place.
- Limit the transfer velocities for flammable liquids in pipelines and give particular attention to non conductive liquids (<1m/s).
- Use an inert gas to remove oxygen from equipment where possible.
- Use dense phase powder transport in preference to manual loading.
- Ensure earthing straps are applied before filling or emptying mobile containers such as tankers, drums, IBC and FIBCs.
- Provide specific process safety training in electrostatics to process Operators and Maintenance teams.



12. COMBUSTIBLE DUST HOUSEKEEPING

HAZARDS

Flammable dusts can cause fires and explosions. Many API pharmaceutical dusts are highly toxic.

WHEN IMPORTANT

When handling e.g. transferring / charging / offloading combustible dusts which could become dispersed.

CHALLENGES IN THE FIELD

- Powder properties not well identified especially for new products.
- Electrostatic and mechanical ignition risks can be difficult to control.
- Leaks from equipment can give rise to external dust zones and dust layers.

RECOMMENDED PRACTICES

- Use "closed" containment systems and local ventilation to minimise dust escaping from equipment and forming combustible layers in the plant.
- Avoid horizontal surfaces where dust can collect on ledges.
- Ensure regular cleaning of facilities to prevent layers forming. Apply the same controls in utility areas (dust collectors etc) as in the manufacturing areas.
- Review SDS sheets or conduct tests to determine dust safety data (Minimum Ignition Energy MIE, KSt, Pmax etc).
- Conduct Hazardous Area assessments for all areas where flammable dust is handled; include equipment internals and externals.
- Ensure equipment handling combustible dusts is Hazardous Area Rated (ATEX) to control electrical, mechanical and electrostatic ignition hazards.
- Ensure operation is well below dust ignition temperatures.
- Identify all ignition sources such as electrostatics, hot surfaces, mechanical impacts or frictions.
- Ensure ATEX equipment is regularly inspected and maintained.
- Pay particular attention to locations where flammable gases may also be present creating "hybrid" mixtures which are more sensitive to ignition.
- Train staff on combustible dust hazard awareness.

Key Learning Points

- **Understand your Combustible Dust** at the Process Conditions
  - Use Dust properties for design decisions and equipment specification.

- **Define and Apply safeguards** for unit operations. Mills, bucket elevators, dryers, bag tipping, dust filters etc.
  - ATEX specification,
  - Earthing/Bonding of components
  - Ventilation to minimise risk of combustible cloud formation
  - Explosion venting/suppression and isolation.
- **Maintain safeguards**
- **Maintain Primary containment** - do not tolerate leaks from equipment!
- Prevent build up of **external dust layers** - HOUSEKEEPING
- Ensure staff and contractors are **aware of hazards and safe practice.**
- Ensure **incident response plans** in place and responders are not put at risk.
- **Fight Normalization of Deviation** – don't get too comfortable.

our shared responsibility to protect society

EPSC