Technology Bulletin

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An Introduction to Automated Material Conveying

Worldwide, plastics processing is conducted on a massive scale, with raw materials produced, shipped, and handled in extremely large volumes. They are delivered to processing plants in large, skid-mounted cardboard boxes called gaylords; in oversized reinforced plastic bags (super sacks); in skidded stacks of paper bags; or by railcar or truckload. Once in the processing plant, these resins usually are handled with a pneumatic conveying system that typically consists of a system of pipes, manifolds, valves, and controls that derive their motive force from a high-velocity stream of air. Typically, this air stream moves as a result of a differential in vacuum pressure that is created at the head of the system by a vacuum pump. In smaller, self-contained conveying systems, the vacuum may be created by a motor or by a fast-moving stream of compressed air that is pulled past a venturi. When granular, pelletized, or powdered materials are exposed to this vacuum pressure differential, they are drawn into the pneumatic conveyor, suspended in the air stream, and moved to their destination.

Figure 1. Raw material usually arrives at a plastics plant by bulk transport.

There are many advantages to pneumatic conveyance in a plastics processing plant: Contamination is held to a minimum. Waste and spillage are minimized, resulting in a cleaner plant and lower housekeeping costs. Personnel accidents, from lifting, or moving resins, or from slips and falls on spilled resin can be virtually eliminated.

While conveyors can be designed and optimized in many different ways, virtually all have many operating features and requirements in common. Each must create and sustain certain types of velocity required to move pellets through the system:

- **Minimum surface velocity** – the velocity required to move a specific material through the system without damage.
- **Settling velocity** – the velocity required to keep materials suspended and flowing in the air stream
- **Drop-out velocity** – the velocity required to lift pellets in vertical segments of the system

All plastic materials have certain characteristics which govern the amount of power or velocity required to move them properly. The specific gravity of a material is related to the amount of air that will be required to lift and move particles or pellets of it through the system. The bulk density of materials (in powders, granules, or pellets) is an important determinant of the size of pipes and receivers in the system.

Materials with bulk densities between 25 and 55 lbs/ft^3 (400 to 880 kg/m^3) are relatively easy to convey, while heavier materials may require more power. Lighter materials have no effect on power requirements, but may require additional system or storage space.

Other material characteristics can create special challenges or problems in the system.

Characteristic	Material behavior	Solution
Friability	Tendency to break into fine particles	Filtration
High cohesiveness	Tendency to clump together	Avoid pneumatic conveying
High abrasiveness	More difficult to move, with a tendency to scratch and scuff the system	Reduce air velocity Utilize special bends and wearplates
Low melting point	Tendency to form stringy "angel hairs" that stick to bends of piping system	Avoid velocity in excess of recommendations Convey with chilled air Use special bends
Acidity	A tendency to corrode system elements	Use corrosion resistant system materials
Aerated/De-aerated	Aerated materials flow freely in air; De-aerated materials tend to pile up and block airflow	Avoid moving de-aerated materials through system

A variety of factors, including the size of the plant, influence the processor's decision whether to install a centralized vacuum conveying system or utilize one or more self-contained loaders, which will be introduced below.

Figure 2. Providing the power behind most large central conveying systems are positive-displacement pumps like those seen here.

High-volume, long-distance material conveying requires the use of the most powerful type of vacuum pump: a positive displacement vacuum pump. Available in a range of sizes, positive displacement pumps use a powerful rotating lobe blower, protected by a vacuum relief valve, and are factory set to draw 12 in. (30 cm) of mercury. These pumps operate on three-phase power and incorporate a filter to protect the pump's inner workings. Due to their power, they can be quite noisy, and so often require a sound enclosure if located near working area. Central dust collection systems are installed just upstream from these large pumps to minimize the amount of residual particles, dust, or other contaminants that are generated by the conveying process.

Peripheral vacuum pumps are ideal for small to medium-sized resin-conveying applications. They are capable of moving free-flowing materials up to 200 ft (61 m) at rates of up to 3,000 lb (1360 kg) per hour or of supplying vacuum power to several smaller loaders at the same time. If dust generation is not a major problem, it is possible to substitute a filter canister for a central dust-collection system. If frequent loading cycles are expected, the pump may be equipped with a sequencing valve that allows the pump to run continuously and eliminate excessive starting and stopping. An aftercooler will protect the pump by keeping temperatures down.

