Leading the way in hazardous area static control

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Earth-Rite® MULTIPOINT II
Controlling Dust Explosions caused by a Static Ignition

Dust explosions within hazardous area processing environments are not a new occurrence, and nor is static being a potential source of ignition. The earliest recorded dust explosion was at Giacomelli's Bakery in Turin, Italy in 1785 where flour dust generated during normal operations came into contact with a mounted lamp. Flour can become combustible if it's too dry and builds up a static charge. The bakery owner was recorded saying that the flour was the driest seen in the bakery that year. A dispersed cloud of flour originated when flour from the upper portion of the warehouse dropped to the confined warehouse below. The resulting explosion that followed injured both the worker shovelling flour into an open flame and a boy who fell from scaffolding, as a result of the flames blowing out windows onto the street. What this incident inadvertently demonstrated, apart from the violent and volatile nature of a dust explosion was an archetypal insight into the 'dust explosion pentagon'.

The five elements outlined are required to initiate a dust explosion. Unlike the fire triangle, a dust explosion requires two additional elements in the form of dispersion of dust particles in the right concentration and confinement of the dust cloud itself. Dispersed airborne dust burns more rapidly and confinement allows for pressure build up. With the additional two elements in place, all five are aligned, increasing the likelihood of an explosion. By definition combustible dust is any fine material that has the ability to catch fire and explode when dispersed with air. By their very nature dust explosions emit an energetic force creating powerful waves of pressure that damages and causes significant harm to plants and people. Those that are unfortunate enough to be a victim of a dust explosion will often be burned by the intense heat within the dust cloud, injured or even killed by falling structures.

Dust explosions cause injuries, destruction of property, and as history will testify to – unfortunately fatalities. The US Chemical Safety Board (CSB) report conducted in 2006 identified 281 combustible dust incidents between 1980 and 2005 that killed 119 workers with injuries sustained to 718 others, along with several damaged facilities. *Source: "Dust Explosion Investigation in Turkey", Mercan Z. Burcu, (2016)*

In the UK, the Health and Safety Executive recorded 303 dust explosions over a nine-year period and German records demonstrate 426 similar incidents over a 20 year period. Unfortunately tragic incidents like these continue to cause significant business interruptions and loss of lives.

Over half of dust explosion incidents can be attributed to one of these four industry sectors: food products, wood products, chemical and metal. The average dollar loss per explosion incident in a typical year is $3.4m.

Dust is a hazardous by-product in many industries, from those handling powders to companies engaged in more sophisticated manufacturing processes. Dust explosions can occur in any industry handling combustible dusts, not exclusive but including:

- Coal
- Wood
- Waste recycling (paper)
- Agriculture
- Chemical
- Metal processing

The National Fire Protection Association (NFPA) 654: Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids defines dust as "A combustible particulate solid that presents a fire of deflagration hazard when suspended in air of some other oxidizing medium over a range of concentrations, regardless of particle size or shape". Many organisations are uninformed and unaware that their processes can produce an atmosphere which can be explosive, and as a result dust can be produced as a seemingly innocuous consequence of their usual manufacturing process.

There are a number of primary ignition sources for a dust explosion:

1. Electrostatic ignition
2. Friction
3. Electrical arcing
4. Hot surfaces
5. Fire
6. Self-ignition

Particle Size

Dust explosions occur when a dispersed combustible material is present in high enough concentration; therefore an explosion hazard exists when dusts are produced, stored or processed and these materials are airborne. When the product being processed is considered combustible and has an appreciable portion of fine material, the potential for having an explosion increases dramatically. Fine powders with low minimum ignition energies (MIE) will regularly reach the minimum explosive concentration (MEC) along conveying systems and may be at risk of combustion by several sources of ignition. One such ignition source is electrostatic discharge.

The minimum ignition energy required to ignite any given powder (MIE) depends on the fineness of a particle, with the lowest values tending to relate to very fine particles. If the MIE is above 10 millijoules, and there are no flammable gases and vapours presents, special measures to minimise static electricity are usually not necessary, however precautions could still be necessary with conductive plant equipment capable of storing high levels of static charge, to minimise electric shock risks for operators.

