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Combustible Dust Awareness

David McEwan
Business Line Manager – Configured Products



SFMCA
Stock Feed Manufacturers' Council of Australia
VICTORIA BRANCH

If you heard there was a gas leak, would you be concerned about an combustible atmosphere? Most likely yes

Is a dust cloud any different?

Approx what percentage of dusts are generally considered combustible?

25% 33% 50% **70%** 90%



Introduction

An explosion can occur when any powdered combustible material is present in an enclosure or, in general, in high enough concentrations of dispersed combustible particles in atmosphere.

Dusts have a very large surface area compared to their mass. Burning occurs at the surface of a solid or liquid, where it can react with oxygen.

Therefore fine dusts to be much more flammable than bulk materials.

1 kg sphere of a material with a density of 1000kg/m^3 would be about 270 mm across and have a surface area of 0.3 m^2 .

If this sphere was broken up into dust particles $50\mu\text{m}$ in diameter (flour particles) it would have a surface area of 60 m^2 .

Dust collected by an extraction system is smaller particulate than process dust.

Increased surface area means material burns much faster and ignites with much less energy.

When this mixture of fuel and air is ignited, especially in a confined space such as a warehouse or silo, a significant increase in pressure is created.



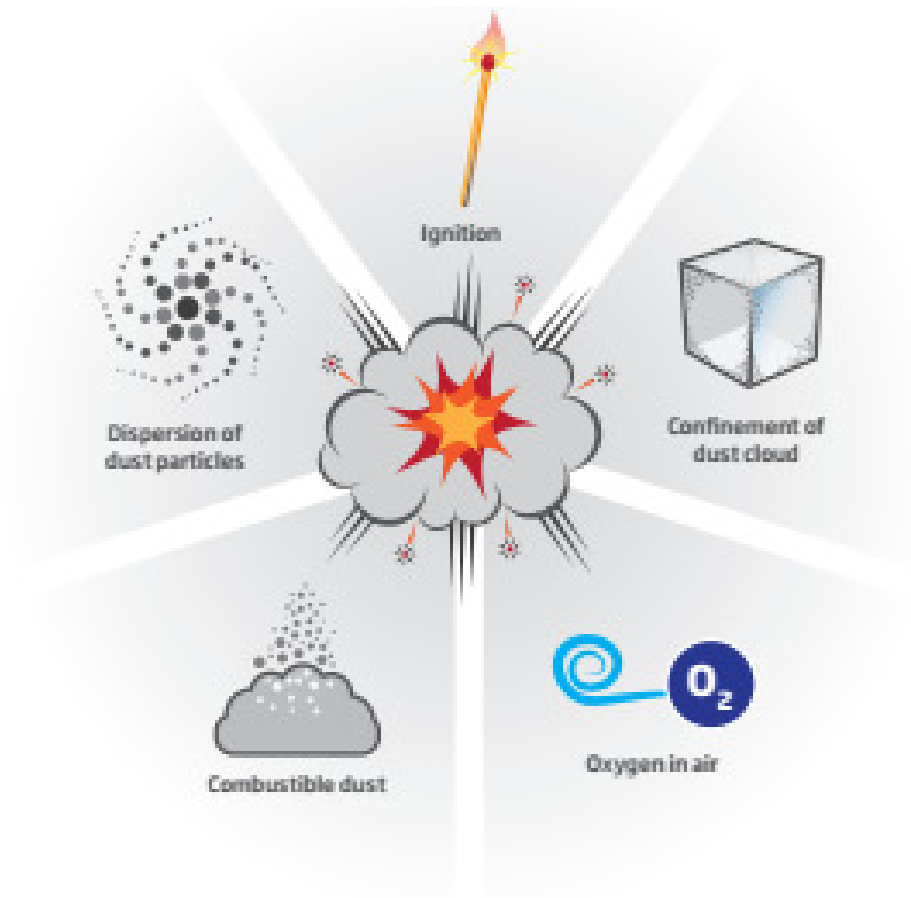
Combustible Dust Pentagon

Inside a dust collector:

- Oxygen is present
- Dust cloud (dispersion) by air stream within collector
- Confinement from walls of dust collector

The only factor missing is an ignition source

All applications should have a risk assessment by qualified personnel to establish level of risk and planned risk mitigation



Terminology

De-flagration – subsonic combustion propagating through heat transfer. ‘Fire’
Pmax is below 0.5 bar typical.

Explosion – rapid combustion of fine particles suspended in air, if this rapid combustion occurs in a confined space, overpressures can build up causing structural damage and flying shrapnel.

Detonation – combustion achieving supersonic speeds.

Dust explosions – primary vs secondary

Kst – maximum rate of pressure rise in a closed system.

Kst is determined by $(dp/dt)_{max} \cdot V^{1/3}$ (explosion behavior of a combustible dust in a closed system).

Pmax – maximum pressure reached in the combustible dust test, if Pmax exceeds 0.4 bar, it is said an explosion has occurred.

St rating – categories for Kst values

St1 – a dust with a tested Kst within the range Kst1 to Kst199

Example, wood dust 95, soap 111, sugar 132, polyethylene 134, printer toner 196.

St2 – a dust with a tested Kst within the range Kst200 to Kst 299

Example, polyester 237, wood flour 224, paint powder epoxy 202, corn flour 200

St3 – a dust with a tested Kst of 300 or above

Example, magnesium 508, aluminium powder 300, ‘hybrids’

Is my dust combustibile?

- Question to ask:
 - Can a dispersed dust cloud support self-sustaining flame propagation?
 - If it can, a flash fire can occur. If this flash fire is enclosed, pressure can build up to the point of failure of the surrounding enclosure.
 - Testing of dust sample from the actual dust collection process is the only true way to evaluate combustibility of dust.
 - In combustible dust test, if pressure exceeds 0.4 bar then it is deemed an explosion has occurred.
- Explosibility Parameters
 - Dust Cloud reactivity (Kst, how fast, and Pmax, how big)
 - Minimum Dust Concentration / Low Explosion Limit (how much)
- Ignition Characteristics
 - Dust cloud minimum ignition energy (MIE – energy level needed)
 - Dust cloud minimum ignition temperature
 - Dust layer minimum ignition temperature



Is my dust combustible?

