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Preventing Dust Explosions

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Ministry of Manpower

Empowered *Workforce*,
Thriving *Workplaces*

Agenda

1. Understanding Combustible Dust (CD) Explosion
2. Risk Management
3. Case Study & Key Takeaways
4. Regulatory Requirements
5. CD Guidelines & Resources

What is combustible dust

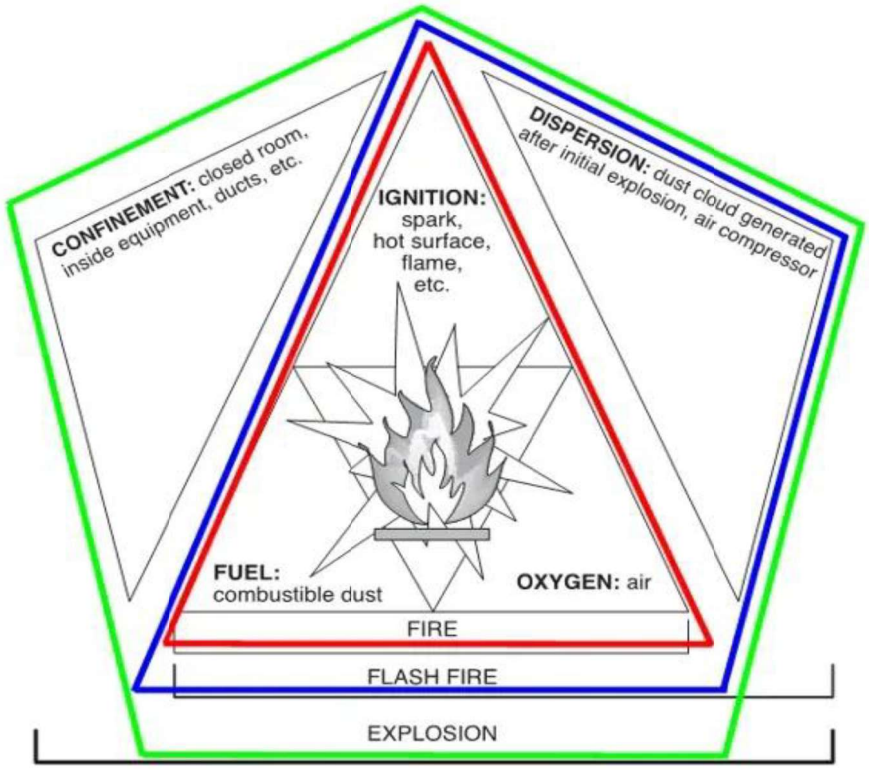
"Combustible dust refers to any finely divided combustible particulate solid (regardless of size, shape, or chemical composition) when processed, stored, or handled in the facility, that presents a flash fire hazard or an explosion hazard when suspended in air or the process-specific oxidising medium over a range of concentrations."

This includes substances listed in the Fourth Schedule of WSH (General Provisions) Regulations.

Possible combustible dusts in general workplaces (non-exhaustive list here) include:

- Organic dusts, found in cargo holds: Grain flour, wood dust, sugar, starch, cocoa powder, coffee grounds, tea dust, charcoal, and dried food products
- Metal dusts, gathered during abrasive blasting, grinding: Aluminum powder, iron filings, magnesium shavings, zinc dust, and titanium particles

