9 Smart Design Features that make Coperion K-Tron feeders more accurate

coperion
K-TRON

9 Smart Design Features
that Make Coperion K-Tron Feeders More Accurate than Ever!

For over 50 years Coperion K-Tron has set the pace for quality and innovation in bulk solids feeding. With over 100 feeding and weighing technology patents worldwide, Coperion K-Tron continues to advance the state of the art.
Below are just some examples of how Coperion K-Tron's tradition of innovation translates into performance-enhancing features that directly benefit you, the bulk solids processor.

1

High-Resolution Digital Weighing

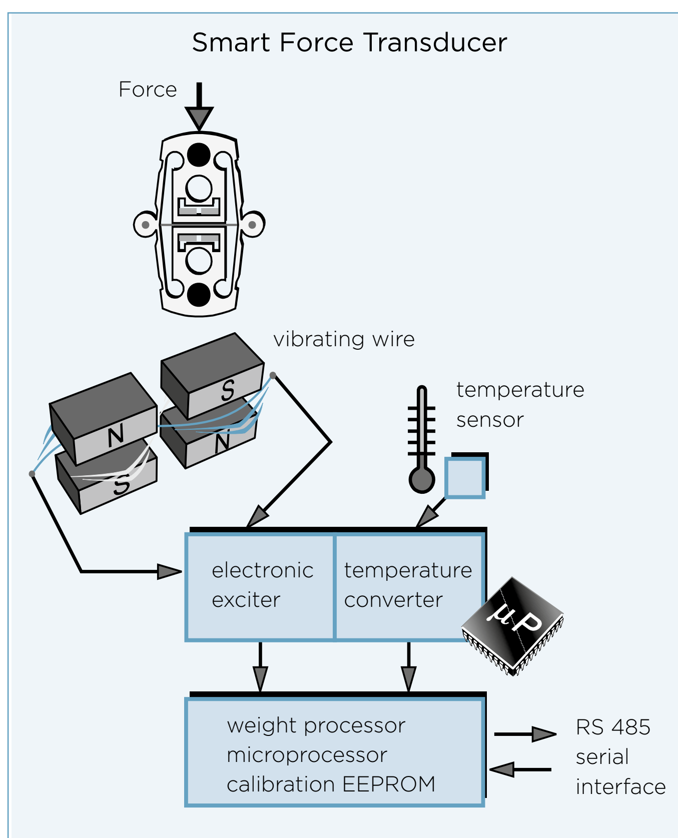
High feeding accuracy begins with precise, high-resolution weighing. Coperion K-Tron pioneered digital vibrating wire weighing technology with the introduction of its two-wire DMT load cell. Today, Coperion K-Tron's single-wire Smart Force Transducer (SFT) represents more than 40 years of evolution and intense development to provide economical, drift-free 1:4,000,000 weighing resolution in 80ms.

Coperion K-Tron's SFT weighing technology provides true digital measurement, affording stable, highly accurate weight sensing plus simple, zero-loss serial data communications. SFT technology exploits the dependency of a vibrating wire's resonant frequency on its tension to measure applied loads. Through mechanical means the applied load is transmitted to the wire causing a change in its resonant frequency from which the value of the applied load is computed in 32-bit precision by an on-board microprocessor. A fully calibrated (linearized, spanned, and temperature compensated) signal is transmitted via RS485 serial communication to the Coperion K-Tron controller. Weight data from as many as twelve SFTs can be transmitted reliably in interference-free digital format over distances of up to 500 meters (1,640 ft).

Coperion K-Tron's SFT technology provides ultra-high weighing resolution, key to feeding accuracy. The resolution of a weight sensor is the smallest weight increment that can be confidently measured. Resolution may be expressed either directly in weight units or as a proportion of sensor range (1:10,000, for example). Two classes of weight sensors are in use today: analog and digital. For analog weight sensors such as the strain gage or LVDT, a distinction between measured resolution and claimed resolution must be drawn. Because its measurement signal is a voltage or current, an analog sensor has the theoretical potential for effectively infinite resolution; that is, *if* it could be converted into an actual measurement. In practice, however, analog sensors have many difficulties to overcome. For example, they are not mechanically perfect, and their properties and performance change with age. Additionally, the output of analog sensors is typically a very low-level signal, often spanning only a few millivolts over its entire operating range. Attempting to digitize this low-level signal requires a very stable power supply and significant amplification. These signals are susceptible to electrical noise, and the many analog components present in A/D converters also change over time.