Under AS NZS 4745:2012 a risk assessment of the application must be completed. If a combustible dust risk/atmosphere is identified, either a preventative or protective system will be designed and installed.

- Product Powder vs Dust
- Test the Dust or Research the application
 - Simtars (Brisbane) approx. \$9,500 per dust test
 - <http://staubex.ifa.dguv.de/?lang=e>
 - Institute for Occupational Safety and Health of the German Social Accident Insurance
- Evaluate the Worst Case
 - Don't assume it can't happen to you
- Understand the Regulatory Requirements
 - Not all AS NZS are law, but worksafe requirements for a safe workplace are law and will reference standards for guidelines
- Engage a Combustible Atmospheres expert



Detailed information on:
Flour, type 700 (→ 3237)

characteristic	
→ Particle size <250 µm [% by weight]	100
→ Particle size <125 µm [% by weight]	97
→ Particle size <63 µm [% by weight]	61
→ Particle size <32 µm [% by weight]	39
→ Median Value [µm]	45
→ Moisture Content [% by weight]	13
→ Lower Ex-Limit [g/m ³]	60
→ Max.Ex-Overpressure [bar]	7,4
→ K _{St} Value [bar m/s]	44
→ Explosibility	St 1
→ Minimum Ignition Energy [mJ]	>100
→ Ignition Temperature BAM [°C]	460
→ Glowing Temperature [°C]	330
→ Combustibility BZ	2

The fineness and moisture content indicated in the first column refer to the state of the dust sample as delivered. The "delivered" state may also be identical to the tested state.

The listed combustion and explosion characteristics always apply only to the dust with the conditions described in the same column.

The data of GESTIS-DUST-EX are compiled and updated carefully. Nevertheless, any liability is excluded (cf. → limits of applicability).

<http://staubex.ifa.dguv.de/?lang=e>

Detailed information on:

Aluminium (+ 2425)

characteristic	
→ Particle size <71 µm [% by weight]	99
→ Particle size <32 µm [% by weight]	71
→ Particle size <20 µm [% by weight]	41
→ Median Value [µm]	23
→ Lower Ex-Limit [g/m ³]	60
→ Max.Ex-Overpressure [bar]	12,4
→ K _{St} Value [bar m/s]	620
→ Explosibility	St 3
→ Minimum Ignition Energy [mJ]	>10
→ Ignition Temperature G-G [°C]	560
→ Glowing Temperature [°C]	n.g.u.450
→ Combustibility BZ	4

<http://staubex.ifa.dguv.de/?lang=e>

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Dust Properties

Each dust has its own properties, note the different K_{st} values for same particle size dust



What dusts are combustible?

Wheat	Carrot	Rice
Egg white	Magnesium powder	Zinc
Coal	Cellulose	Garlic
Epoxy Resin	Vinyl	Ascorbic Acid
Onion Powder	Gluten	Bronze
Cocoa	Sugar
Soap
Aluminium	Polyethylene	Polystyrene
	And so on	
	And so on	
	And so on.....	

Its only a 'little bit of dust'

- Some dust generating processes produce a very small amount of dust.
- Example:
 - Bulk bag filling into 20 kg bags, dust extraction collects 3 g of dust per bag
 - Operator runs at 2 bags per minute -> 120 bags per hour
 - 8 hour shift 960 bags per day at 3 gram of dust per bag = 2.88 kg per day
 - Dust collector has 100 ltr bin, using a bulk density of 600 kg/m³ bin holds 60 kg
 - So the operator empties the bin every second Friday with around 28 kg of powder
- The air movement inside the dust collector keeps some of the dust in a cloud so there is always a combustible dust cloud inside the collector (with up to 28kg of fuel in the collection bin).

Its only a little bit of dust

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Industry Awareness

First combustible dust incident recorded 1785, Turin, Italy.
Flour dust ignited by a lamp in the storeroom in bakery.

In 2003, 3 major events in USA prompted the chemical safety board to investigate.

West Pharmaceuticals	6 dead Dozens injured Hundreds of jobs lost
CTA Acoustics	7 dead 44 Injured Extensive facility damage
Hayes Lemmerz International	1 dead 3 Injuries Extensive facility damage



Industry Awareness

In 2008, single major event in USA prompted landmark investigation

Imperial Sugar event

14 dead
38 Critical injuries
Extensive facility damage
US\$8.8M fine from OSHA

Between 2008 and 2012, CSB documented 50 examples of combustible dust accidents.

Each event occurred in a manufacturing or processing facility where the site owners had ignored obvious risks.

Ignoring the risks resulted in 29 fatalities and over 150 injuries.