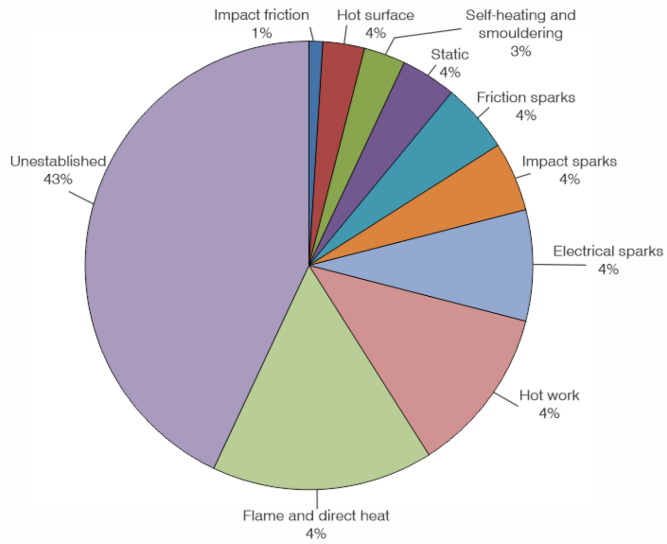


Fig. 1 - Causes of dust explosions around the world from 1785 to 2012 Source: Dynamic Risk Analysis of Dust Explosions", Yuan Zhi, (2015)

In the chemical and pharmaceutical industries the typical energies required for ignition can be relatively low (especially in flammable dust/vapour hybrid atmospheres), whilst in the food industry, MIEs are usually somewhat higher.

The ease of ignition and severity of combustible dust explosions are typically influenced by particle size. Finer particles are more explosive because they have large surface areas relative to their weight, allowing them to rapidly react with oxygen when dispersed in air and ignite.

In NFPA 654, dusts are defined as 420 microns (μm) or smaller. In perspective, the particle size of table salt is around 100 microns.

Powder		
	Zinc	200
	Wheat Flour	50
	Polyethylene	30
	Sugar	30
	Magnesium	20
	Sulphur	15
	Aluminium	10
	Epoxy Resin	9
	Zirconium	5

Minimum Ignition Energy of explosive / flammable materials (Source: IChemE)

Material	Size (Microns)
Talcum powder, red blood cells fine silt, cocoa	5 to 10
Pollen, milled flour, coarse silt	44 to 74
Table salt	105 to 149
Cornstarch from the Port Wentworth facility storage silo	10
Powdered sugar product from the Port Wentworth facility	23
Granulated sugar product from the Port Wentworth facility1	286

Note 1: Sample first passed through 500 um sieve Source: Investigation Report. Sugar Dust Explosion and Fire. U.S. Chemical Safety and Hazard Investigation Board. (2009)

Fig. 2 - Particle size of some common combustible and non-combustible materials

The Dangers of Primary and Secondary Explosions

One of the main dangers of a dust explosion is when combustible dusts ignite it causes a chain reaction. Dust explosions create their own self-sustaining domino effect which continues as long as there is fuel. A secondary explosion occurs when dust accumulated on floors or other surfaces is lifted into the air and ignited by the primary explosion. This occurs from the resulting primary explosion, liberating dust from surrounding surfaces (beams and ledges) causing them to be dispersed and suspended in air. The secondary explosion propagates from the resulting dust cloud. With multiple explosions and the structural integrity of the facility already compromised, the results can be catastrophic.

There is often both a primary and secondary explosion allowing for a transition from fire to multiple explosions and vice versa. A primary explosion usually occurs inside the process vessel such as sieves, dryers, mixers, conveying systems and silos. It is within this environment that five elements of the dust explosion pentagon are met. The resulting impact of the first usually ignites the second. Unburned fuel from the primary explosion is ejected by the blast outside the enclosure causing dust to become airborne where it is susceptible to ignition and is able to create a secondary explosion. A secondary explosion can be more destructive than the primary due to the increased concentration of dispersed combustible dust and greater ignition source. The resulting shockwave of a first explosion will damage and often rupture the self-contained vessel where the initial blast manifested itself from, allowing the explosion to propagate through the plant.

Fig 3. - A confined and vented dust explosion courtesy of IEP Technologies

Imperial Sugar – Sugar Dust Explosion and Fire
Source: Investigation Report. Sugar Dust Explosion and Fire. U.S. Chemical Safety and Hazard Investigation Board. (2009)

The Imperial Sugar explosion at their sugar refinery in Port Wentworth, Georgia, US in 2008 claimed the lives of 14 workers and critically injured 36 others. A year before the blast in 2007 the company had produced 1.3 million tonnes of sugar, making it one of the largest sugar refineries in the United States. A series of violent sugar dust explosions obliterated the site, with 12% of the 160 acre facility completely destroyed. All 14 casualties of the blast in a CSB investigation were "most likely the result of the secondary explosions and fires". Prior to this destructive incident, the Port Wentworth facility had operated for more than 80 years without experiencing a devastating dust explosion; however there was a history of long-standing problems of sugar dust and spilled sugar in the packing buildings and silo penthouse from 1970 – 2007. It is likely that although conditions suggested that an incident should occur, the sugar dust never accumulated to levels above the minimum explosible concentration (MEC). It was just luck and fortune that spilled sugar dust never reached levels where the concentration was high enough for an explosion to propagate through a plant. Internal correspondence documented this as "knee deep" levels in some areas. Two months prior to the incident, an internal inspection showed that tonnes of sugar were accumulating on the floor of the facility. This provided much of the fuel for the secondary explosions.

