

Introduction

Calcium carbonate (CaCO_3) is one of the most popular mineral fillers used in the plastics industry. It is widely available around the world, easy to grind or reduce to a specific particle size, compatible with a wide range of polymer resins and economical. As an additive in plastic compounds, CaCO_3 helps decrease surface energy and provides opacity and surface gloss, which improves surface finish. In addition, when the particle size is carefully controlled, CaCO_3 helps increase both impact strength and flexural modulus (stiffness).

Calcium carbonate may be used with a myriad of thermo-plastic resins. Polypropylene compounds are often filled with calcium carbonate to increase rigidity, an important requirement for operations at high temperatures. In PVC, calcium carbonate is used with flexible compounds such as tubing,

wire and cable insulation, latex gloves, trash bags and in rigid compounds such as extruded pipes, conduits and window profiles.

Conveying CaCO_3

The design of a feeding or pneumatic conveying system is heavily influenced by a bulk solid's particle shape, size (aspect ratio) and particle size distribution as well as the particle's roughness, hardness (abrasiveness), and density.

In the case of calcium carbonate these characteristics vary widely depending on the source and production process for the individual samples. The sieve analysis below illustrates the difference in particle shape, particle size and particle size distribution for two samples of calcium carbonate.

The large number of particle interactions (see sidebar on page 2) makes it impossible to establish a clear correlation between a

filler's properties at the particle level and its flow behavior as a bulk solid. As a consequence, pneumatic conveying systems cannot be purchased "off-the-shelf" and must be engineered for each situation individually. Both systems engineering and equipment selection are affected by differences in a bulk solid's characteristics. Laboratory tests are often necessary to help determine a material's properties and behavior.

A pneumatic conveying system generally consists of five basic components: a gas motive, a conveying line, a dispensing device, a material-gas separator and controls.



Aerolock™ Rotary Valve

Dispensing Device

When selecting a dispensing device, it must be taken into consideration that some grades of CaCO_3 are light and fluidizable and may flood convey lines. In such cases, a rotary valve should be considered to meter the material into the line. Rotary valves can be used for pick up in either pressure or vacuum pneumatic conveying systems. With adhesive grades of CaCO_3 the product will tend to build up and not release from the blades of a drop-through rotary valve. In this case a blow-through style rotary valve is necessary; air is blown through each pocket as the valve turns, dislodging material from the blades. The installation of a fluidizing cone in the feed bin is also helpful in controlling the flow of the material.

However, if the CaCO_3 tends to coat the interior of the convey line, a flexible hose could be considered because flexing of the line helps prevent build-up on the walls of the hose.

In vacuum sequencing systems, it is a good precaution to use a purge valve to allow the line to clear between conveying sequences. First, a shut-off valve at the pickup of a vacuum system is closed to allow vacuum to build in the line. Then the valve is opened, creating a pressure wave that helps clean off any coating of material adhering to interior surfaces of the convey line.

Material-Gas Separator

Often CaCO_3 will adhere to the filter, causing it to blind over and reduce filter efficiency. For sticky grades of CaCO_3 using filter bags instead of pleated filter cartridges may help reduce the tendency of the CaCO_3 to stick to the filters. In extreme cases the use of PTFE filter media is recommended.

Some calcium carbonate grades may require a steeper discharge cone in order to allow complete emptying of the hopper. Flow aids such as vibrators or fluidizing pads inside the receiver

Conveying Lines

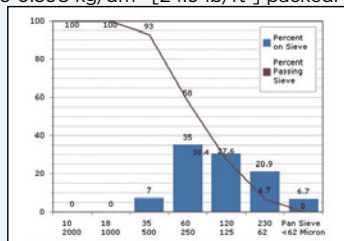
Calcium carbonate powders can cause many problems in conveying systems, including sticking in hoppers, flood feeding into convey lines, building up inside convey lines, and blinding over filter bags and cartridges in receivers.

Rigid pipes may be used as a convey line for highly fluidizable to slightly adhesive CaCO_3 .

Calcium Carbonate Sieve Analysis

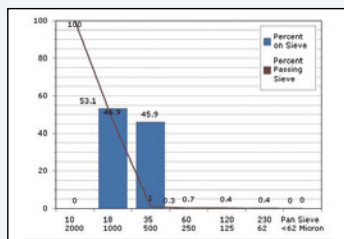
CaCO_3 Sample A

99% pure precipitated calcium carbonate (PCC); bulk density varies from 0.301 kg/dm^3 [18.8 lb/ft^3] loose to 0.398 kg/dm^3 [24.9 lb/ft^3] packed.