Industry Awareness

Other documented events

Halifax Grain Elevator explosion Aug 2003

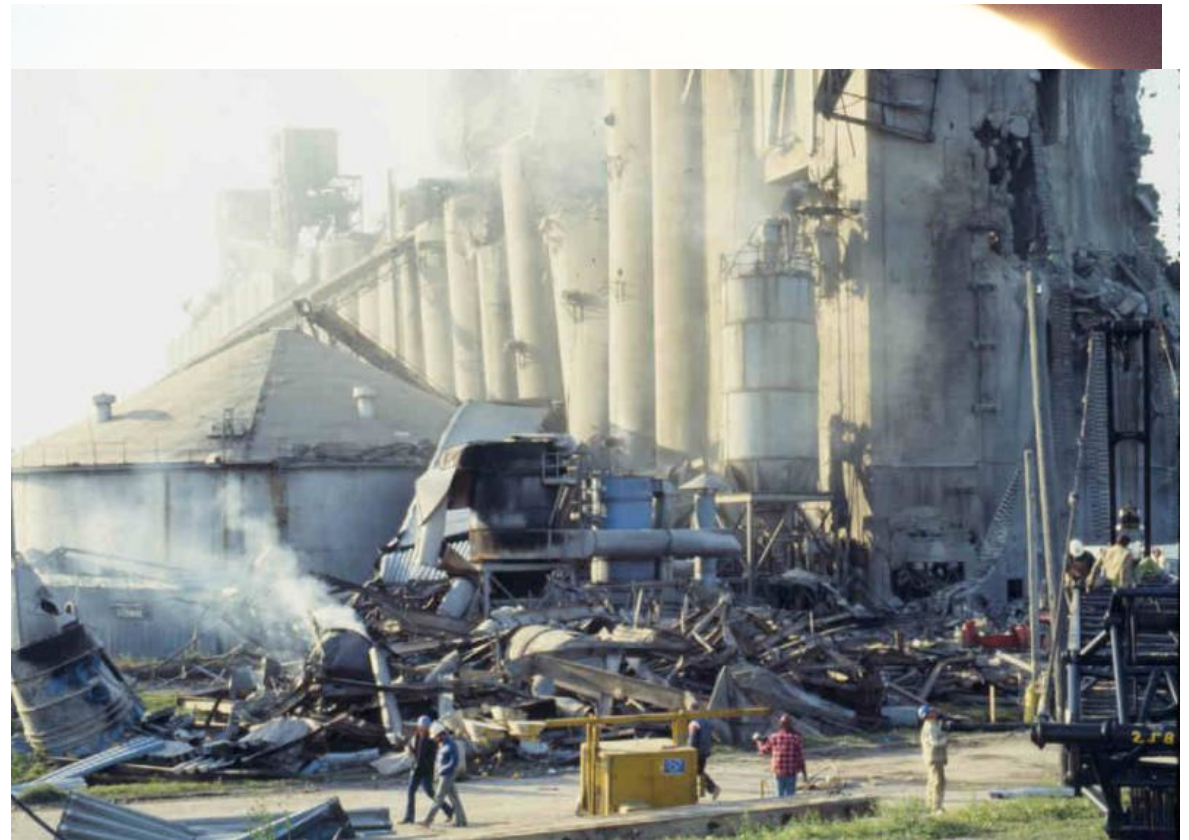
Westwego Grain Elevator explosion Dec 1977
36 dead

OSHA investigated 25 years of cases between 1976 and 2012

503 explosions

677 injuries

184 deaths



Industry Awareness

2003, Gunnedah NSW.

Saturday evening, 7:50 pm, pet food factory boiler fails, which exploded gas bottles, which exploded wheat dust.

Cost \$10 Million

35 Jobs lost.

30 homes damaged, some shifted from their foundations.

Damage radius 1.5km



Industry Awareness

August 2, 2014, 7:37 am

Kunshan, Jiangsu province.

Zhongrong Metal Production Company

Polishing metal (aluminium) wheels for GMH

265 employees present at time of event

44 died at scene, another 31 died in local hospital that day

71 died between August and Dec 2014.

114 registered as injured.

19 months later, more than 70 victims still being treated in local hospitals.

Final death toll over 200

Client had been warned the dangers but ignored risks.

3 executives were charged along with 11 government officials.

Sentences from 3 years to 7 ½ years.