As a result, although an A/D converter may provide 16 or even 20 bits of display resolution (e.g. 1:250,000), the actual measurement resolution of the system is typically much less, on the order of 1:10,000-30,000 full scale. Additionally, most A/D converters necessarily sample the data periodically rather than continuously, effectively ignoring a portion of the weight data, further compromising the accuracy of the weight measurement.

The resolution power of the digital approach, as exemplified by Coperion K-Tron's vibrating wire Smart Force Transducer technology, does not rely on post-measurement amplification and digitization of a millivolt-level signal. Rather, it counts the exact number of the thousands of wire vibrations occurring during a brief, accurately timed measurement period. This approach is truly digital in nature. Errors associated with amplification or digitization are nonexistent, and all available weight data is captured. SFT weighing technology is capable of delivering a true measurement resolution in excess of 1:4,000,000 in 80 ms. To equal the resolving power of this digital approach, the strain gage or LVDT would have to sense changes in the microvolt range, and would have to accurately preserve such a small change in output through the processes of amplification and digitization.

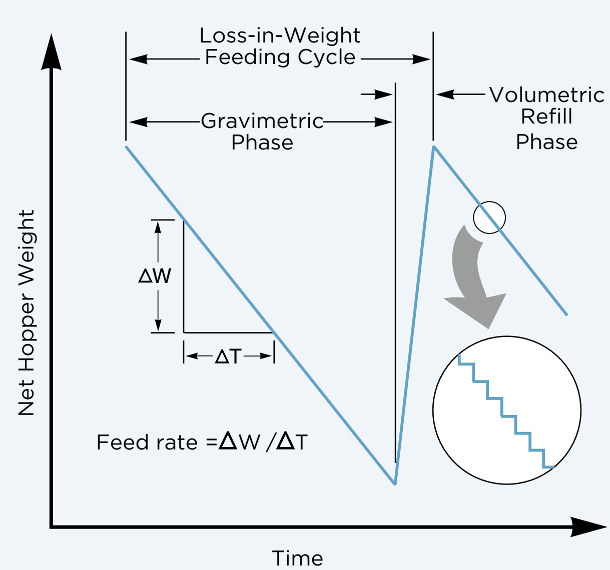


2 Fast Weighing and Control

Many of today's demanding processes require high feeding accuracy over very brief timescales, often just a few seconds. Coperion K-Tron's advanced weighing and loss-in-weight control dynamics enable up to 112 weighments and 12 associated control adjustments to be performed every second, optimizing instantaneous feeding performance in these critical applications.

In loss-in-weight feeding, system weight declines with time. The mathematical slope of system weight vs time represents feed rate. In practice, targeted system weight declines in many small, brief steps. The descent of each step is the reduction in system weight to be achieved over the time interval represented by the width of the step. As each step is completed, measured system weight is compared to targeted system weight, and any difference will give rise to a corrective speed signal. If measured weight is less than target weight, too much material has been discharged, and metering speed will be reduced. Conversely, if too little material has been delivered, measured weight will exceed target weight, and metering speed will be increased. While this approach provides a basic means of feed rate control, of concern to processors requiring a high degree of short-term feeder accuracy is the width (duration) of the steps, and the number of distinct control actions that will occur during a typical 'momentary' timescale. Additionally, to ensure the best momentary performance, any deficit or excess of material delivered during one step must be corrected in the next. Since the number of discrete control actions contained in a typical 'momentary' performance timescale is lowest for low-rate applications, it is these instances that deserve closest scrutiny. For low rate feeders (<10 lb/hr) employing low measurement resolutions on the order of 1:30,000, only 1 to 2 control actions are typically possible over a timescale of 5-10 seconds, while with the measurement resolution of 1:1,000,000 afforded by Coperion K-Tron's SFT weighing technology, 60 to 120 control actions are typical in similar application. As explained above, when a 'step' is completed any difference between the measured and targeted system weight will give rise to a corrective control action. However, to compensate for previously detected under- or over-feed conditions, an additional metering speed correction is invoked. To provide compensation, the controller automatically totalizes net cumulative feed rate errors and augments its current command signal to quickly correct the overall deficit or excess.