Cause and Aftermath

Granulated sugar was stored in three 100ft tall silos and then conveyed into packing buildings where it was packaged for distribution. The primary dust explosion occurred inside the enclosed steel conveyor belt used to transport granulated sugar under silos 1 and 2. Airborne combustible sugar dust accumulated above the minimum explosible concentration inside the unit, this triggered huge secondary explosions and fire throughout the packing buildings. In the aftermath of the incident the CSB reported that for many years granulated sugar on these conveyors was exposed to possible contamination from debris that could fall into the sugar. As a result, to mitigate against the issue, Imperial Sugar added the installation of a stainless steel frame to enclose each belt assembly to protect granulated sugar from debris and contamination. These panels were able to be removed for clean-down operations but were not equipped with a dust removal or explosion venting system and essentially confined the sugar which harnessed accumulation of product. Sugar dust accumulated to an explosive concentration above the MEC within the conveyor, and with an overheated bearing the likely ignition source, an explosion occurred. In addition, multiple potential dust ignition sources were identified inside the enclosure.

Imperial Sugar CEO, John C Sheptor stated "accumulated sugar likely acted like gun powder" and called combustible dust "a silent risk that needs to be addressed". It will come as no surprise that in 'The Dust Hazard in Industry' publication, Gibbs concluded that "Sugar, dextrin, starch and cocoa are the most dangerous, sugar exceptionally so. Sugar ignites when projected as a cloud against a surface heated to below red heat, and when ignition has taken place, the flame travels throughout the dust-cloud with great rapidity". In wake of the explosion, The Occupational Safety and Health Administration (OSHA) cited Imperial Sugar for 108 instances of "wilful violations related to the combustible dust hazard, including the failure to clean dust and not using appropriate equipment or safeguards where combustible dust is present". At the time the proposed fine of $8.7 million was the third largest in history following the sugar refinery explosion. This incident highlights the devastating effects that any dust explosion can have on people, businesses, communities and the economic climate.

Mitigating Static Discharge in Powder Processing Operations

In manufacturing and handling process industries in flammable and combustible atmospheres, the threat of static electricity is ever present. There are certain types of dust handling plant equipment in which static electricity is readily generated. These include mills, conveyor belts and pneumatic conveying systems. In potentially explosive atmospheres, the amount of energy contained in spark discharges from plant, equipment and even people may be sufficient to ignite many fine dusts produced during handling loose solids such as powder, granules, pellets and flakes. Electrostatic charging of isolated plant equipment or materials is likely when moving dusty materials in quantity. It is fundamentally critical to take necessary precautions to mitigate discharges that are powerful enough to cause ignition of a dust cloud. All potential sources of internal and external static discharges from process equipment situated in zoned and classified areas must be accounted for and managed in the appropriate way. If they are not sufficiently bonded and grounded, isolated components in conveying and dust collection systems are capable of holding large amounts of static electricity. Isolated components usually result from design oversight or after maintenance teams reassemble fittings without re-establishing static bonding connections. Pipes, valves, blowers, hoppers and other components engaged in powder transfer processes can be isolated from each other due to the insulating properties of parts like rubber gaskets or through general wear and tear. The most secure means of mitigating charge build-up is to bond and ground components to a reliable verified earth.

Although generation and accumulation of static electricity is invisible and discrete, it holds a very real possibility of a potential discharge igniting combustible atmospheres. To mitigate electrostatic discharges igniting combustible dusts, companies should risk assess their processes and equipment to ensure any potential sources of ignition are identified and managed correctly. Each explosion threat presents its own unique challenge. The variables involved, from the combustible material, ignition source, process vessel, operational procedures and environmental conditions all impact on the severity of risk. There are a number of practical solutions to consider in order to safeguard the plant, people and processes, such as grounding/bonding, explosion venting, suppression, isolation amongst others.