Combustible Dust Awareness

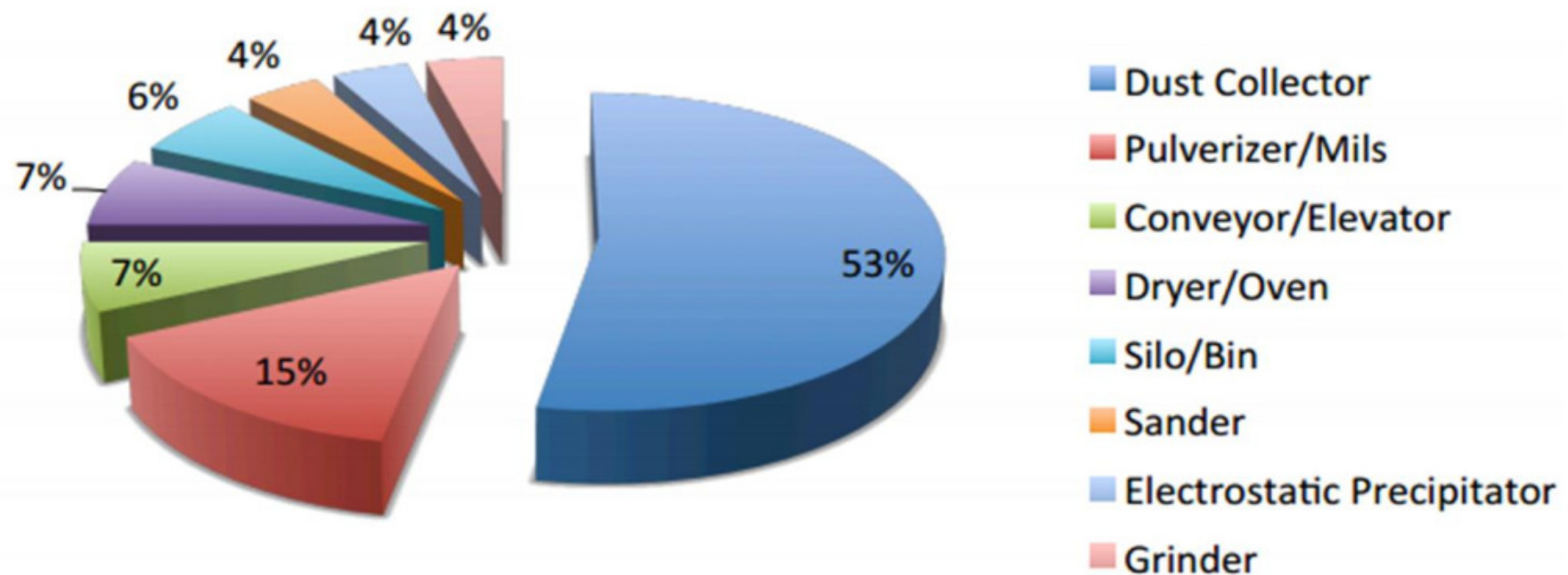


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Incidents location

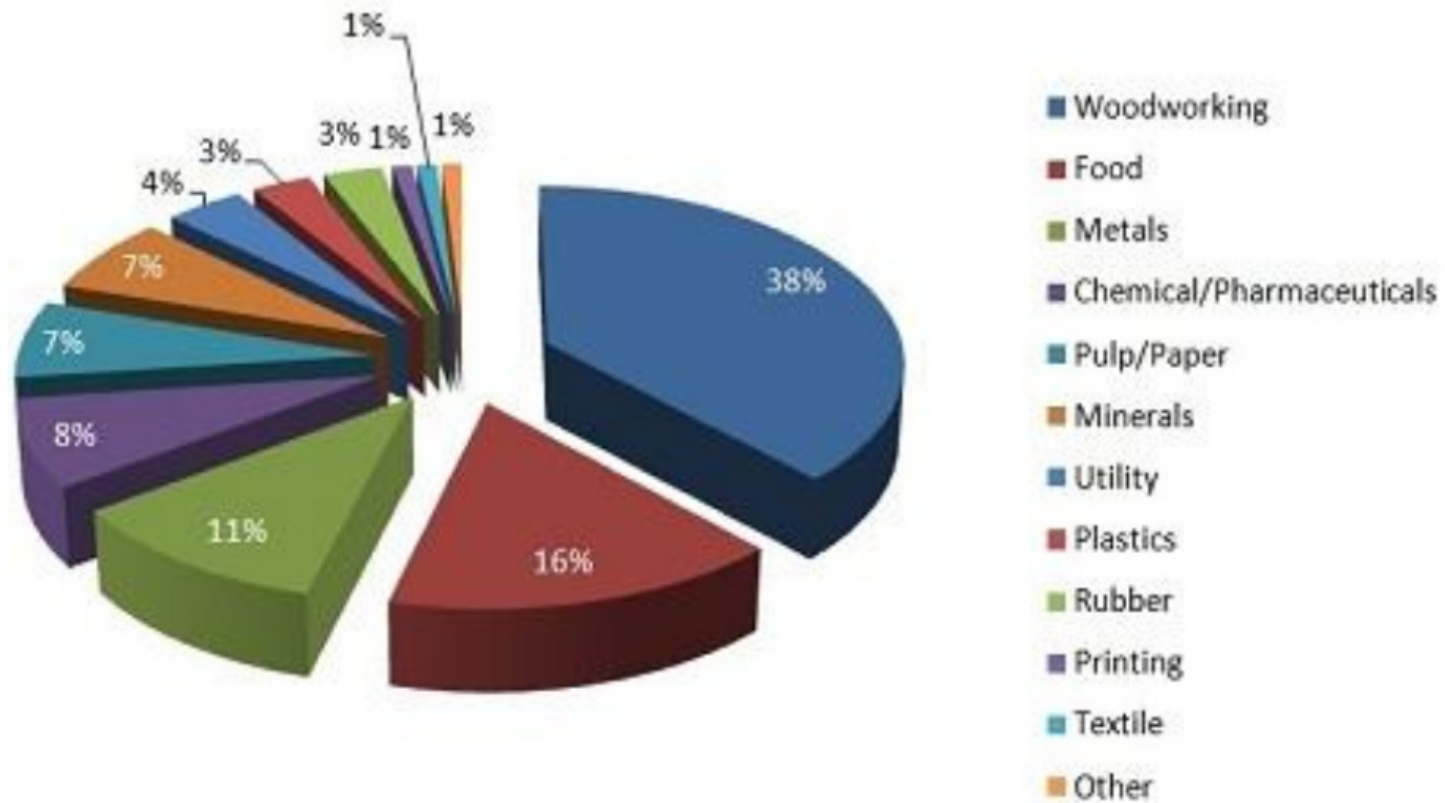
CSB investigated 281 further incidents between 1980 and 2005.

44 different states, various applications, various dusts.



Global loss by Industry

Wood, food and Metal are responsible for 65% of global reported events.



Constructing a protective system

Know the strength of the vessel

Calculate the area of explosion relief panel required

Allow for the explosion panel to discharge into a safe area

Fireball length is $10V^{1/3}$

For a 1m^3 vessel, fireball length is 10 mtr

For a 4m^3 vessel, fireball length is 15.87 mtr

Extract / Control / Isolate / Monitor

Extract the combustible dust from the workspace, reducing the chance of combustible dust cloud existing in workspace.

Control the potential fireball by placing the dust collector in a place where explosion panels can discharge to a safe area.

Isolate the potential risk by keeping any event away from workspace using inline isolation valve.

Monitor the activation of safety devices (explosion relief panel, isolation valve) – stop process.

Controlling a dust explosion

1. Build a vessel that can contain the increase in pressure.
Pressure vessel, flame and pressure will want to go 'somewhere'.
All vessels have a pressure limit (P_{red} value).
2. Let the pressure out, create a weak point – explosion relief vent.
Creates a control point by being able to predict where the fireball will exit the vessel.
Ensure that any explosion relief vent:
 - a) is tested and certified.
 - b) can discharge to a safe area.
 - c) correctly sized and installed in line with relevant standards (NFPA68, EN14491, VDI3673).
2. Remove the oxygen from the vessel.
Use an active system with a sensor that detects the start of an event and reacts in milliseconds.



