

## **Safe Handling of Sugar for Refineries and Consumers**

### **MAC Equipment, Inc**

Mike Althouse, Doug Carroll, Graham Cooper, Nathan Egbert, Jonathan Thorn

#### **I. Introduction**

Significant recent events have caused sugar refiners to review how materials are handled in their production facilities. Historically the refiners have used mechanical means (screw conveyors and bucket elevators) to handle bulk sugar. Recent changes in legislature atop industrial incidents have caused producers to seek alternatives, such as pneumatic conveying, as well as address the issue of dust collection in refineries.

#### **II. History**

A visit to sugar refineries around the world will quickly reveal the industry standardization of mechanical handling techniques, but it will also show the difficulty in maintaining these systems and the hazards than can be created. Being a commodity product, the refiners are accustomed to large throughputs of relatively low margin product. Screw conveyors for horizontal conveying and bucket elevators for vertical conveying offer lower power requirements than other methods, thus many plants were built to accommodate the limited flexibility of these systems. Mechanical systems tend to occupy large areas of plant space, often create interferences and are largely only effective in straight paths. A well planned facility can use these system types effectively. But, the need to expand or modify processes can lead to inefficient layouts the original plan did not intend to support.

Mechanical conveyors are revered for their simplicity in that most every maintenance staff is capable of maintaining these types of systems. However, the large number of moving parts and pieces can result in significant maintenance volumes. In addition, mechanical systems contain immense surface areas and joints that can translate into system leaks which occupy man hours dedicated to housekeeping. As these plants age, the cost of proper upkeep tends to grow. Over time, budget limitations and labor force reductions serve only to make this task more difficult and services are sacrificed; usually housekeeping in favor of keeping the equipment operational. The long term effect of this trend is to accept areas of the plant that are dust laden or that contain large amounts of spillage thus creating a potentially dangerous environment.

In the wake of several recent industrial accidents, government regulatory bodies, such as OSHA (Occupational Safety and Health Administration) and NFPA (National Fire Protection Association), have issued new regulations governing the handling of materials such as refined sugar that have the potential to create an explosive environment. OSHA has placed sugar refining, manufacturing and bakeries (operating under SIC codes 2062, 2063 and 2052) in a high risk category, making those facilities a target for inspection under their National Emphasis Program (NEP). NFPA regulations 61, 68, 69 and 654, concerning explosion venting, suppression and isolation, have all been updated and released between 2006 and 2008. The extent to which these regulations have changed, to be discussed in a later section, have caused refineries to reexamine their material handling methods and are giving new light to pneumatic conveying as an alternative.

### III. Pneumatic Conveying

Pneumatic conveying is a method of moving dry materials through pipelines using air or other gas as the motive force for transportation. While pneumatic conveying requires greater power requirements than mechanical means, there are several inherent advantages that make it attractive:

- 1) There are few moving parts in a pneumatic conveying system, most of which are located at the source or at the destination.
- 2) The material travels through an enclosed pipeline which both protects the material and can virtually eliminate housekeeping.
- 3) The piping layout is extremely flexible in the path that can be chosen and the relative plant area that it occupies. It is relatively easily changed with changing needs.
- 4) The nature of the pneumatic conveying system integrates filtration as a means of delivering the material to the destination.

There are two basic methodologies to conveying material pneumatically; Dilute Phase and Dense Phase.

Dilute phase, or lean phase, uses a high velocity air stream to entrain the material and carry it down the convey line. Air velocities for sugar using this method typically range from 4000-6500 FPM (20-33 m/s). These systems operate at low pressures or vacuums (< 14.7 PSI, 1 bar) and are very simple in their operation. The high velocity conveying tends to degrade the sugar as it impacts elbows and other piping components, so this type of conveying should be applied to materials in which size reduction is not a concern. This method is most common in users of sugar product, such as bakeries, where the particle size of the sugar does not impact the quality of the product. Refineries will use dilute phase conveying on reclaim sugar that will be reconstituted or on milling operations. While the cost of dilute phase equipment is relatively low, the degradation of the material often prevents it from being applied to sugar production.