Dust Explosion Pentagon



Red – 3 elements for a fire

Blue – 4 elements for flash fire

Green – 5 elements for combustible dust explosion

Source: https://www.hallam-ics.com/blog/combustible-dust-fundamentals-nfpa-652

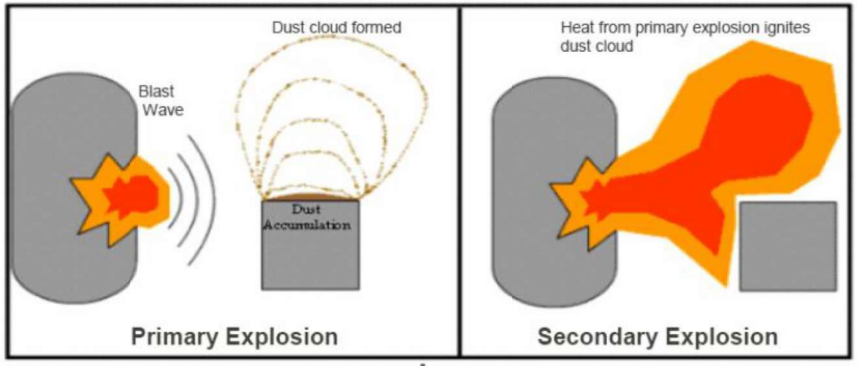
Secondary Explosion

A primary explosion in an area where fugitive dust has accumulated may shake loose more accumulated dust or damage a containment system (such as a duct, vessel, or collector).

Thereafter, the additional dust dispersed into the air may cause one or more secondary explosions when ignited. These can be far more destructive than a primary explosion due to the increased quantity and concentration of dispersed combustible dust.

Examples:

- Imperial Sugar incident, 2008 (14 fatalities, 28 injured)
- Kunshan Zhongrong Metal Product Company, 2014 (146 fatalities, 114 injured)
- Stars Engrg Pte Ltd, 2021 (3 fatalities, 7 injured)



Areas/Works where dust hazards can be found:

- Manual handling of particulate solids e.g. pouring into mixers or reactors
- Confined Spaces like silos to store organic solids e.g. grains or coal.
- Dust collectors for organic powders, metal dust, wood dust.
- Abrasive blasting, grinding, polishing and wood working areas

Types of combustible dusts & typical Kst values

Organic

- Low K_{st} e.g., sugars, flour, potato starch, wood dust
- Mostly food products and not classified as chemicals

Plastic

- Moderate K_{st} e.g., PVC, PMMA, PE

Chemical

- Moderate K_{st} e.g., sodium stearate, calcium acetate, sulphur

Metal

- High K_{st}[1] e.g., magnesium, aluminium

[1] K_{st} is defined as the deflagration index of a dust cloud. It is a generalized number used to estimate the anticipated behaviour of dust deflagration or explosion, allowing an approximation of a dust's explosive power compared to other dusts.