Loss-in-weight Feeding
Principle of Operation

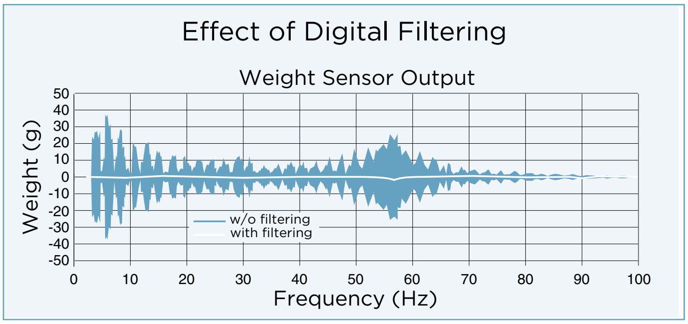


3 Vibration Immune Weighing

Achieving high gravimetric feeding performance on the process line requires discriminating between weight data and the contaminating effects of inertial forces induced from ambient vibration and shock. Coperion K-Tron's exclusive dynamic digital filtering algorithm continuously identifies and extracts spurious inertial components from the weight measurement, even in severe process environments.

Ambient vibrations transmitted through the feeder's mechanical connection with its operating environment can adversely affect weighing accuracy, especially in the short term. While the use of flexible connections and shock mounts reduce the transmission of vibration forces to the weighing system, the ideal approach is one that combines these measures with a weighing system that is itself able to discriminate between the load to be measured and the transient forces imposed by vibration. To address this challenge, Coperion K-Tron's SFT vibrating wire weighing technology employs sophisticated digital filtering to identify and extract frequency components characteristic of in-plant vibration. All filtering is performed in real time by an on-board microprocessor. SFT weighing technology delivers reliable, high-resolution performance even in process environments where vibration from nearby motors and machinery is present. To distinguish between the load to be measured and the forces induced by vibration, a sophisticated digital filtering algorithm is applied to identify and extract frequency components characteristic of in-plant vibration.

For a weighing system measuring varying loads in a typical plant environment (which includes all gravimetric feeding equipment) a simple weight averaging filter does not work well at all. The result with such a simple filter, even under ideal conditions of a constant vibration frequency, is a significant delay in the output signal. Under real plant conditions where the feeding system is exposed to varying vibration frequencies as surrounding machinery starts and stops, the output of a simple averaging filter displays erroneous



weight changes. The net result is degraded feeder performance. Coperion K-Tron's SFT technology employs a digitally implemented filter specifically designed for gravimetric feeding applications. Because the filter is implemented in a digital form it is easy to adjust the filter's performance by changing its gain settings. The default filter gains have been optimized to achieve a steep slope for the selected cutoff frequency while still providing a fast settling time with minimal overshoot. Filter gains can be adjusted by the feeder controller through the serial communication link based on the type of feeder being controlled, feed rate setpoint, and other dynamic feeding conditions.

In the accompanying illustrated example, two vibrating wire scales, each carrying a 10 kg static weight, were subjected to +0.025 G vertical vibration at frequencies ranging from 3 to 100 Hz. The two scales were identical except for the fact that one scale used non-digital filtering while the other scale employed Coperion K-Tron's exclusive digital filtering algorithm. Half-second weight measurements were recorded at 0.25 Hz intervals throughout the test range. A five-second interval was allowed between measurements at each frequency step. The top plot shows significant signal contamination associated with the sensor employing non-digital filtering. In contrast, the lower plot illustrates the effectiveness of Coperion K-Tron's digital filtering in suppressing vibration. While effective throughout the test range, Coperion K-Tron's digital filtering has been specially configured to suppress vibrations most characteristic of the typical plant environment: 10 Hz vibrations are diminished by a factor of 20,000, and 20 Hz vibrations by 200,000.