Explosion relief venting

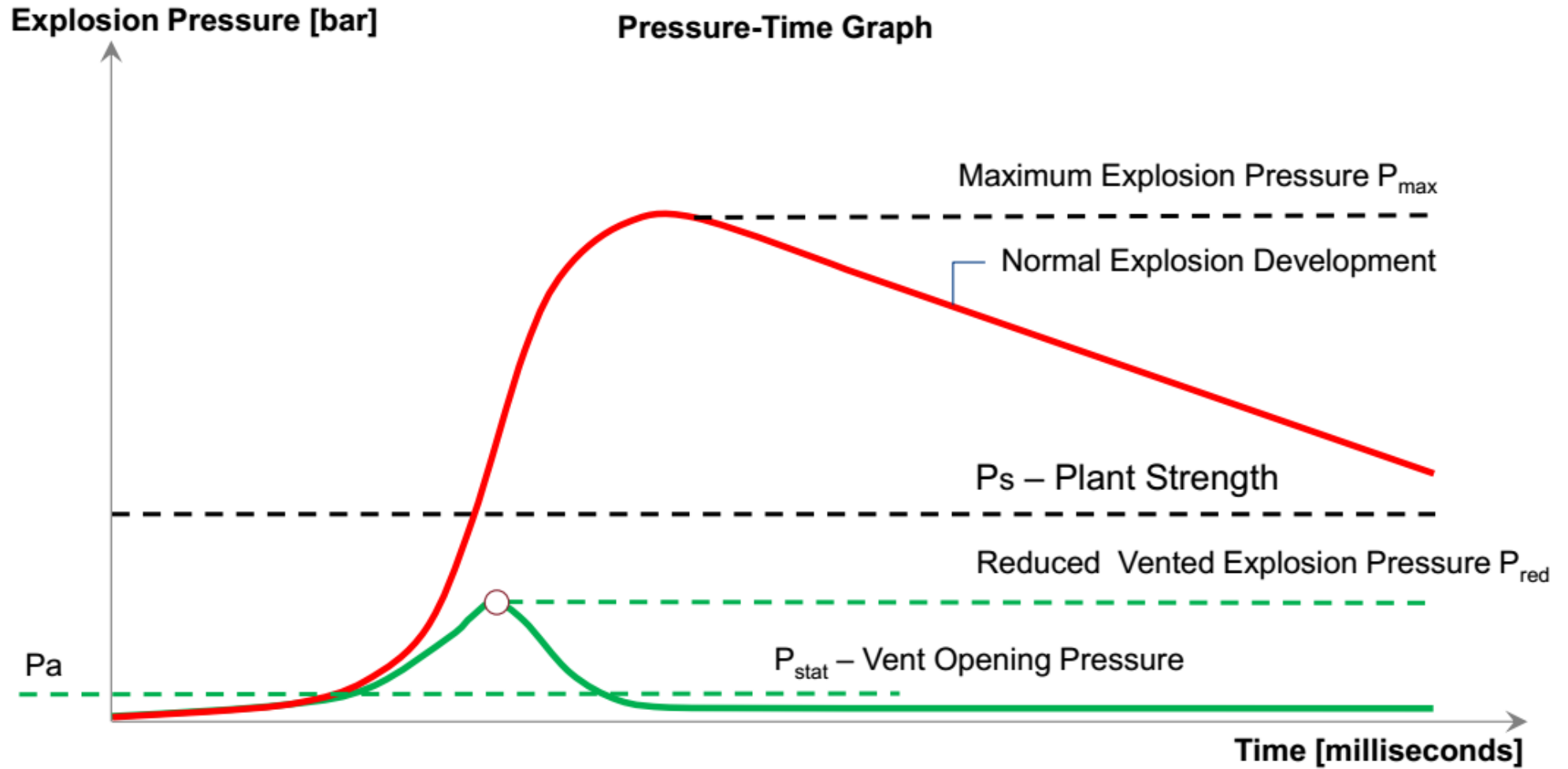


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Explosion relief venting



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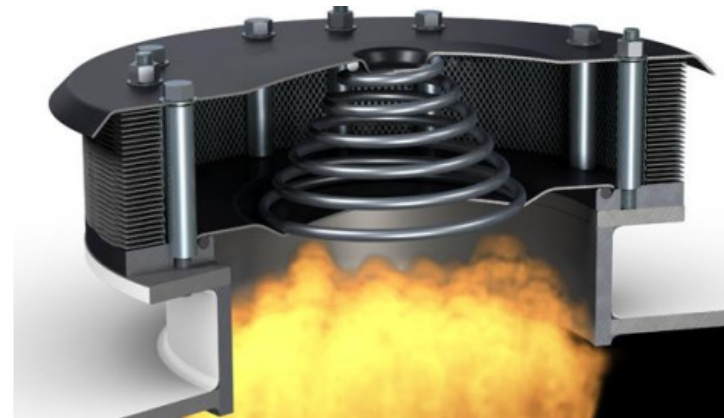


Locate explosion panels safely

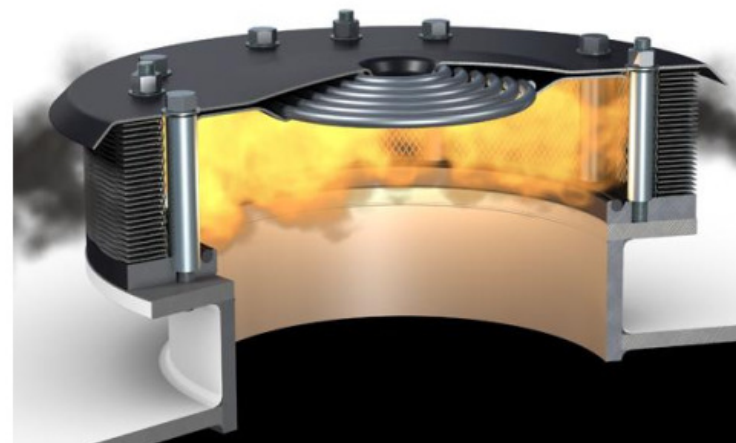


Explosion Venting

- System Design: real vent area vs. reduced explosion pressure, P_{red}
- Vent sizing calculated by:
 - EN14491 / VDI 3673
 - Activation pressure
 - K_{st} , P_{max}
 - Vessel shape
 - Vent efficiency