Combustible Dust listed in Fourth Schedule

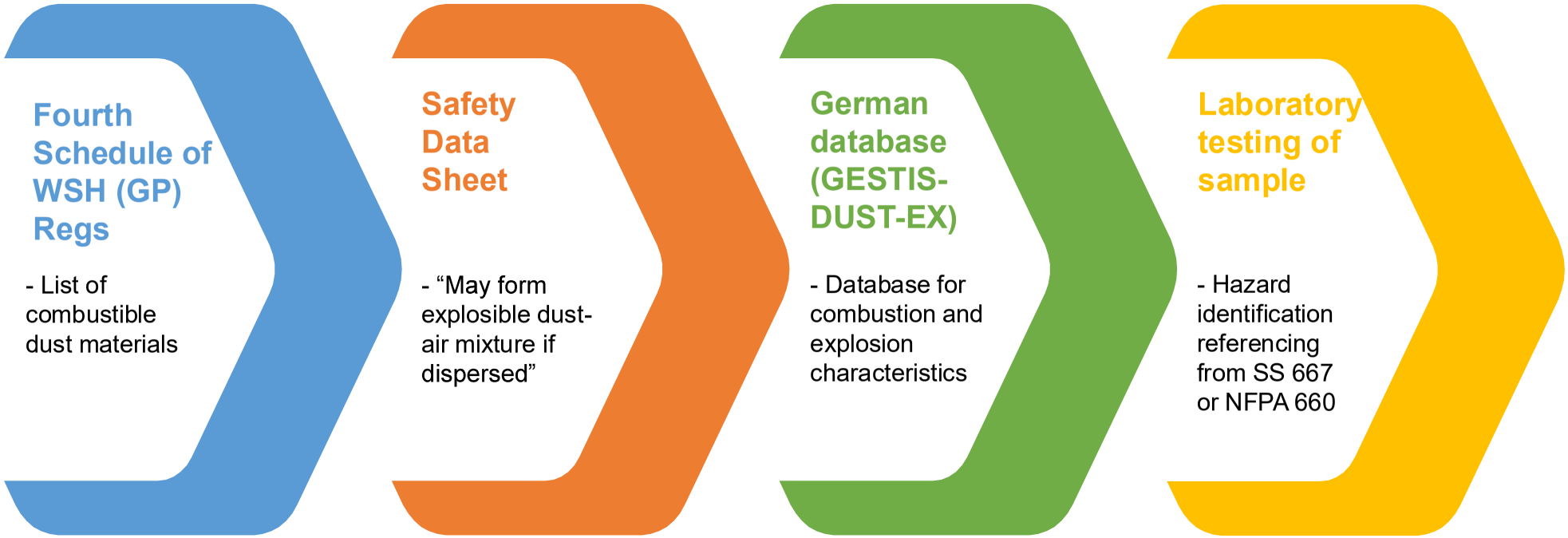
Organic Combustible Dusts			Threshold quantity per substance
1. Alfalfa 2. Apple 3. Beetroot 4. Carbon black 5. Carrageenan 6. Carrot 7. Cereals (for example, barley, corn, oat, rice, rye and wheat) and their derivatives 8. Charcoal 9. Coal 10. Cocoa 11. Coconut and its derivatives 12. Coffee 13. Coke 14. Cotton and its derivatives	15. Egg white 16. Garlic 17. Grains (malted) 18. Grains (spent) 19. Grass 20. Hops 21. Lemon peel or pulp 22. Linseed 23. Locust bean gum 24. Milk and its derivatives 25. Olive pellet 26. Onion 27. Parsley 28. Peach	29. Peanut 30. Peat 31. Potato and its derivatives 32. Soot 33. Soybean and its derivatives 34. Spice 35. Sugar 36. Sunflower seeds 37. Tapioca 38. Tea 39. Tobacco 40. Walnut 41. Xanthan gum 42. Yucca seeds	100 kg
43. Cellulose	44. Cork	45. Wood	25kg

Plastic Combustible Dusts	Threshold quantity per substance
1. Epoxy resin 2. Ethylene-vinyl acetate copolymer 3. Melamine 4. Polyacrylamide 5. Polyacrylonitrile 6. Polyethylene 7. Polypropylene 8. Polyvinyl acetate 9. Polyvinyl alcohol 10. Polyvinyl butyral 11. Polyvinyl chloride 12. Terpene-phenol resin 13. Urea-formaldehyde-cellulose	100 kg
14. Phenolic resin 15. Polymethyl acrylate	25kg

Chemical Combustible Dusts		Threshold quantity per substance
1. Adipic acid 2. Ascorbic acid 3. Calcium acetate 4. Calcium stearate 5. Carboxy methyl cellulose 6. Dextrin 7. Lactose	8. Lead stearate 9. Methyl-cellulose 10. Paraformaldehyde 11. Sodium ascorbate 12. Sodium stearate 13. Sulphur	100 kg
14. Anthraquinone		Any quantity

Metal Combustible Dusts			Threshold quantity per substance
1. Bronze 2. Copper 3. Iron	4. Iron carbonyl 5. Manganese 6. Silicon	7. Tantalum 8. Titanium 9. Zinc	100 kg
10. Aluminium	11. Magnesium	12. Niobium	Any quantity

Managing Dust Risks: Hazard Identification



Risk Evaluation – Dust Hazards Analysis (DHA)

DHA is a systematic review to identify and evaluate fire and explosion hazards, and identify control measures for risk reduction

The DHA, led by a competent person,

- Identifies hazardous scenario
- Provides a link between hazards and specific control measures