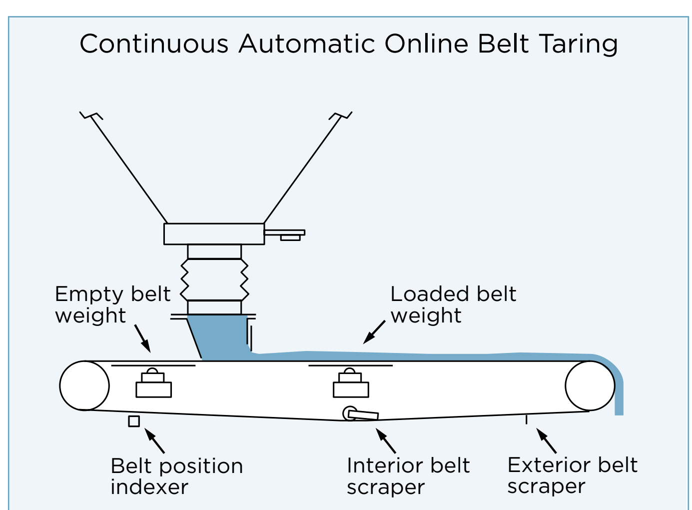
4 Weigh Belt Re-Taring

Coperion K-Tron's exclusive Continuous Auto-Tare feature eliminates out-of-tare feed rate errors and tedious, periodic weigh belt feeder recalibration. A second SFT weight sensor, positioned upstream of the material bed, continuously senses empty belt weight. The controller then subtracts indexed belt weight from the load measurement, assuring moment-to-moment accuracy even with sticky materials.

Weigh belt feeders are often a good choice when feeding relatively free flowing materials not requiring containment. Weigh belts operate by continuously weighing a moving bed of material on its short conveyor, and controlling belt speed to result in the desired flow rate at discharge.

Taring or zeroing is a major concern since both the belt and material are weighed, and any error in tare produces a repetitive and systematic error in feed rate. Sources of potential changes in tare include belt wear, impregnation of material into the belt, and adherence of material on the belt. Changes in belt weight due to material buildup are inevitable, and the use of a belt scraper at discharge and elsewhere within the feeder minimizes but, for many materials, cannot eliminate the concern. Thus, periodic taring has historically been required.

Early efforts to address the issue of periodic taring included partial automation of the taring procedure. Upon user demand the empty belt feeder would be cycled through a single belt revolution and a single tare value correction would be automatically generated. To account for variations in belt weight along the length of the belt (important in lower belt speed applications), an indexing feature was later added so belt weight could be measured and recorded inch-by-inch along the belt's length. During operation, these indexed belt segment tare values would be applied in order as the corresponding belt segment passed over the weighing section. While both these measures simplified the taring process and made it more accurate, taring remained a burdensome and periodic requirement, and tare drift remained a problem.



To resolve these difficulties and fully automate the taring process, Coperion K-Tron developed its exclusive Continuous Auto Tare feature. By adding a second weigh sensor upstream of the material inlet where no material bed is present, taring can be accomplished accurately, automatically and continuously on-line without emptying the feeder. This approach to real-time, fully indexed taring eliminates concerns of belt weight variation regardless of cause, and helps ensure the highest possible weigh belt feeding accuracy.

5

Smoother Discharge

Single screw loss-in-weight feeders operating at low rates often produce an unsteady discharge within one revolution of the screw, resulting in mass flow pulsation. Coperion K-Tron's exclusive Screw Speed Modulation algorithm records the pulsation and adjusts screw speed to compensate for the effect, minimizing mass flow variability. In critical timescale applications where high accuracy must be maintained over short sample times, discharge pulsation can significantly increase sample-to-sample variability. Possible mechanical remedies include conical screws, rotating tubes, extended tubes, threaded spiral ends, paddles, etc. Depending on the application some are feasible, others not. And despite additional costs for these solutions there is always a residual pulsation.

To minimize the pulsation effect without mechanical means, Coperion K-Tron's exclusive Screw Speed Modulation algorithm produces increased accuracy over short sample durations as well as at low rates (screw speeds below 60 rpm). By recording the periodic pulsation and appropriately adjusting screw speed to compensate for the effect, mass flow variability associated with screw position can be substantially reduced.