Dense phase conveying uses a low velocity air stream to push discreet slugs of material through the convey line. Air velocities for sugar using this method typically range from 400-1600 FPM (2-8 m/s). The resistance created as slugs slide against the pipe wall generates much higher convey pressures than its counterpart. Convey pressures can range from 20-45 PSI (1.3-3 bar) and typically employs compressed air as the air source. A convey vessel is filled with material and then sealed. The convey air is applied and distributed around several vessel ports to influence the flow of material from the vessel. The combination of air velocity and controlled material flow creates a system of slow moving slugs throughout the system. Although typically a batch process, a second vessel can be employed to create a continuous feed whereby the two vessels alternate their fill and convey cycles. A continuously fed dense phase system can convey 15-20% more product through the same line size as compared to its batch counterpart. Air assistance (air injected at various points along the pipeline often called boosters or density stabilizers) is used on many products and has been found to improve the convey characteristics of granulated sugar. A well controlled dense phase system can transfer granulated sugar and generate less than 0.5% fines (minus 150 mesh) by weight, the equivalent of many mechanical transfers featuring multiple legs. Dense phase conveying has been a staple for many years by sugar users, such as drink mix producers, to convey granulated sugar with minimal degradation. Sugar refineries are finding they too can utilize this method and realize the safety and cleanliness required in their facilities.

#### **IV. Filtration**

Regardless of the conveying method used, it is important in sugar handling facilities to employ dust collection systems that are properly designed, resist moisture, use proper components and are ultimately 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). In either case, a poorly assembled dust collection system that is not properly maintained will result in poor functionality that emits sugar dust into unexpected areas of the plant. This airborne dust in turn creates housekeeping and explosion safety concerns that are wholly avoidable. However, when dust or material is spilled it is also important to have a method to easily reclaim or remove the spillage. Central vacuum systems fill this need efficiently. Together these approaches can help refineries operate in a safe, efficient manner that conforms to or exceeds OSHA's NEP expectations.

Proper dust collection system design goes beyond selecting the right filter, but also includes ductwork design, dampering and fan selection. Hoods and ductwork must be configured for proper capture and convey velocities for the particular application. Dust accumulation in any part of the system with a hygroscopic material like sugar dust will result in a crust of hard material that must be manually removed. The inclusion of cleanout or inspection openings in the ductwork will also promote proper maintenance (recommended 10-20 ft, 3-6 m intervals) and help keep the system in good working order. Insulation may be required on certain duct areas to prevent the condensation of water inside the duct when large temperature swings and moisture are present. Manual dampers should also be placed at strategic locations to help drive the distribution of the air from various pick-up points. Finally, fan selection can greatly impact the performance of a dust collection system. While fan specifics will not be discussed here, a fan professional can describe the importance of the fan type, operating point on the fan curve and motor size. When sizing the fan, consideration should be given to an AC inverter or fan damper to compensate for changes in pressure drop as the filter media becomes seasoned. A fan seeing the low differential pressure of new filter media can overwhelm a baghouse if designed for the future, higher differential pressures of media nearing the end of its useful life. These considerations in conjunction with filter design will produce a very robust dust collection system.

In addition to the basic system design described above, dust collection systems handling sugar should also account for critical moisture concerns in the environment. Moisture can come from a variety of sources in a dust collection system. 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. A small leak in a flange or ductwork may draw moisture into the system if located outdoors or in a washdown area. Moisture can also enter the system via condensation in the compressed air supply. This usually affects the filter media directly when compressed air is used to clean the media. The negative effect of moisture can devastate a dust collection system. A little extra time spent reviewing psychometric charts, securing leaks and properly maintaining compressed air driers can go a long way toward system reliability.