CaCO_3 Sample B

95% pure granular calcium carbonate; bulk density varies from 1.378 kg/dm^3 [86 lb/ft^3] loose to 1.474 kg/dm^3 [92 lb/ft^3] packed.

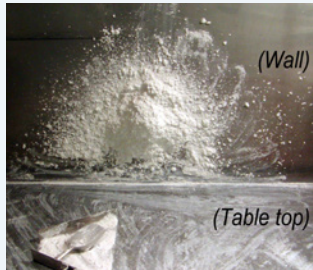


Particle Interactions

Three distinctive relationships affect the flow behavior of mineral fillers in pneumatic conveying and feeding systems: Particle-particle, particle-equipment and particle-environment interactions.

Particle-Particle

Particle-particle interactions are directly related to the filler's chemical composition and physical characteristics rather than bulk properties. The most important particle-particle forces are the electrostatic or van der Waals forces of attraction between molecules. As the separation between particles increases, the van der Waals forces decrease, explaining why the addition of small particles to cohesive powders improves their flowability. Other particle-particle forces include capillary forces, responsible for liquid bridge formation, and sintering forces, responsible for solid bridge formation. Capillary forces develop in the presence of water vapor in the gas phase whereas sintering forces develop when material migrates due to diffusion or viscous flow. Interparticle forces contribute to the cohesive characteristics of fine powders and their tendency to form aggregates or agglomerates.



Particle-Equipment

The flow of solid particles inside a vessel or a pipe is a function of two important characteristics, wall friction and shear strength. Wall friction relates to how particles slip on a contact surface while shear strength is the resistance that the powder bulk offers to deformation, or how particles slip relative to each other.



Particle-Environment

Particle-environment interactions deal with external forces (e.g., temperature, relative humidity, vibration, gravity, aeration, etc.) exerted over the aggregate of particles. The air Relative Humidity (RH) and the filler's hygroscopic nature are often coupled with increase cohesiveness because of inter-particle liquid bridges; temperature affects the particle's crystallinity behavior, promoting "caking", while pressure increases the contact points between particles, causing "compaction" or more inter-particle adhesion.



hopper will usually help ensure quicker and more complete discharge of the receiver.

Application Example

The sieve analysis on page 1 illustrates the difference in particle shape, particle size and particle size distribution for two samples of calcium carbonate. While Sample A is a precipitated calcium carbonate (PCC) with a relatively low bulk density, Sample B is a granular calcium carbonate with a much higher bulk density.

The diagram on page 3 shows a schematic representation of the pneumatic conveying system required to transfer the calcium carbonate from a storage bin into a feeding system in a compounding operation.

In this example, a customer needs to transfer 4.5 t/h (10,000 lb/h) of calcium carbonate from a storage bin (1) to a filter receiver (2) located on top of a rotary valve (3) for the extrusion of PP and CaCO₃ at a plastics compounding facility. The facility is located at 305 m (1000 ft) elevation with an average daily temperature of 29.5°C (85°F) during the entire year.

The selected calcium carbonate sample would need to be pneumatically conveyed over 30 meters (100 ft) horizontal distance and 15 meters (50 ft) vertical distance with four 90-degree angle elbows (4) present in the system. The blower (5) would be located in such a way that the air line

would be 15 meters (50 ft) long (when combining horizontal and vertical distances) with no more than 2 elbows.

The significant particle characteristic differences between the two CaCO₃ samples result in the selection of different equipment components as well as different sizing of the entire system. A higher blower horsepower (5) is required for calcium carbonate B to provide the increased system airflow and vacuum necessary to maintain dilute phase conveying at the required rate. Differences in the bulk density and particle characteristics determine the adjusted rotary valve (3) throughput to maintain the desired rate. To this end, for the much denser material B, the volumetric throughput is much lower than calcium carbonate sample A.

The filter housing diameter is determined based on the can velocity restriction for each sample. Maximum can velocity is the largest vertical velocity through the filter housing that will allow the majority of material to fall out of the airstream. The filter cloth area for each material is based upon the filtering characteristics of each sample.

Particle size plays a large role in determining the necessary filter cloth area required for the materials. The larger the particle size, the easier it will be to separate from the airstream; therefore less filter cloth is required. Table 1 summarizes some of the equipment differences for these two samples.