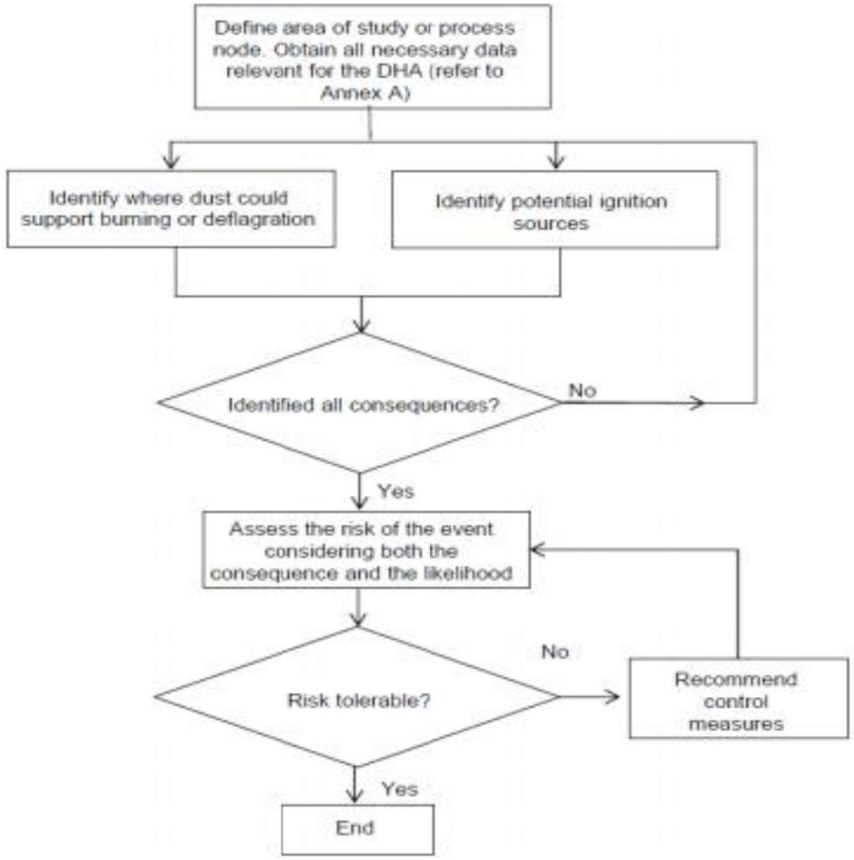
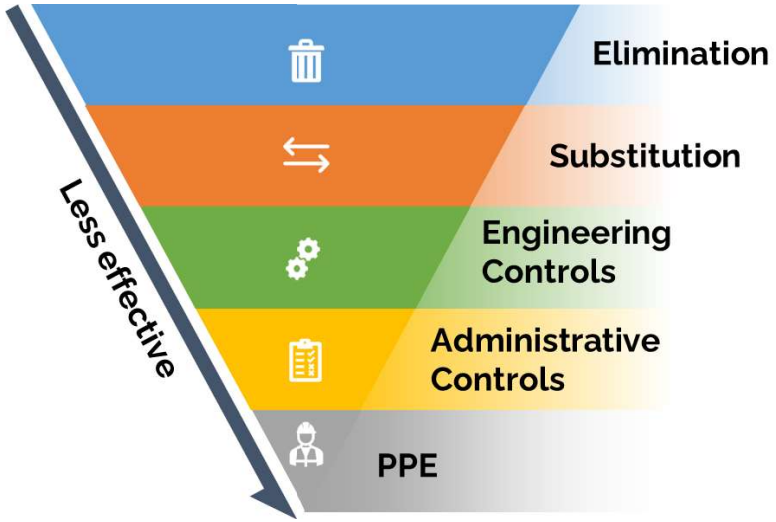


Figure 2 – Dust hazard analysis (DHA)

Reference: SS 667 : 2020, Figure 2

Preventing Dust Explosions

- To prevent dust explosions, workplaces can remove one or more elements from the pentagon
- Always aim for higher-level controls where possible
- Higher-level controls provide more reliable and sustainable protection
- Multiple controls can be used together for better protection