Regardless of size, central conveying systems have a similar physical layout. The pump is at one end, preceded by a filter or dust collection system. At the other end are material receivers that are mounted on surge bins and other storage

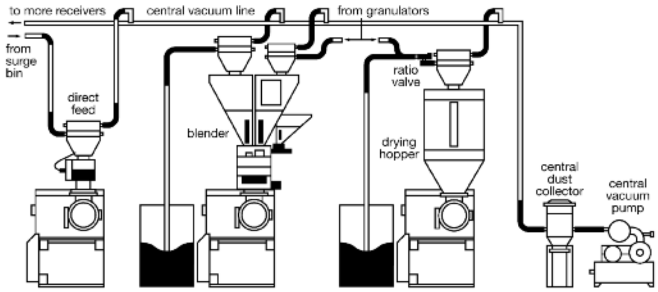

Figure 3. This schematic shows many of the components in a central vacuum conveying system.

containers, hoppers that serve individual molding machines, or hoppers located on conditioning equipment like dryers, blenders or feeders. Operation of the entire system is directed through an integrated control system.

Receivers and Loaders

Vacuum material receivers provide the end point for materials drawn through a vacuum conveying system. Normally located near processing machines, they consist of a body, lid, and filter and are equipped with inlet and outlet connections. These connections are linked via tubes to the main vacuum line. Receivers often sit on top of some type of hopper, enabling pellets or other materials to be delivered directly to a point of use such as a blender, dryer, or processing machine.

As materials are drawn by vacuum through the main line, they are diverted to a single receiver through control system inputs that isolate the receiver by closing off a sequence of valves. This diverts the vacuum-driven flow to the receiver where the material loses velocity, and falls into the receiver. The vacuum air, no longer carrying the material, passes through the filter and returns through the dust collector to the vacuum pump. Ordinarily, the level of material in the receiver is monitored by a level switch, which signals the central system to stop loading the receiver when it is full.

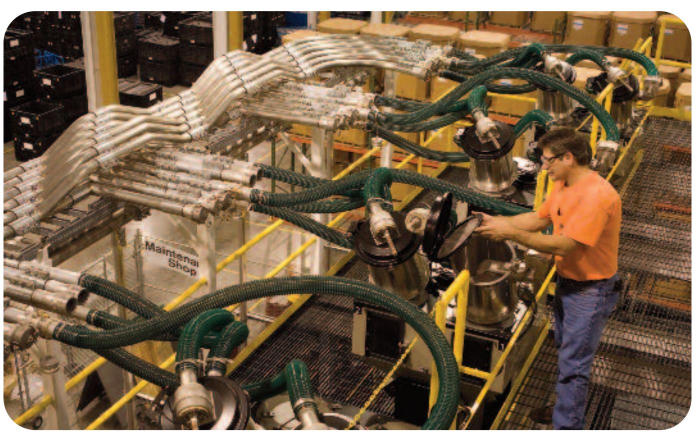

Figure 4. Vacuum material receivers, like these shown on a mezzanine above a blending station, separate plastic pellets from conveying air and deliver the resin to processing machines.

When the vacuum cycle is completed and the material is enclosed in the receiver, a flapper valve opens and allows the material to fall from the vacuum receiver into the hopper or the machine throat. The flapper then closes, ensuring that vacuum can be held through the receiver on the next conveying cycle.

As noted, multiple receivers usually are connected to a single vacuum source. Each is equipped with vacuum sequencing valves, which are controlled at a receiver-mounted terminal box, with electronic connections to the master control panel for the entire system. Other control functions associated with receivers include material-line valve controls (for common material line isolation), internal demand-level switches, ratio valves to enable virgin/regrind mixes, and direct or gravity feeds.

For many years, vacuum receivers looked very much like the cone-shaped hoppers that are common on injection molding machines. A lid was added to accommodate material inlet and vacuum outlet connections or, in the case of self-contained loaders (see below), a vacuum motor would be mounted to the lid. More recently, however, Conair has

Figure 5. Conair Access receivers are angled to allow easier maintenance and cleaning.

re-envisioned the vacuum receiver. With the trend toward lean production techniques such as fast job and mold changes and lean inventory management, direct feed “hoppers” appeared. These units usually have a cylindrical body, often made of clear glass, mounted on the feed throat of the molding machine. Only a small amount of material would be held at any given moment so they were much easier to clean out during a material change. Also, when loading dried material, residence times are reduced, minimizing the possibility of moisture regain in the receiver. When supported by appropriate automation and a well-engineered pneumatic conveying system, direct feed provides a continuous and reliable supply of resin while eliminating the time required to clean out and manage excess resin in the machine hopper when it is time for a new job to run.

