APPLICATION REPORT

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Managing explosive dust risk in sugar handling

Dust explosions in the food industry have caused serious industrial accidents resulting in multiple fatalities and severe structural damage. Explosible dusts in the food industry include flour, custard powder, instant coffee, sugar, dried milk, potato powder and soup powder.

Generally, all powders except inorganic minerals should be assumed to be explosible, unless testing shows this not to be the case.

Dust is defined as powders with particles less than about 500 micrometres in diameter, but finer dust will present a much greater hazard than coarse particles by virtue of the larger total surface area of all the particles.

To support combustion, the dust must also consist of very small particles with a high surface area to volume ratio, thereby making the collective or combined surface area of all the particles very large in comparison to a dust of larger particles.

In testing it is found that approximately 70% of the powders handled by industry can form combustible dust. A dust explosion can happen when a flame propagates through combustible particles that have dispersed in the air and formed a flammable dust cloud. Whether an explosion happens or not depends on the supply of oxygen to the fire and the concentration of the fuel. If the concentration of the oxygen or the fuel is too high or low, then an explosion is very unlikely to occur.

Industrial dust explosions require an ignition source, these can include: mechanically generated impact or friction sparks, electrical sparks, high surface temperatures, electrostatic discharge, ingress of foreign materials between moving contact surfaces and open flames.

A dust explosion can only ever occur if ALL of the following criteria are met:

- Combustible dust
- Dust capable of becoming airborne
- Particle size distribution of dust capable of flame propagation
- Concentration of dust within the explosion limits
- Ignition source must be present
- Atmosphere must contain sufficient oxygen

Eliminating just one of these requirements would make a dust explosion very unlikely.

For the purposes of the various regulations, an explosive atmosphere is a mixture with air, under atmospheric conditions, of flammable gases, vapours, mists or dusts in which, after ignition has occurred, combustion spreads to the entire unburned mixture.

A potentially explosive atmosphere is an atmosphere which could become explosive due to local and operational conditions.

Imperial Sugar Case Study

On 7th February, 2008, a huge explosion and fire occurred at the Imperial Sugar refinery in Savannah, USA, causing 14 deaths and injuring 38 others, including 14 with serious and life-threatening burns. The explosion was fuelled by massive accumulations of combustible sugar dust throughout the packaging building.

An investigation was carried out by the U.S. Chemical Safety and Hazard Investigation Board which in its final report proposed a series of safety recommendations. Imperial Sugar was urged to comply with National Fire Protection Association (NFPA) recommended practices for preventing dust fires and explosions.

Imperial Sugar subsequently embarked on a $200 million-plus reconstruction project to rebuild the Port Wentworth, USA sugar refinery. The project team needed a solution to safely convey crystal sugar at high capacities over long distances with minimum product degradation occurring during transportation.

Pneumatic conveying pipeline at Imperial Sugar

Imperial Sugar engineers visited various plants, not necessarily just sugar refineries, to look at conveying systems and get feedback from people who had worked with pneumatic conveying over a period of years. The company also talked to different equipment manufacturers during its investigation to assess how each company would approach its process challenges. Ultimately, Imperial Sugar selected Mac Process, a member of the Schenck Process Group, to design and install continuous dense phase pneumatic conveying systems for the reconstructed plant because they demonstrated a complete understanding of its requirements.

“Mac Process was very enthusiastic about the opportunity to work on our project and developing safe solutions for our unique challenges,” said Brian Harrison, vice president, technology at Imperial Sugar. “We were betting 100% of our material handling on the system. Because it would handle all of the production of this facility, we wanted somebody who would be comprehensive in their approach to providing engineering solutions, and we thought Mac Process brought that to the table from the beginning.”

Together with its sister company in the UK, (Clyde Process) Mac Process designed and installed 15 continuous dense phase systems at the refinery with rates at 68 tonnes per hour over total distances of up to 140 metres. These were complete systems with modularised dense phase vessels, Dome Valves®, airlocks and dust collectors. In addition, Mac Process designed safety protection systems by applying the hierarchy of explosion protection principles. Pressure vessels were built for explosion containment. Conveying lines and ancillary equipment are fitted with either explosion venting or explosion suppression to minimise the chance of an event being propagated through interconnecting systems.

Imperial Sugar has been extremely pleased with the support throughout the project, according to Mr Harrison. “As we’ve gone through the different phases of the start-up, the checkout procedures were first class,” he said. “Systems started with very few faults. Any issues we did have were minor, and Mac Process always had the right people on-site to address those.”

Safe handling of combustible dusts - Equipment & Systems

Sugar cane refineries and sugar beet factories use mechanical handling equipment, such as belt & bucket elevators, belt conveyors and screw conveyors to transport crystal sugar to conditioning silos and then to packaging plant because they are the conventional solution, mainly due to their relatively low power requirements. These types of traditional mechanical conveying systems are large, with considerable internal volumes and external surface areas, they have a tendency to over-carry material and leak out dust.