The general design of the dust collector unit will also impact the safety and performance of a filtration system. The selection of filter media is the first critical decision to be made when designing a filter. Typical selections include a bag media with structural cage or pleated cartridges. The pleated cartridge is attractive in some cases because it can house eight times the cloth area of a similar sized bag, allowing a far more compact filter design. However, sugar dust in particular tends to pack in the pleats and not be released during cleaning; severely restricting the media effectiveness. Wider pleat cartridges are available (with 25% less cloth area) that help combat this effect, but in general, bag and cage media is preferred when handling sugar. Although more head height is required to employ the bag type media, it is more forgiving to high moisture excursions and other upset conditions. When pulsed for cleaning, bag media flexes and will break off any sugar caking that has accumulated on the outside. If there is a high probability of moisture, special coatings and bag materials are available including oleophobic media that prevents the absorption of moisture into the fibers. Other advances in fiber technology have produced bag media that can achieve particle emissions levels approaching that of the cartridges. While both cartridge and bag media are prevalent in sugar applications, if a compact filter design is not required, then bag media is preferred.

The selection of a cleaning system for a baghouse in sugar applications is another important decision. Mechanical shaker cleaning is all but extinct as the moving parts are difficult to access and cleaning of the media is severely limited. Pulse jets are the most common cleaning device found on filters. Compressed air (80-100 PSIG, 5.5-7 bar) is used to initiate a shockwave or pulse of reverse air to displace material accumulated on the outside of the media. An advancement on this design uses medium pressure (7-12 PSIG, 0.5-0.8 bar) supplied by a dedicated positive displacement blower. Medium pressure cleaning reduces energy consumption up to 50% as compared to a high pressure cleaning mechanism. Media fibers stretch less with the lower pressure pulse but the media surface still gets cleaned effectively. The result is increased bag life, reduced emissions during each pulse and subsequently reduced overall emissions. A premium is paid to equip a filter with medium pressure cleaning, but medium pressure filters typically provide a short payback period and eliminate the moisture concerns involved with compressed air.

Other filter design criteria that should be considered include grounding and access to the media (for removing and changing). In addition to accepted explosion protection devices, which will be discussed in the next section, the prevention of static accumulation in the media can reduce the risk of an explosion. Metal parts integrated but isolated in filter media (ex. cages and metallic cartridge cores) can provide a conduit for static charge to build near the tubesheet and arc. For materials such as sugar with a low ignition energy level, grounding between any metal in the media and the tubesheet should be provided. A method to access the media is also included in the design of a filter. The simplest and least expensive method is the bottom load unit where media is accessed through a door in the main body. However, to do so workers must enter a confined space on the dirty side of the filter which can create safety and comfort concerns. Its counterpart is the top load unit where the media is accessed from above the tubesheet on the clean side of the filter. This feature is typically more expensive but much cleaner and safer for the employee. In recent years options for side entry filters, where the media is installed and accessed horizontally, have also become available. While limited to smaller filter sizes, this design allows employees to access media at chest height and exceeds the safety and comfort of even the top load unit. Together, these additional considerations can improve safety, make the filter easier to maintain and reduce its energy consumption; all important concepts in the sugar production arena.

A dust collection system alone cannot keep a plant clean and dust free as housekeeping must be part of any good dust collection plan or design. There will always be a spill or an accidentally closed blast gate that produces a dust emission point. Manual cleaning (shoveling and sweeping) is very labor intensive and can often create additional airborne dust. Central vacuum systems are an effective way to clean industrial environments that will minimize recontamination and the labor cost of housekeeping.

Central vacuum 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, multi-story plants or portable, single user systems can be moved throughout the plant by cart or forklift. A central vacuum 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. The correct system requires forethought into the plant integration (what areas of the plant) and the types of materials it will be dealing with (dust, bulk material, etc). The expectations will have an effect on the type of vacuum producer used, line size, separator and discharge device selected. A good understanding of the need is critical to the performance of the system.

