

THORN, JONATHAN O., MAC Equipment, Inc., 7901 N.W. 107th Terrace, Kansas City, MO 64153. **Pneumatic conveying in sugar production.**

ABSTRACT

In sugar production facilities, mechanical conveying methods are a prominent means of handling granulated sugar product. However, recent events and changes to government body policy have made pneumatic conveying an attractive alternative to mechanical means. Maintenance reduction, cleanliness and plant safety are advantages that pneumatic conveying can provide. Sugar is transported through enclosed pipelines with few moving parts to be maintained. Integrated filtration systems allow the sugar to be delivered to its next destination in a clean and dust-free environment. Most importantly, pneumatic conveying of sugar materials more easily facilitates the use of explosion protection methods advocated by the NFPA. While overall power consumption is greater in pneumatic conveying systems, as compared to mechanical systems, this cost can be offset by short and long term savings in protection devices, product safety and maintenance. Bolstered by other advantages such as process flexibility and small plant footprints, pneumatic conveying systems are gaining acceptance in sugar production facilities as a viable means of material transport.

Background:

Material handling of sugar following the granulator in a refinery can be conducted by one of three means: gravity flow, mechanical conveying or pneumatic conveying. Gravity flow is a very simple and effective tool but it is limited to what can be done through elevation changes in a process. Mechanical conveyors (bucket elevators, scrolls, belts and drag conveyors) are an effective way to transfer large quantities of material relatively short distances and in straight lines. However, the typical transfer leg of a process using mechanical means will incorporate multiple conveyors and will be limited in overall distance. Mechanical systems are most valuable when the transfer path is kept simple and short. As distances become greater and the transfer path becomes more complicated, the number of mechanical systems will increase; subsequently increasing the number of motors and the number of moving parts. Each of these mechanical conveyors will need an external dust collection source to insure dust free operation, require frequent inspections as well as routine maintenance to keep them in good, safe working order. In addition, recent government safety guidelines advocate explosion protection devices be implemented on each conveyor in addition to other design changes to improve safety. Finally, mechanical conveyors are generally susceptible to food protection issues. With a multitude of moving parts and access hatches, foreign material can enter the product stream from a number of sources. The aspect can be minimized by applying mechanical systems in operations where they are most effective (as opposed to universally) thereby limiting the total number of units or legs.

Pneumatic conveying is a method of moving dry materials through pipelines using air or other gas as the motive force for transportation. Pneumatic conveying has long been a preferred method of sugar handling for user-plants because 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; easily modified with changed needs.
- 4) The nature of the pneumatic conveying system integrates filtration as a means of delivering the material to the destination.

The majority of the equipment is located at the source and destination with primarily piping in between. Therefore, the cost and difficulty of transferring materials further distances does not increase proportionally. Inspections and maintenance on moving parts is still required, but there are fewer parts and the devices are instrumented to provide feedback to the controls as to when a device is not operating properly. Controls for pneumatic conveying systems typically provide a larger degree of feedback than controls on mechanical systems, which allows operators to correct problems before the issue becomes catastrophic. Pneumatic conveying systems offer several inherent operational advantages and recent focus on process safety has increased its visibility in the sugar refining industry.

Dilute Phase:

Dilute phase, or lean phase, pneumatic conveying uses a high velocity air stream to entrain the material and carry it down the convey pipeline. 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, therefore this type of conveying should be applied to materials in which size reduction is not a concern. Sugar supplying a mill can be conveyed in this method as any size reduction will not affect the milling process. Likewise, non-sugar products like starch, powdered sugar and reclaim material can use dilute phase reliably without concern for particle size reduction.

The cost of dilute phase system is comparatively low and the equipment is relatively easy to operate. An air movement device, such as a PD blower, creates roughly a constant airflow through the pipe. A heat exchanger is placed on the discharge of the air movement device to remove any heat effects from the air compression. Material is then metered into the airstream by a rotary airlock valve. The airlock valve must have specific clearances to create an effective seal and comply with fire protective directives as a blocking valve for propagation. The material is carried to the destination where a storage device receives the material and its integrated filter releases clean air to the atmosphere. The cost and simplicity of the dilute phase system make it an effective transfer system option, however material degradation often will prevent it from being employed on primary transfer systems for sugar in a refinery.

Dense Phase:

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 dense phase typically employs compressed air as the air source. When using dense phase on granulated sugar, a convey vessel is filled with material and then isolated with valves. The convey air is applied and distributed around several vessel ports to direct 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 semi-continuous system whereby the two vessels alternate their fill and convey cycles (see Figure 1). A semi-continuous dense phase system can convey 15-20% more product through the same line size as compared to its batch counterpart. This concept becomes important when dealing with high tonnage systems.