6

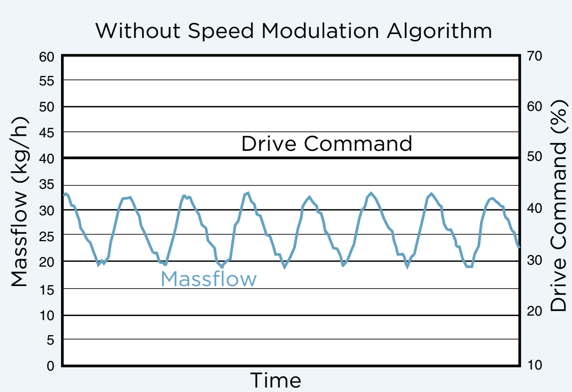
Optimized Feeder Refill

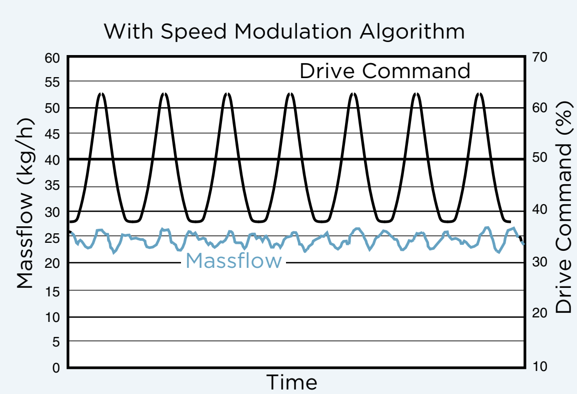
During loss-in-weight hopper refill, sensed weight is not useful to control feed rate. While others simply freeze screw speed until refill is complete, Coperion K-Tron's exclusive Smart Refill Technology memorizes recent gravimetric performance at various hopper weights and varies screw speed to compensate for changes in material density during refill, maintaining accurate performance and enabling a smoother transition to normal operation.

Due to its operating principle, loss-in-weight feeding requires that the feeder be continuously weighed. Thus, the feeder cannot be constantly resupplied with material; it must be periodically refilled. Lacking any basis for weight-based control during this brief but periodic refill phase, maintaining momentary feeder accuracy becomes a concern. Traditionally, a constant metering speed was maintained throughout the refill phase—a speed corresponding to the screw speed associated with gravimetric control just prior to entering the refill phase. If, for example, metering speed averaged 60 rpm just prior to the system sensing the need to refill the supply hopper, screw speed would be maintained at that 60 rpm for the full duration of the refill operation. After refill was completed, material had settled, and the feeder sensed an appropriately declining system weight, the feeder would be returned to gravimetric operation where metering speed once again became the parameter of control.

The problem with the traditional approach is that in most cases bulk density within the metering zone (the area from which process material is drawn) increases as material rises in the hopper. When metering speed is held constant throughout refill, an overfeed condition will be experienced. Then, when gravimetric control is restored after refill completion, the feeder will sense the high density condition and will abruptly reduce screw speed. Laboratory tests and field experience involving many hundreds of materials show that, in practical terms, headload-related loss-in-weight overfeeding may range anywhere between 1% for relatively constant-density materials to 10-15% for powders and other materials whose density can vary substantially.

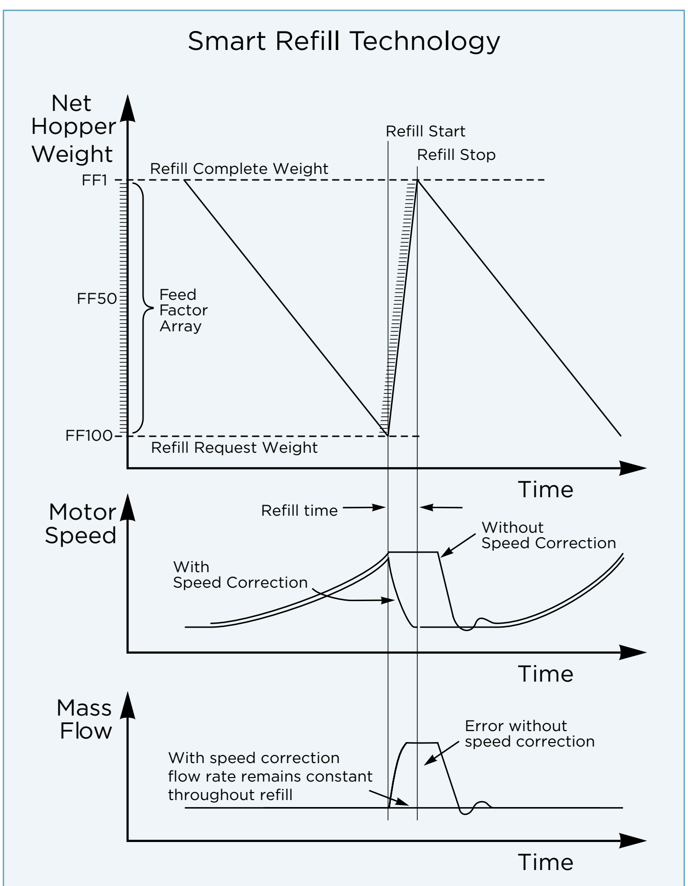
Effect of Screw Speed Modulation Discharge Pulsing