More recently, Conair has developed angled receivers made from spun tubes instead of welded sheet. They are substantially easier to manufacture, which keeps costs down, and the angled receivers make it much easier for operators to reach inside for cleaning or other maintenance.

Self-Contained Loaders

As an alternative to the dedicated vacuum pump, piping, and controls involved in a central conveying system, molders can employ one or more self-contained vacuum loaders.

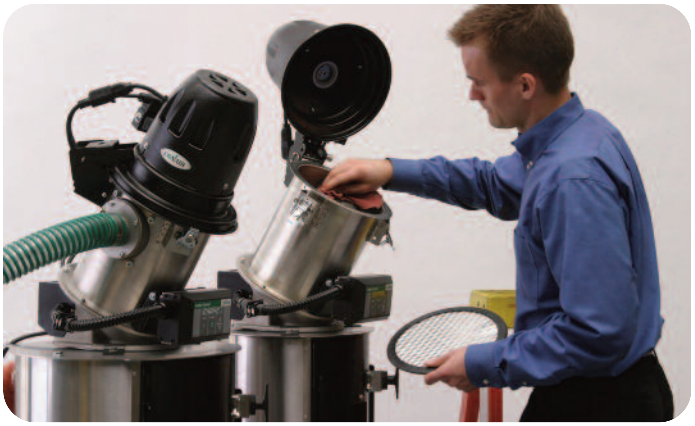

Figure 6: Self-contained loaders use a built-in vacuum motor or venturi vacuum generator and can operate independently of a central vacuum system.

These can be used either as a supplement to a larger central system, or as a substitute material handling system. The function of self-contained loaders is identical to that of a central vacuum system, but these loaders operate locally rather than centrally.

Self-contained loaders are available in a range of sizes. They provide a versatile, portable conveying capability suited to moving pelletized or regrind materials to hoppers, bins, or processing machines. The smallest self-contained loaders are designed for low volume conveying to small machine hoppers, drying hoppers, or additive bins on feeders or blenders.

Larger models provide a larger body, motor, and filter and move larger volumes of material. While basic loaders are available in standard or built-to-order configurations, others are far more modular and flexible in design, enabling a wide range of configurations:

- Ratio loading capability (for virgin/regrind mixing)
- Closed-cycle air purging between different materials
- Automatic, post-load filter blowback and cleaning
- Gravity or air-powered discharge (for materials with poor flow)
- Direct-feed viewing chambers for machine throat loading

And, thanks to an ever-expanding array of controls, these loaders offer easy conveyance of both virgin and regrind materials, remote operation, and quick-connecting components to simplify disassembly, cleaning, and reassembly.

Material Handling Controls

There are three basic approaches to controlling central material handling systems. The original approach, referred to as central I/O (input/output), has each controlled device (usually loaders) wired discretely back to a main control panel. This configuration requires the lowest possible equipment investment, but the complicated wiring increases installation costs. Still these control systems remain viable for smaller operations where the equipment layout is not likely to change.

Larger plants tend to install control networks utilizing "remote" or "distributed" I/O configurations. Remote I/O configurations have I/O hubs strategically located around the plant to support nearby wire material-handling equipment. Then these remote hubs are wired back to a central control panel. In distributed configurations each loader has its own I/O modules, which are linked to a common communications bus to both main and remote operator interface panels. To monitor or manage materials, personnel can utilize operator interface panels, obtain system information, or issue commands to the PLC and material handling system via a local network. These larger systems are readily scalable, able to handle simultaneous operator inputs, and capable of handling 100 or more loaders, plus pumps and related equipment.

Figure 7. From a central panel, processors can control the operation of dozens of loaders in a material handling system.

Recent advances in control technology make it easier to provide even such complex material-handling capabilities as ratio loading, purging, fill-sensing, multi-source/multi-destination, proofing, reverse regrind convey, and other high-end functions. These controls are expanding the capabilities of even relatively small, simple control systems and opening the benefits of central conveying to almost any processor.