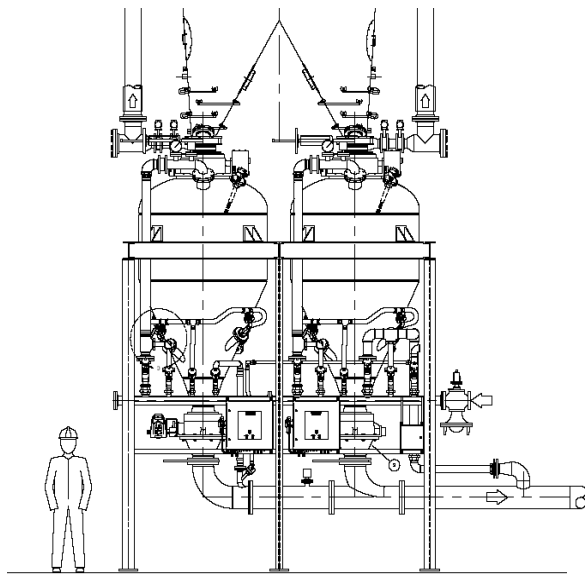


Figure 1. Dense phase stack-up with dual vessels

Airflow to the system is primarily fed through the air controls on the vessel with some supplementary air added to the convey line. The supply air pressure is regulated to the supply air header so the pressure in the vessel and convey line cannot exceed this setpoint. The rate at which a particular system can push material (assuming a fixed distance and fixed line size) is proportional to the pressure. If a variable control pressure regulator is used on the supply header then the pressure, and subsequently the convey rate, can be controlled remotely. The regulated air from the header is then distributed around the convey vessel with orifice plates operating in a non-critical airflow regime.

Supplementary air is injected at various points along the pipeline called density stabilizers. When conveying sugar using dense phase, the slugs of material have a tendency to become larger as the material gets further down the convey line. The supplementary air helps to keep the slug size smaller and improve the conveying characteristics of granulated sugar.

The valving on the convey vessels is critical to their reliable operation. Due the high rate of cycling on large capacity systems the selection of inlet, outlet and vent valves will directly impact performance and longevity. Sugar is a difficult material for valves in that its characteristics (can become sticky, presence of small particles) can greatly reduce seal life. A dome type valve with an inflatable seal is ideal in that the seal is recessed as

the valve opens and closes, preventing material from impacting the seal integrity. In addition, the valve dome rotates completely out of the material flow allowing for higher vessel refill rates and reduced material impact. Periodically, a diverter valve is required downstream to select from two or more destinations for the flow of material. A tunnel type valve is common in dense phase systems because it maintains the shape of the pipeline through the valve causing reduced interference. However, tunnel type diverter valves will also have difficulty with sugar material getting into the seals. A cavity purge can be used to minimize the issue. As an alternative, a modified dome valve has been effectively employed to maintain pipe integrity while still offering a robust seal arrangement. Proper valve function is critical to system operation and should be enhanced by instrumentation for the operator to monitor.

Safe handling of sugar is a key aspect of using pneumatic conveying in lieu of mechanical methods to transfer material in a refinery. There are three protection methods are used to protect various devices from dust fueled explosions: containment, suppression and venting. The primary pressure vessels used to drive the convey systems use containment methods. A standard pressure vessel will already have a pressure rating sufficient to contain compressed air. Its design can be enhanced to add the additional pressure that would accompany deflagration (40 bar design in this case), therefore protecting the integrity of the device. Indoor storage devices will use chemical suppression accompanied by isolation to relegate risk. Isolating devices such as rotary airlocks and knife gates will keep flames from propagating beyond the storage device. Pressures sensors will identify possible events and activate a chemical blanket to quench any flame. Outdoor storage devices are typically too large in volume to effectively suppress and therefore venting of the device to a safe area with rupture panels is the most effective method of protection. Between these features and devices, a pneumatic conveying system can deliver sugar throughout a plant or refinery in safe and effective manner.

Plant Impact:

Designing and operating a sugar refinery based around pneumatic conveying represents a shift in mindset from typical industry practices. Pneumatic conveying based designs offer enclosed pipelines and filtered source/destination which improves product safety and reduces dust emission potential. The close proximity of source and destination are no longer a core advantage of the transfer system so processes can become more spread out and plant layouts become more flexible. In addition, devices on pneumatic systems are inherently more instrumented and therefore lend themselves to a central control system that can be remotely monitored and operated. When handling sugar pneumatically, product degradation is a concern. A typical dense phase system can transfer granulated sugar and generate between 0.4-1.0% fines (minus 150 mesh) by weight depending on the length of the transfer. Freshly granulated material has also been found in some situations to generate a scaling on the ID of the convey line likely due to inherent moisture. Long term, a method to periodically remove the scaling is required. Finally, the power requirements to operate a pneumatic conveying system are approximately 1.2X-1.8X that of mechanical equivalents. The disparity is lessened as the convey run becomes greater in distance and complication (increasing the required

number of mechanical legs). Overall, pneumatic conveying can be effectively employed in sugar refineries at the large tonnages required. There are aspects of maintenance, product, utility and safety that will influence whether using pneumatic conveying in a particular application is viable.

Expected EFG Sugar Transfer Rates in TPH (MTPH)				
	Convey Distance			
Line Size	100 ft (30 m)	200 ft (60 m)	300 ft (90 m)	400 ft (120 m)
6" (150 mm)	28 (25)	21 (19)	18 (16)	16 (15)
8" (200 mm)	48 (44)	36 (33)	31 (28)	28 (25)
10" (250 mm)	75 (68)	57 (52)	49 (45)	44 (40)
12" (300 mm)	105 (95)	80 (73)	69 (63)	62 (56)
14" (350 mm)	125 (114)	96 (87)	83 (75)	74 (67)

Figure 2. Expected tonnages in a dense phase pneumatic conveying system.