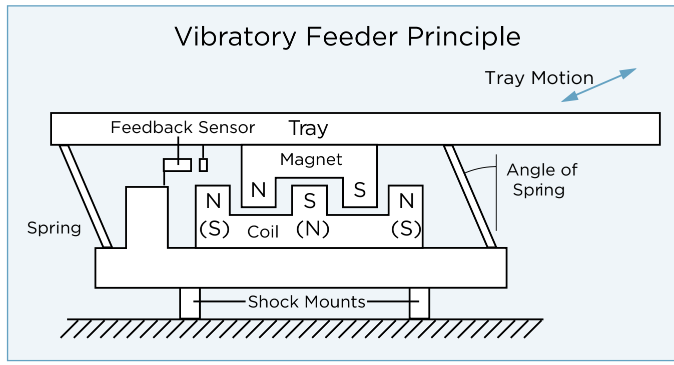
The preferred solution to this problem begins with determining the relationship between system weight and material density within the feeder's metering zone. If that relationship is known, metering speed need not be held constant throughout refill but may be smoothly reduced as the hopper is refilled in such a manner as to avoid overfeeding and preserve feeder performance throughout the refill phase. To ensure the highest possible feeder accuracy throughout the refill phase, Coperion K-Tron developed a concept called the refill array to enable metering speed to be gradually adjusted during refill to precisely counterbalance the effects of variations in material density occurring within the metering zone as hopper weight increases.

During refill, metering speed is determined by an array of indices called feed factors. These values correspond to material density and its mechanical behavior within the feeder. They are computed and stored during the entirety of the gravimetric feeding phase immediately preceding each refill. On the basis of increasing hopper weight during refill, material density within the metering zone may be inferred, and a metering speed corresponding to its feed factor array value may be used. In this way gravimetric feeding accuracy during the brief refill may be maintained, and, once refill is complete, re-entry to gravimetric operation is smooth.



7 Advanced Vibratory Feeding

Where uniform discharge is critical, especially at very low rates, Coperion K-Tron's patented 3-loop loss-in-weight vibratory feeders are the choice. One control loop maintains tray resonance, a second loop varies amplitude to control rate, and a third loop reflects the mechanical dynamics associated with the unique combination of material and feeder to trim output to the highest attainable accuracy.



In vibratory loss-in-weight feeding the system controls the motion of the tray. This motion includes tray displacement as well as the rate of oscillation. The vibratory drive motor consists of a permanent magnet and an electromagnet, also known as a coil. As the control signal voltage level changes, the magnetic field generated by the coil changes intensity, and as the control signal changes sign, the coil's magnetic field changes polarity. This changing of the coil's magnetic field strength and polarity applies force to the permanent magnet and causes the motion of the tray. Springs are mounted on an angle to the tray to force the tray in both an upward and forward motion.

The motion of the material along the tray may be characterized as a series of hops or jumps along the length of the tray. This motion is generated by the vibratory tray throwing or launching the material forward. The distance between hops is determined by the tray displacement, and the frequency (number of hops per second) is determined by the tray's oscillation frequency. Therefore, actual motion of the material is a combination of the tray displacement and frequency.

To optimize the material motion on the tray, Coperion K-Tron's vibratory control matches the frequency of vibration of the tray to the mechanical resonance frequency of the vibratory system and material regardless of friction, tray loading, and temperature effects. At this frequency the power required for a given displacement is at a minimum, and the efficiency of the vibratory motor is maximized. This more efficient drive requires less voltage and hence a smaller transformer and power supply. Resonance tracking also eliminates the need to tune the system for a fixed frequency. Displacement control adjusts the command frequency to maintain a constant displacement. Displacement control accounts for changes in the system such as added friction from the non-linear behavior of the flexures and material flow in the inlet.

Actual displacement is measured by a sensor inside the vibratory unit. This sensor produces the feedback signal which is a sine wave whose amplitude is directly proportional to the tray displacement. Vibratory drive voltage is varied to maintain displacement.