Control and Management of Combustible Dust

Enclosure	• Do not store materials in the open • Enclose equipment with sufficient safety features to prevent combustible dust explosion
Dust control	• Local exhaust ventilation system (flame-proof) • Proper housekeeping (no dry sweeping)
Ignition source control	• Effective grounding and bonding • Use of non-sparking tools • Use suitable flame-proof equipment e.g., flame-proof forklift, flame-proof dust collectors
Explosion prevention and protection	• Provide explosion vent • Install spark detectors
Training	• Provide training on combustible dust hazard • Communicate the precautionary measures to be taken
PPE	• Workers working with combustible dust to be equipped with necessary PPE e.g., fire retardant clothing, static dissipative safety shoes

EX-proof flood lights

ATEX rated vacuum cleaner

Grounding points

Bonding points

Flame-proof forklift

Case Study: Stars Engrg Pte Ltd

24 February 2021

Tuas, Singapore

Potato starch powder

3 fatalities, 7 injuries

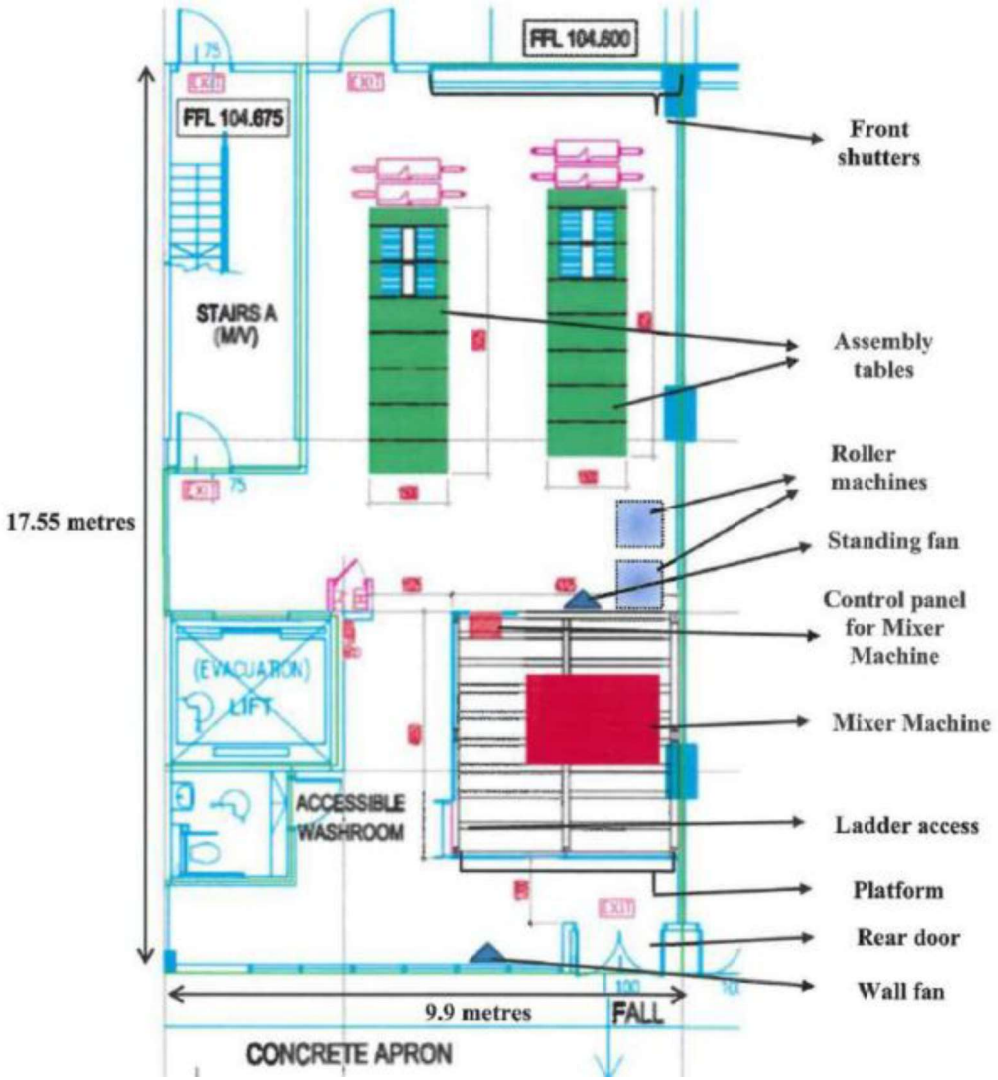
Source: Report of the Inquiry Committee for the accident at Stars Engrg Pte Ltd on 24 Feb 2021