Due to the large number of moving and wearing parts then the possibility of mechanically generated impact or friction sparks increases. Additionally as the plant ages over time then regular maintenance becomes more onerous and the cost of upkeep increases. The long-term effect of this high maintenance and labour intensive housekeeping is to eventually accept areas of the plant that are dust-laden or contain large amounts of spillage. Of course, this creates a potentially explosive atmosphere and sets some of the conditions for an atmosphere which could become explosive.

Clyde Process Twin Dense Phase CD Pumps

What can be done to prevent or mitigate the effect of a dust explosion?

The design and operation of safe processing facilities must fulfil legislation such as the European ATEX directives or American NFPA standards. The manufacturer can design to mitigate the effects of an explosion if the formation of explosive atmospheres cannot be prevented and/or the ignition sources cannot be prevented however some basic safety principles applied to the workplace itself are an essential starting point.

Hierarchy of explosion safety principles

The first consideration must be to eliminate the risk. Elimination (Prevention) techniques can be achieved in two ways:

1. Elimination of the explosive atmosphere - Reduce the level of product processed to below the lower explosive limit (LEL) or process the product with inert material.

2. Elimination or avoidance of ignition sources by reducing mechanical and electrical sources of ignition, prevent explosion propagation.

Eliminate dusts and spillages in the workplace with centralised vacuum cleaning system

Elimination of the explosive atmosphere - Clean up the dust

A dust collection system alone cannot keep a plant clean and dust free, so housekeeping must be part of any good dust collection plan or design. Manual cleaning (shovelling and sweeping) is very labour intensive and can often create additional airborne dust. Central vacuum cleaning systems are an effective way to clean industrial environments that will minimise re-contamination and the labour cost of housekeeping.

Central vacuum cleaning systems can be tailored to the particular needs of a variety of plants and processes. Installed systems can be designed for multiple users in large, mutli-storey plants or portable, single-user systems can be moved throughout the plant by cart or forklift. A central vacuum cleaning system can efficiently handle routine floor and wall cleaning of very light dust or deal with large spills that would otherwise require heavy lifting or large machinery. A good understanding of needs is critical to the performance of the system. Forethought into plant integration and the types of materials the system will handle, whether dust or bulk material, will determine the type of vacuum producer used, line size, separator and discharge device selected.

Grounding of all components to prevent the build-up of a static charge is also required. This includes grounding media, flexible vacuum hoses and tools.

Considering labour costs and the risk induced by spilled product and airborne dust, a well-designed central vacuum cleaning system can pay for itself in a short period and is a good investment for any sugar processing facility.

Elimination of the explosive atmosphere - Remove the Dust at Source

Regardless of the conveying method used, it is important to employ dust collection and filtration systems that are properly designed, resist moisture, use proper components and are maintenance friendly. Dust collectors can be integrated into the process (such as silo bin vents and milling dust collectors) or be ancillary units (such as bucket elevator aspirators and load out spout displacement air collectors.)

Dust collection systems handling sugar must account for critical moisture concerns in the environment. Certain production processes may create or release moisture, for example, milling of sugar can free inherent moisture in the crystal structure to the air stream. Similarly, ambient moisture can be drawn in from the environment. In both cases, insulation may be required on certain duct spans to prevent the condensation of water inside the duct when large temperature swings and moisture are present.

Cylindrical dust filtration units are ideally suited to the handling of sugar dust as they are far more hygienic than square type units simply due the fact that they do not have the internal corners as do box type filter constructions. The internal corners of box type dust filters create perfect hidden areas where sugar dust can gather, compact and eventually lead to hygiene issues if not cleaned out regularly, usually by someone having to enter the dirty filter chamber and manually chip the build ups away.

A small leak in ductwork may draw moisture into the system if located outdoors. Moisture can also enter the system via condensation in the compressed air supply, this usually affects the filter media directly especially when contaminated high pressure compressed air is used to clean the filtration media. A way around the moisture (and also bacterial contamination) issues associated with using high pressure plant air, is to use a medium pressure cleaned style filter with a Roots type positive displacement blower providing the cleaning air. Dust filters cleaned by this low pressure method are as efficient if not better at cleaning long filter socks or cartridges plus they are also much more economical to operate.

Elimination or avoidance of ignition sources - Safe Handling

Dense phase pneumatic conveying of both crystal and agglomerated sugars has been applied for many years by food and drink industry manufacturers. Soft drink mix producers, for example, utilise dense phase pneumatic conveying (rather than mechanical conveyors or lean phase modes of pneumatic conveying) to convey sugars into a dissolution process. This type of gentle slow velocity conveying protects the integrity of the sugar particle thereby avoiding any degradation of the functional sweetness and dissolution properties that are necessary for high quality consistent drink production.