A central vacuum system for sugar requires many of the same precautions as a dust collection system. As with dust collectors, moisture can have an adverse effect on system performance in both what is drawn into the system and the compressed air used in cleaning. Grounding of all components to prevent the buildup of a static charge is also required. This includes grounding media, flexible vacuum hoses and tools. Explosion protection must also be considered in the design. Considering labor costs and the risk induced by spilled product and airborne dust, a well designed central vacuum system can pay for itself in a short period and is a good investment for any sugar processing facility.

## **V. Explosion Mitigation**

The primary objective behind the regulations put forth by OSHA and NFPA is the protection of employees and facilities from explosions fueled by combustible dust and it places particular attention on the sugar industry. Housekeeping benefits related to both pneumatic conveying and dust collection have been detailed in previous sections. For more information regarding regulations and suggested procedure where housekeeping is concerned, see section IX.E of the OSHA combustible dust NEP and NFPA 654, Annex D. The following will explore available explosion prevention and mitigation techniques as outlined by the NFPA. Documentation of NFPA design can be used to demonstrate a company's efforts to abate combustible dust hazard, as suggested in IX.E of the referenced NEP (OSHA). The following sections will discuss three primary forms of explosion protection: venting, suppression and containment.

The most common form of explosion protection to date is the explosion vent. 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. This is a widely accepted and tested method and rather inexpensive compared to the equipment it protects. However, the use of explosion venting alone does not bring said protected equipment into compliance with the NFPA design standards. 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. The NFPA 68 2007 standard on explosion

venting design has increased the restrictions applied to vent ducting and has significantly limited the applications where the vents can be ducted. When ducting is not feasible, flame arresting/particulate retention devices (flameless vents) are another option for passive protection. However, these are considerably more expensive than standard venting or suppression and would still require isolation equipment as described above. Explosion venting of enclosures has been effectively used for many years, but proper application as directed in new regulations are making it more difficult to employ and thus give rise to consideration of other methods.

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 (ex. 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. In addition, a suppressed enclosure does not have restrictions on where it can be placed in the plant as is the case with the venting option. Suppression systems are generally thought to be more expensive than venting options. However, with the inclusion of isolation, the ability to operate the isolation equipment with the suppression control system can put the two on more equal standing. 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 through increased control capability making this method of explosion protection more attractive in the marketplace.

Explosion containment is a passive form of protection that involves designing the enclosure, per ASME boiler and pressure code, to withstand the pressure generated by an event. Containment design also requires that all connected equipment (piping, airlocks, valves, etc) be designed for containment pressures. Calculation of the containment pressure is put forth in a straight forward manner in NFPA 69. In most instances, isolation is still required to prevent the deflagration from migrating to areas that are not pressure rated. While the cost increase of pressure rating a standard enclosure is extremely high, the cost of equipping an ASME code 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. As with the suppression technique, these vessels are not restricted in their placement within the plant. Containment is not a cost effective solution in general, but in cases where venting and suppression are not possible it is a feasible alternative.

As discussed, the primary methods of explosion protection offer varying degrees of cost and flexibility depending on the enclosure and its location. Other techniques to prevent or mitigate deflagration are discussed in NFPA 654, section 7.1.2 and are acceptable under OSHA's combustible dust NEP. For dust collectors located outdoors, venting will likely continue to be the most widely used form of protection with the addition of isolation. The main shift in culture will likely occur on protection of equipment located indoors as suppression and containment become more prominent.

## **VI. Conclusion**

Producers, refiners and users of sugar in industrial applications are examining alternative methods for sugar handling and sugar dust mitigation, in order to address significant changes in safety directives from government bodies. Designs that include pneumatic conveying, dust collection, central vacuum systems and integrated explosion protection are helping plants cope with the changing safety aspects of these directives when applied to the sugar industry.

Written by:

Jonathan Thorn, Director of Technology

Mike Althouse, Director of Filtration

Doug Carroll, Account Executive, Food

Graham Cooper, Executive Dir, Clyde Technologies

Nathan Egbert, Technical Support Engineer

MAC Equipment, Inc.

7901 NW 107<sup>th</sup> Terrace

Kansas City, MO 64153

[www.macequipment.com](http://www.macequipment.com)

800-821-2476