Case Study: The Production Process

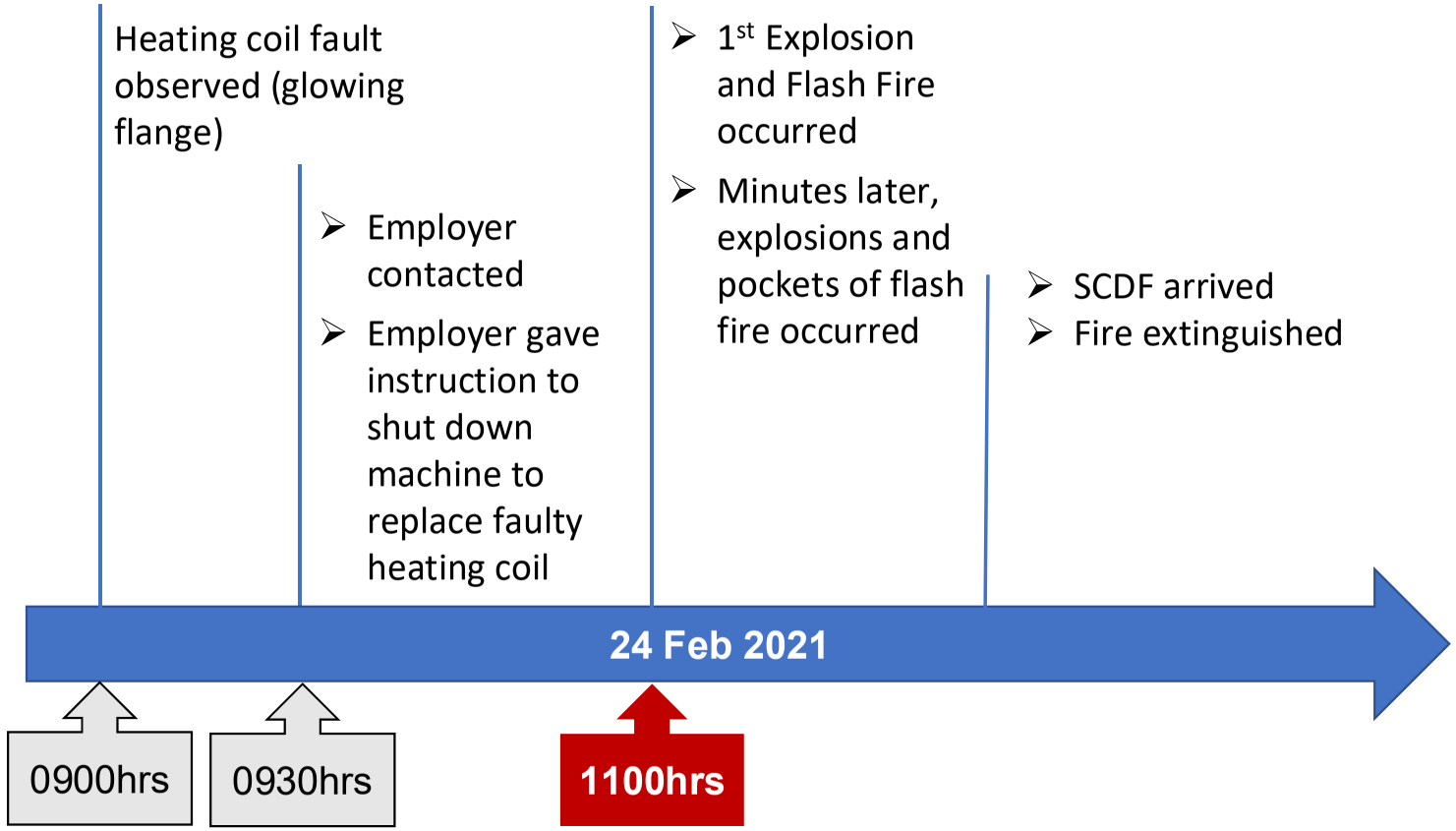
Fire Clay Making	• Mixer machine to heat up water in mixing chamber. • Add potato starch and other ingredients with heated water in mixing chamber till pasty consistency is achieve
Fire Clay Processing	• Pour out fire clay from mixer machine and laid out on the platform and subsequently transfer to ground floor • Workers at flatten fire clay to 10mm with roller machine • Passed to next roller machine to further flatten fire clay to 5mm
Fire Wrap Assembly	• Two sheets of aluminum roll are cut and taped to create a width of 1.1m for fire wrap • Layers of fire clay and other ingredients are placed on the aluminum sheet • The layers are enfolded with the plastic sheet and shrink-wrapped with heat