Table 1:
Differences in Conveying Equipment Selection

Equipment	Sample A	Sample B
Blower size	16 kW [20 HP]	20 kW [25 HP]
Rotary Valve Throughput	15 m ³ /hr [531 ft ³ /hr]	3.6 m ³ /hr [128 ft ³ /hr]
Rotary Valve Efficiency	84%	92%
Adjusted RV Throughput	17.9 m ³ /hr [632 ft ³ /hr]	3.9 m ³ /hr [139 ft ³ /hr]
Filter Housing Diameter	1.4 m [54 in]	0.9 m [36 inches]
Filter Cloth Area Required	17.7 m ² [191 ft ²]	7.5 m ² [81 ft ²]
Maximum Can Velocity	21.3 m/min [70 ft/min]	No restriction

Feeding CaCO₃

The selection of the appropriate feeding system for each of the illustrated calcium carbonate samples is determined by two main variables: the characteristics of the mineral filler (e.g., particle size and shape, gas permeability, bulk density and angle of repose) and the required feed rate.

Loss-in-Weight (LIW) feeders provide total containment of the raw material and dust and optimal feed rate performance to guarantee overall end product quality. LIW feeders are available in a variety of configurations, where the hopper size, feeding device and weighbridge are tailored to the specific characteristics, flow properties and flow rates for the material to be fed.

Volumetric vs. Gravimetric

Most feeders may be categorized as volumetric or gravimetric. Volumetric feeders operate by delivering a certain volume of material per unit time and are the lowest capital cost feeding solution. However, volumetric screw feeders cannot detect or adjust to variations in a material's bulk density. As a result, these feeders are most effective with relatively free-flowing

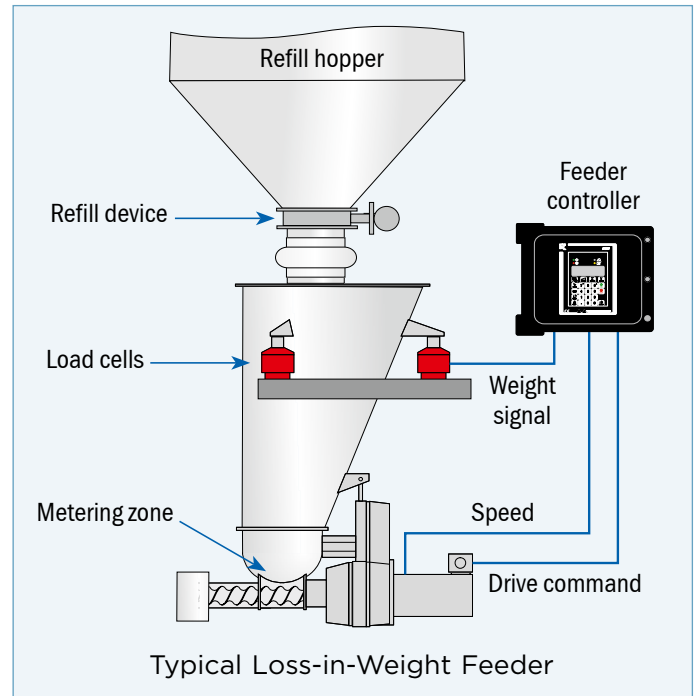
materials with consistent bulk density, such as pellets, and in applications where a guaranteed feeding accuracy is not crucial.

In gravimetric feeding, dry bulk material is fed into a process at a constant weight per unit of time. Gravimetric feeding provides better monitoring of the feeding process with a feedback loop that measures weight and speed, thereby determining actual weight of material being fed on a second to second basis.

Hopper Selection

Once the size and type of feeder is established, a hopper of the appropriate shape and size must be selected to contain the right amount of filler required for a continuous plastics compounding operation. Hoppers are available in cylindrical, asymmetrical and symmetrical shapes and in sizes from one liter to several hundred liters.

A feeder hopper is sized based upon the refill requirements of the feeder and the space available. A general "rule-of-thumb" is to use 12 hopper refills per hour and the maximum fill level in the hopper should be 80% of the hopper volume. A large hopper may not be desired because of incremental cost, space requirements, and the possibility of material compac-



tion due to particle interactions. Thus, the hopper size selection is initially estimated using the following theoretical calculation:

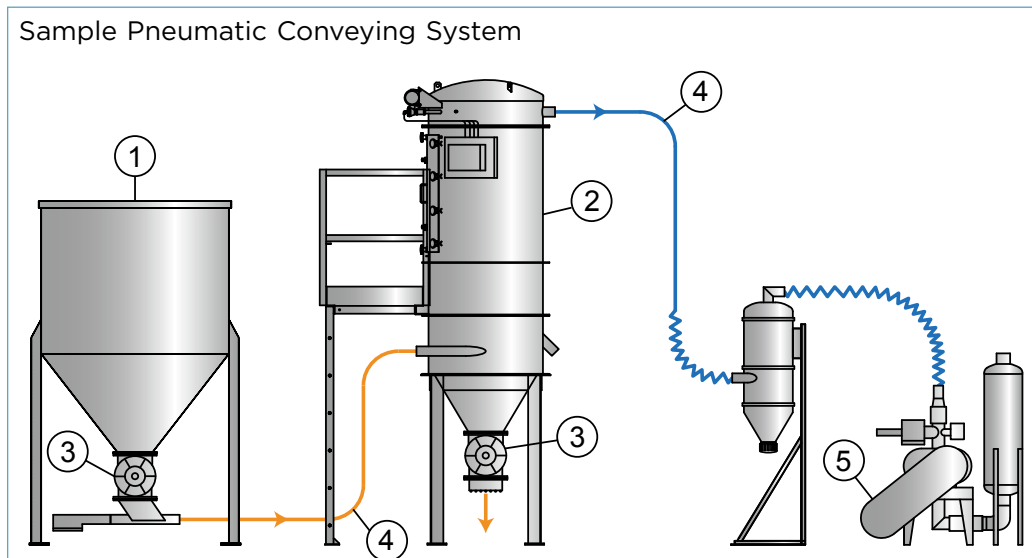
$$\text{Hopper Capacity} = \frac{\text{Flow rate}}{(\text{Bulk Density} \times 0.8 \times 12)}$$

Precipitated calcium carbonate tends to compact in hoppers



K2-ML-T60 Twin Screw Feeder

and may cause rat-holing and bridging. The ActiFlow™ Bulk Solid Activator is a simple and efficient flow aid device that works by inducing particle-particle vibrations, thus preventing the formation of highly dense material points inside the hopper. In addition, ActiFlow



Conveying and Feeding of Calcium Carbonate in a Plastics Compounding Process

helps reduce head-room requirements and eliminate cleaning concerns because there is no need to use mechanical agitators inside the hopper. For extremely cohesive materials alternative mechanical agitators are available.

Feeding Device

Feeding devices vary depending on the bulk material to be fed: single screw or Bulk Solids Pump™ for free-flowing powders and granulates, twin screw feeders for difficult powders, vibratory trays for fibers and friable materials.

While a single screw feeder may work with free-flowing grades of CaCO₃, a twin screw feeder is generally recommended to achieve a reliable result. A variety of screw designs are available according to the flow rate and characteristics of the mineral filler. The most common screw profiles are

concave, auger, spiral and double spiral. The objective of the screws is to discharge the bulk solids uniformly into the plastics compounding process. Screws also serve to stop the material flow when the screw feeder is stopped and prevent flooding effects with fluidizing bulk solids.

Calcium carbonate's tendency to compact also occurs on metal surfaces like the feeder's screws. For this reason, two intermeshing co-rotating self-wiping screws are needed to keep the screw surfaces clean and free of material buildup.

Weighbridge

The weighing system can range from small capacity platform scales to large three point suspension scale systems. All K-Tron weighing systems employ patented, digital Smart Force Transducer™ (SFT) weighing technology with

1:4,000,000 in 80 ms weighing resolution as well as vibration and temperature drift immunity.

Sample Feeding System

Table 2 shows an example of ideal feeding systems for two calcium carbonate samples.

Conclusion

The correct design of a pneumatic conveying and/or feeding system for calcium carbonate in plastics compounding operations is not a trivial proposition because of the number of variables that affect powder flow. The return on investment (ROI) of a plastics compounding plant hinges on the proper selection of the most cost-effective pneumatic conveying and feeding system. Particle characteristics as well as particle interactions with other particles, with equipment and with the environ-

ment influence the selection of equipment and system design. Coperion K-Tron's experienced systems engineering group has the know-how to design the smart solution for any application.

The Coperion K-Tron Advantage

- Every solution is developed by drawing from Coperion K-Tron's extensive experience in providing material handling solutions.
- Fully-equipped professional testing facilities located around the globe.
- Extensive range of conveying and feeding equipment available.
- The Coperion K-Tron Systems Group can supply integrated systems with one source management and customized controls.

Table 2:
Differences in Feeding Equipment Selection

<i>Equipment</i>	<i>Sample A</i>	<i>Sample B</i>
Feeder model	K2-ML-T60	K2-ML-D5-T35 or -S60
Hopper size	180 dm ³	50 dm ³
Agitation	ActiFlow or Arch-breaker	none
Feeding Device	twin concave screws	single auger screw / twin auger or spiral screws
Weighbridge	3 load cells	D5 platform scale



Various twin screw designs