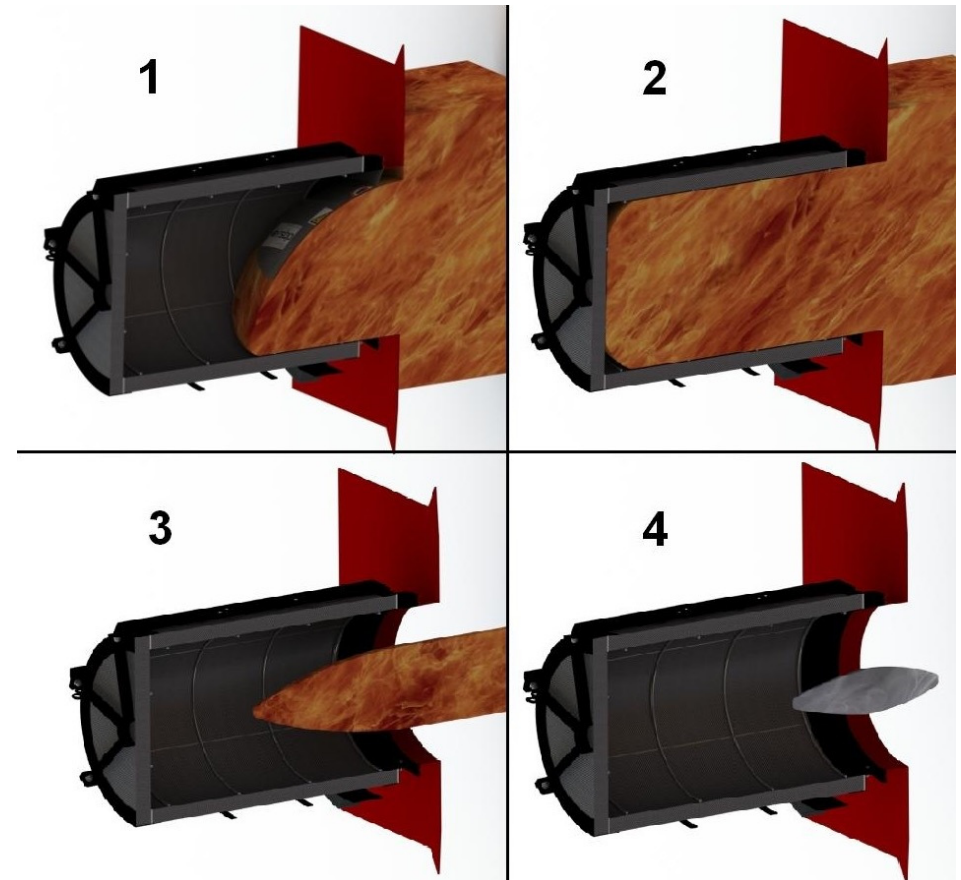


Valve closed



1. Pressure increase in vessel bursts explosion relief panel.
2. Flameless vent chamber fills with fireball and pressure.
3. Fireball energy is diffused by the outer mesh of the flameless vent.
4. Escaping heat and pressure are dramatically reduced by the outer mesh of the vent.

Exclusion zone reduced and fireball quenched





Explosion Ducting

1. Explosion Vent Ducting less than $\frac{1}{2}$ Hyd diam in length has no effect on explosion vent area calculations.
2. If relief panel ruptures, vent duct becomes part of vessel for calculation purposes.
As required explosion vent area is directly related to vessel volume, the adding of the vent duct may require increased vent area on main vessel.
3. Vent duct may cause pressure to roll back into dust collector from a secondary event.
4. Ensure construction strength of vent duct matches dust collector P_{red} .



Suppression System



Explosion Detectors



Control Unit



**Explosion Suppression
Extinguisher**

Protecting workspace

Even if a dust collector is fitted with correctly sized explosion relief venting, a flame front can be forced back up the inlet duct and travel back down the duct to the workspace.

An isolation valve in the dirty air duct can prevent the flame front from making it to the workspace:

- ensure the installation is correct, duct length and number of bends

- ensure ducting between the dust collector and isolation valve can handle the pressure

- isolation valves are rated to maximum K_{st} and P_{max} values

- tested and approved valves only

Passive valve

- Flap valve, poppet style, quick acting slide valve

Active valve

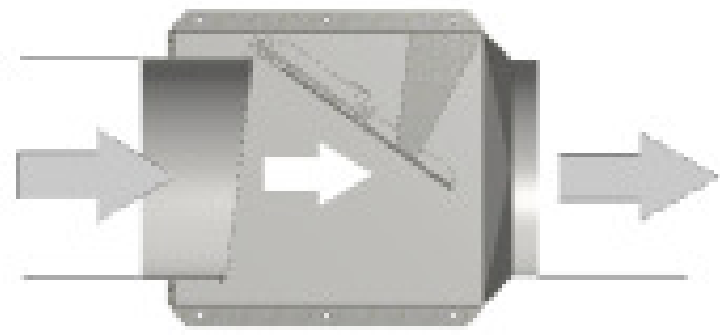
- Uses sensor to activate a valve driver

Standards EN16647, NFPA69

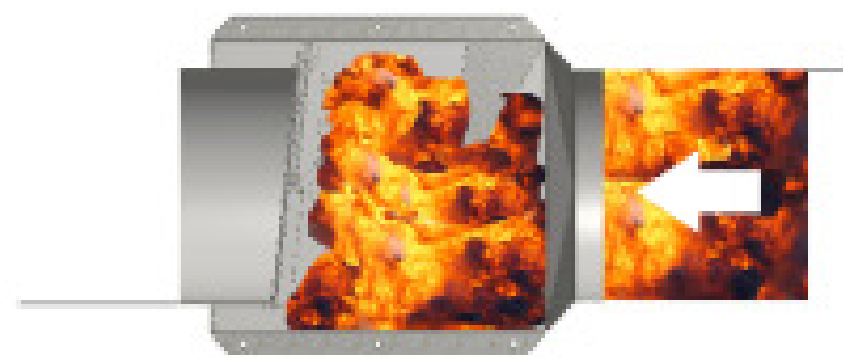
Limitations Metallic dusts, MESG, K_{st} and P_{max} values