Case Study: The Layout

- The worksite measured about 17.55m by 9.90m
- Mixer machine and its control panel was placed on a raised platform
- 2 roller machines were located between the assembly tables and the platform
- 2 assembly tables were placed near the front shutters



Case Study: Sequence of Events



Case Study: Incident Analysis

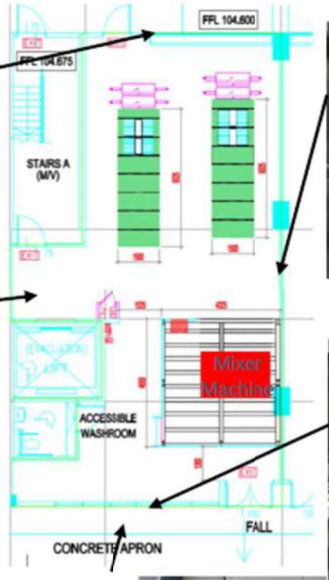
- Mixer machine was used in overheated conditions as a closed system, leading to mechanical rupture
- Oil vapour was expelled and subsequently ignited due to the sudden rupture, leading to the **primary explosion** and the **subsequent secondary flash fires.**
- Secondary flash fires were most likely due to the ***combustion of potato starch powders***.

Source: Report of the Inquiry Committee for the accident at Stars Engrg Pte Ltd on 24 Feb 2021

Case Study: Aftermath of Incident

damaged front shutters

collapsed false ceiling in lift lobby



hole blasted out on side wall

rear wall blasted outwards

debris outside rear wall

Source: Report of the Inquiry Committee for the accident at Stars Engrg Pte Ltd on 24 Feb 2021

Case Study: Safety Lapses

- No risk assessment and safe work procedure for mixing activities and for use and storage of combustible dust
- No proper training provided to workers for safe use of mixer machine
- No emergency evacuation plan was developed
- No toolbox meeting was conducted to discuss general work activities or highlight hazards that workers were exposed to.
- Failed to provide a local exhaust ventilation system to prevent the accumulation of the combustible starch powders in the workplace
- Improper housekeeping methods by dry sweeping.
- No fire-resistant PPE provided to workers

Key Takeaways to Preventing Dust Explosions

- Never underestimate the risks of dust explosion – the consequences can be severe!
- Regular housekeeping is a simple and critical control measure for preventing and mitigating secondary explosions.
- Maintain the effectiveness of control measures, e.g.
  - Check protective equipment, including PPE; Oil stains affecting the effectiveness of fire resistance of overalls
  - Maintenance of engineering controls e.g. explosion prevention devices, ATEX equipment and grounding/bonding systems

Source: Dust Safety Science