Static grounding and bonding systems look to mitigate static as an ignition source before combustible material is allowed to ignite. In safety terms in relation to the dust fire pentagon, removing the ignition source mitigates one of the key elements required for an ignition. Of course it is not always possible to completely mitigate the risk of dust related explosions but despite the potential for extensive losses; such as human life, damage to facilities and downtime in production, there are measures that must be taken and history has shown this has not always been the case.

The nature of a powder processing operation means that the generation of static electricity is to be expected in all parts of the system because of the movement of the particles through equipment. Therefore, regular maintenance is required to stop material from clogging up the machinery. Regular disassembly for cleaning and maintenance can result in bonding connections being missed or not made correctly when the equipment is reassembled. Vibration and corrosion may also degrade assembly connections so it is imperative to ensure that no parts in the assembly become isolated from a true earth ground. The most effective way of ensuring complex equipment used in powder processing operations cannot accumulate static electricity is to provide a dedicated static grounding solution such as Newson Gale's MULTIPOINT II system that is capable of monitoring the ground connection to components at risk of isolation. Such a solution is able to halt the flow of product and alert personnel to a potential hazard should a component lose its connection to ground. This is especially important if the ground connection point to the equipment is not readily visible or isn't easily accessible for example, grounding clips. Powder processing equipment presents more of a challenge compared to standard applications as there are metal parts that can make up larger assemblies that can be electrically isolated from each other. The risk of removable sections becoming isolated conductors will occur if:

1. Each section does not have a sufficiently low path to ground to safely dissipate charge.

2. The correct reassembly of equipment after cleaning between operations and regular examination of bonding straps between the metal pipework and duct sections by plant personnel is not routinely carried out.

In Summary

Areas for consideration to mitigate dust cloud accumulation:

1. Maintain a plant in a leak-tight condition (damaged seals, loose bolts)

2. Reduce labour involved in cleaning by designing plants within the minimum number of horizontal ledges where dust can settle

3. Electrical plant equipment may be at risk of overheating if dust deposits settle

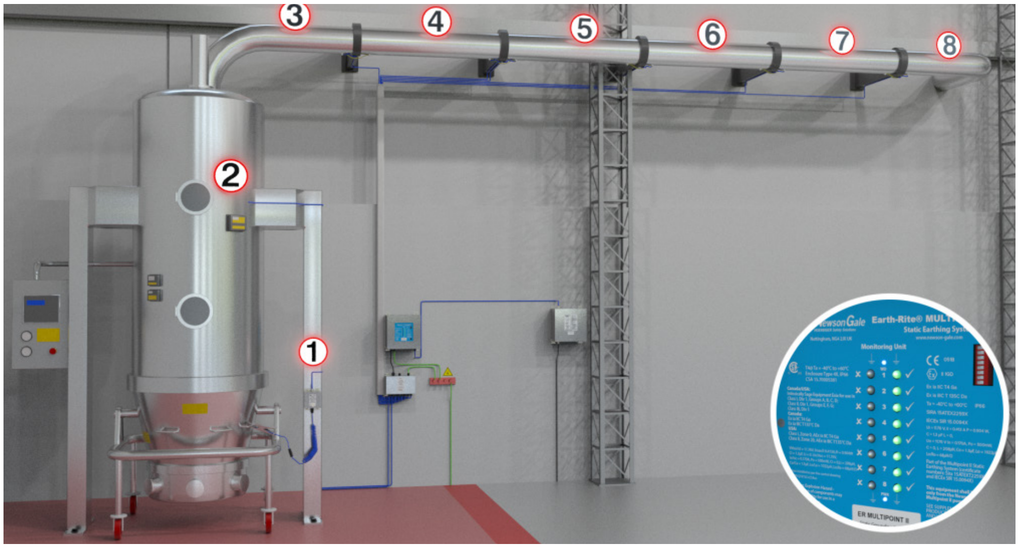
4. Introduce technical measures to safeguard against an explosion

One of the most important mitigation measures is maintaining a clean working environment. If dust deposits are allowed to accumulate, they can provide fuel for a secondary explosion.

To mitigate against uncontrolled static discharges posing a fire and explosion hazard in powder processing operations, a thorough static audit conducted by qualified personnel should be carried out.

For situations where potentially isolated components are identified dedicated grounding equipment should be installed to monitor and control the release of static electricity, thereby removing a primary source of ignition in combustible dust atmospheres.

Given such hazards exist within industry today; good housekeeping, strict maintenance practices, and ignition risk identification and mitigation are paramount in mitigating a dust explosion.



This example demonstrates the Earth-Rite MULTIPOINT II system grounding and monitoring parts of the conveying system which could be at risk of isolation.

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