Passive 'flap' valve

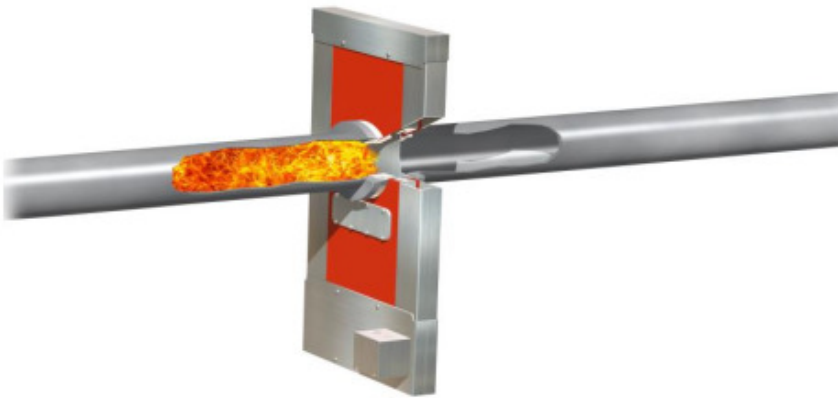
Suction direction



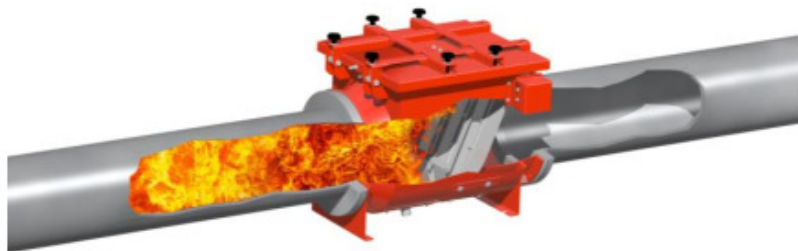
Explosion direction



Active Mechanical



Active Chemical



Passive Mechanical



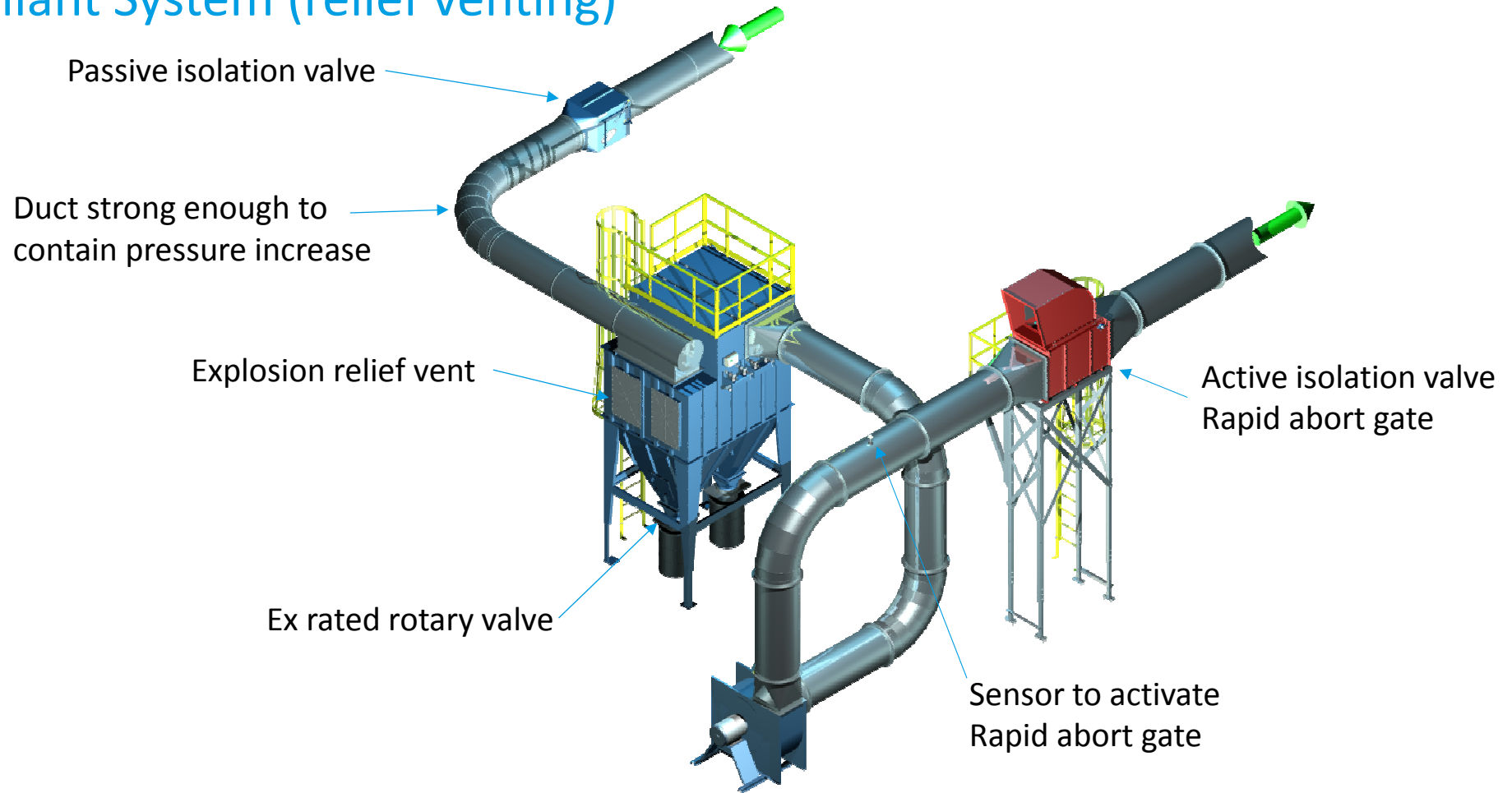
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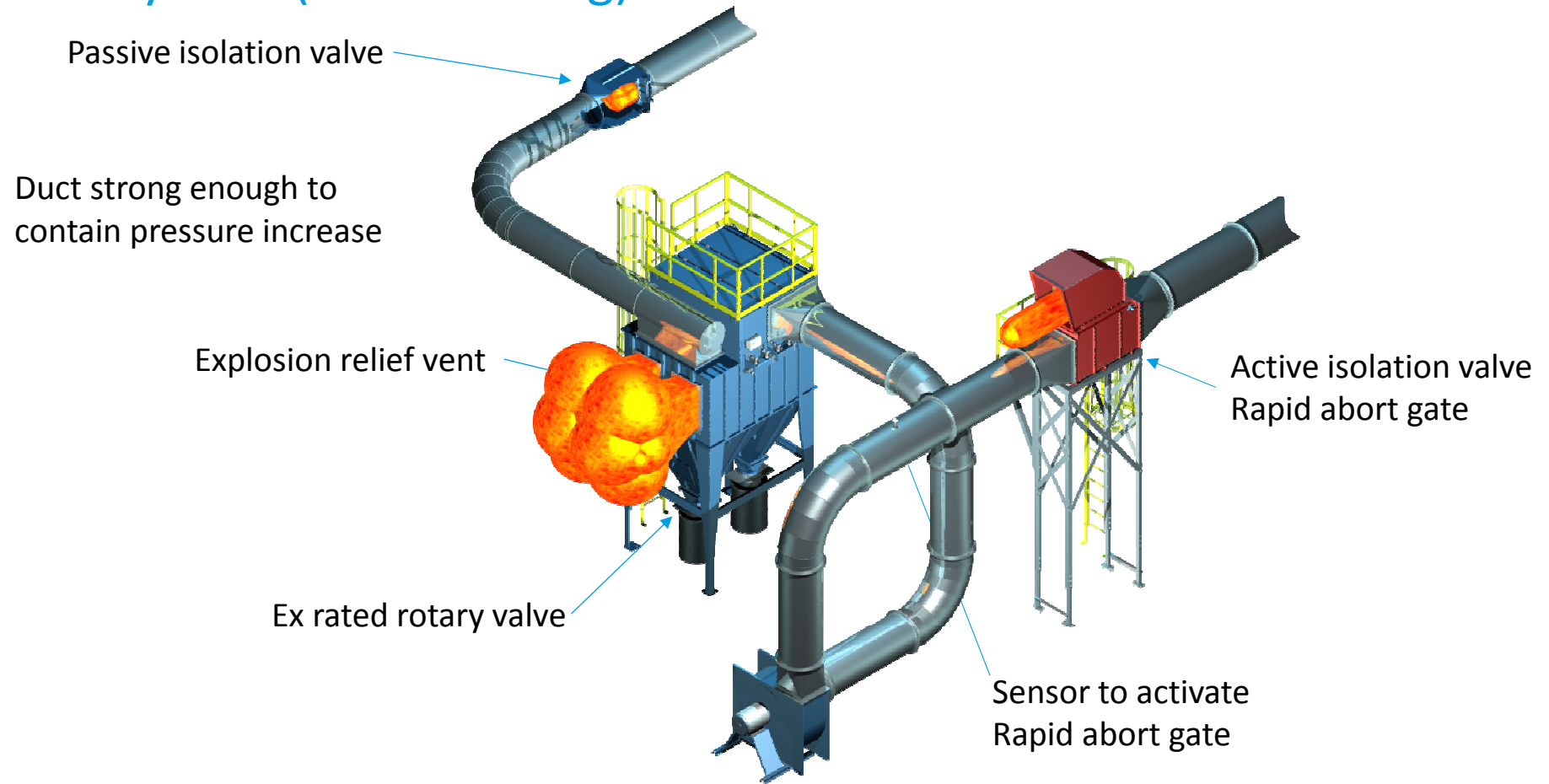
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Dust Explosion without the Explosion Isolation Flap