Sugar factories and refineries are now also finding they can utilise this pneumatic conveying method, to not only increase safety and cleanliness in their facilities, but also ensure that their crystal sugar is handled in the most efficient manner.

Pneumatic conveying requires more power but has far fewer moving parts than mechanical conveyors. The enclosed pipelines used to transport the sugar protect it from contamination and virtually eliminate the breakdown of the sugar crystals into smaller particles, that become airborne dust particles and so become a potential dust explosion hazard.

The basic concept of pneumatic conveying relies on using a gas flow (usually air, but can also utilise inert gases such as nitrogen) to move material along a pipe line by creating a pressure differential. The bulk solid is transported with the gas flow as the gas moves towards the area of lower pressure. This concept makes the integration of air filtration equipment very simple as all material being conveyed down the pipe line is received in a vessel of some kind and the solid is separated from the air stream, so making it possible to also separate any dust present before passing onto the next stage of the process, be it conditioning silos or packing plant.

Today's competitive contract supplier environment means that sugar producers have responsibility for product quality and functionality all the way into a customers factory, so selecting the right bulk handling method, including bulk tanker unloading, is especially important.

Continuous dense phase conveying therefore presents several advantages for the sugar producer and processor:

- Totally enclosed so relatively clean & more environmentally acceptable
- More hygienic
- Satisfy all ATEX/NFPA requirements
- Extremely flexible in terms of re-routing and plant expansion
- Relatively economical to install
- Simple and economical to maintain
- Safer to operate and maintain
- Quieter (air mover can even be located remotely)

Safe handling of combustible dusts - Protective systems

If Elimination (Prevention) techniques cannot reduce the risk to a safe level then protective techniques will need to be applied. Protective techniques should be considered in the following order.

1. Explosion Isolation
2. Removal of Personnel (when explosion risk is present)
3. Explosion Relief Venting
4. Flameless Venting
5. Explosion Containment
6. Explosion Suppression

Explosion Isolation may need to be considered first as other areas of the process may be dependent upon avoidance of ignition sources such as explosion propagation. Selection of devices and their correct use must be ascertained.

Removal of Personnel when explosion risk is present. This may involve locating specific items of process in a remote location, establishing an "exclusion zone".

Eliminate dusts inside the process equipment with Air filtration

Explosion Relief Venting to a safe place, that is, not a manned area and one that avoids the risk of secondary explosions in the working area. The most common form of explosion protection to date is the explosion vent as it is both effective and economical.

An explosion vent is placed on an enclosure, protecting it from over-pressurization during an event. Venting is a passive method of protection in that it does nothing to prevent, detect or control deflagration; but rather directs the result to a presumably safe area of the plant.

In the event of deflagration, some means of isolation—such as airlocks, fast acting gates or chemical blocking—must be employed to prevent propagation of the explosion through connecting ductwork to other parts of the system. Vented enclosures located indoors must also be placed adjacent to an exterior wall so that the deflagration can be safely and efficiently ducted outdoors.

Flameless Venting - When ducting direct to atmosphere is not feasible due to distance or location of plant items then flame arresting/particulate retention devices (flameless vents) are another option for providing passive protection. Flameless devices vent into a non-manned (restricted) area generally 2m distant from the device but overcome the risk of secondary explosions in the working area.

Explosion Containment such that the process equipment resists the maximum explosion pressure developed. Explosion containment is a passive form of protection that involves designing the enclosure to withstand pressure generated by an event. Containment design requires that all connected equipment (piping, airlocks, valves, etc.) be designed for containment pressures. In most instances, isolation is still required to prevent the deflagration from migrating to areas that aren't pressure rated. While the cost increase of pressure rating a standard enclosure is extremely high, the cost of equipping a vessel to handle containment pressures is rather low. For this reason, containment is most often employed where the enclosure has already been designed as a pressure vessel or where chemical contamination is unacceptable.

Pneumatic conveying pipe lines

Explosion Suppression is an active form of protection that detects an event and then blankets the exposed area with a chemical flame suppressant. The typical system uses a predetermined number of canisters filled with pressurized suppressant (e.g. sodium bicarbonate,) a control system complete with power supply and monitoring, fast-acting isolation and a method to detect the event (usually pressure increase.) An advantage of this method is that early detection and fast deployment of the suppressant can prevent the primary deflagration from escalating to the detonation stage.

The use of an active system with required detection and control devices can be more cumbersome when compared to passive systems. Active systems must be maintained, inspected, and can be subject to false positives due to pressure fluctuations generated by the equipment. Early suppression techniques were found to be somewhat unreliable, but with advancements in electronic technology, a majority of these issues have been resolved making this method of explosion protection more attractive in the marketplace.

Together, these sugar handling, dust collection & dust removal techniques plus explosion protection measures can help sugar producers and users operate in a safe, efficient manner and at the same time reduce maintenance costs and assure product quality.

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