Compliant System (relief venting)



Compliant System (relief venting)



Duct Velocity – system design

Internal duct velocities should be such that dust cannot settle in the duct.

Correct duct velocities means the internals of the duct stay clear and design duct areas remain, maintaining speeds and design pressure losses.

Typical lean phase conveying of dust collection systems keep dust levels below LEL within the duct, combustible dust settling in the extraction duct increases the risk of de-flagration occurring in the ducting.

Correct duct design will maintain internal velocities

- reduces internal pressure losses
- ensures weight of ducting not overloading duct supports
- avoid the fireball finding more fuel in duct and creating a larger explosion within the duct.

Explosion in ducting can accelerate and exceed Mach 1 – detonation.



Housekeeping, Housekeeping, Housekeeping

Since dust explosions need fuel, they are most likely to occur in the dirty air chamber of the dust collector. Internal of dust collectors handling combustible dust are considered Zone 20 area.

Dust collectors can be fitted with control equipment to stop a fireball or direct a fireball to a 'safe place'.

Correct designed extraction will remove the dust from work space.

No dust extraction system captures 100% of dust, and spills can happen. Diligent housekeeping will reduce the chance of secondary dust explosions occurring as well as reducing potential zoned areas.



Secondary Explosion

Secondary events are typically in workplace where workers and other equipment are at risk.

Correct design protects life and equipment.

Correct zoning of areas can reduce ignition sources by specifying correct equipment to be protective.

Protect your workspace, protect your workers, protect your investment
Avoid a secondary event



Evaluate

- Know the dangers:
 - Does process or components increase risk?
 - Can improvements / changes reduce the risks?
- Test or Research
- Complete Dust Analysis Document or Combustible Dust Document.
- Evaluate the Worst Case:
 - 'If you complete a risk assessment, and someone gets hurt, your risk assessment was wrong'.
- Understand the Regulatory Requirements
- Use certified equipment and safety devices.

Standards

AS NZS 4745:2012 *Code of practice for handling combustible dusts*

AS NZS 3931 *Risk analysis of technological systems – Application guide*

AS NZS 31000 *Risk Management Standard*

NFPA 68 *Standard on Explosion Protection by De-flagration Venting* – review due early 2018

NFPA 69 *Standard on Explosion Prevention Systems*

NFPA 652 *Standard on the Fundamentals of Combustible Dust*

NFPA 654 *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*

EN 14491:2012 *Dust Explosion Venting Protective Systems*

EN 16447:2014 *Explosion Isolation Flap Valves*

EN 15089:2009 *Explosion Isolation Systems*

EN 14373:2005 *Explosion Suppression Systems*

EN 14034:2004 *Explosion characteristics of dust clouds*

VDI 3673 *Pressure release of dust explosions*

AS/NZS 60079 *Australian Hazard Area Standards*

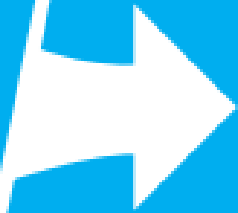
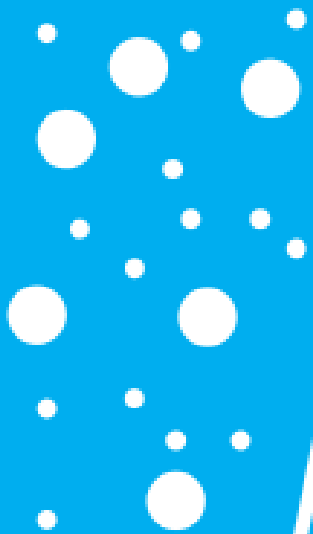
AS/NZS 80079 *Explosive atmospheres (sect 36, non electrical components)*

Steps to prevent dust explosions

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Capture



Contain



Clean



Capture dust before it escapes into a work area by using properly designed, installed, approved and maintained dust collection systems.

Contain dust within equipment, systems or rooms that are built and operated to safely handle combustible dust.

Clean work areas, overhead surfaces and concealed spaces frequently and thoroughly using safe housekeeping methods to remove combustible dusts not captured or contained.

We filter, clean and recycle for eco-efficiency in industrial environments.