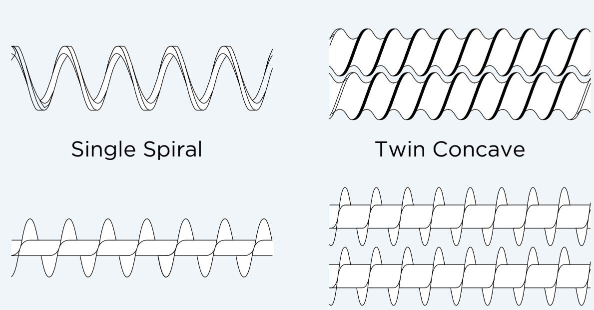
After the vibratory controller start-up, the resonance tracking system algorithm initiates. This algorithm runs at one-tenth of the rate of the displacement control algorithm (i.e., for every ten updates of the signal's amplitude to maintain displacement, the signal's frequency is changed). The frequency is changed to minimize the phase angle. After the minimum point is passed, the tracking algorithm changes the direction of the frequency modifications and cuts the frequency change step size in half. The minimum frequency step size is 0.01 Hz. Assuming the vibratory system is undisturbed, the algorithm tracks the operating frequency to the resonance point and passes back and forth across this point in small steps. The tracking algorithm is always operating and the frequency of the output signal is never locked. In this way highly accurate vibratory loss-in-weight feeding is made possible, with the added benefit of smaller, more economical drive components operating at much reduced power requirements.

8 Most Material Handling Solutions

Over fifty years of feeding more than 7,000 process materials worldwide, Coperion K-Tron has developed the widest array of feeding and material handling and conditioning solutions available. Today, with practical innovations such as the PowerSphere feed bowl for superior screw fill, Coperion K-Tron continues to advance the material handling state-of-the-art.

To effectively and reliably feed a broad range of materials, Coperion K-Tron has developed an extensive array of screw sizes and geometries, each with its own ability to handle a particular type of material over a specific range of rates. Each screw design is offered in a range of diameters and pitches to cover nearly any desired feed range.

Basic Screw Geometries



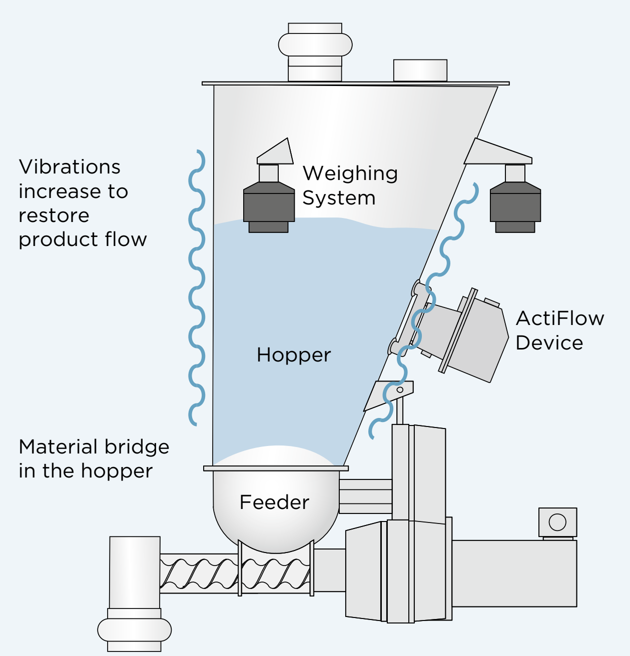
Of special note is the basic distinction between the material handling capabilities of the twin screw versus single screw or auger design. Where two screws intermesh and co-rotate, the result is the formation of relatively sealed, forward-moving pockets of material. Thus, the twin screw acts in the sense of a positive-displacement pump to first capture floodable or hard-to-flow materials, and then forcibly move them to discharge. An added advantage is the self-wiping action of the screws that helps keep the screw surfaces clean and free of buildup. Single spiral or auger screws, on the other hand, do not possess this positive displacement type pumping action, and thus are not recommended or appropriate for floodable or sticky, hard-to-flow materials.

Coperion K-Tron's PowerSphere feed bowl was developed to provide highly consistent screw fill, using a horizontal agitator with most materials to achieve good screw fill. By filling the screw consistently, regardless of head pressure, fewer and less drastic adjustments to screw speed are required and accuracy is enhanced. The unique hemispheric design acts to regulate material pressure directly above the screws whether the hopper is full or nearly empty.

Coperion K-Tron's Quick Change/Clean Feeder is a versatile model that includes interchangeable twin screw (T35) and single screw (S60) bowl/screw sets, allowing quick and easy interchange when materials change on short, customized runs.

Coperion K-Tron offers a variety of hopper designs and agitation methods for handling troublesome materials. Sticky, hard-to-flow, or compacting materials may require some form of agitation in the hopper zone to assist flow, condition the material to a roughly consistent density, and to ensure uniform screw fill, all of which

ActiFlow Principle of Operation



are required for the best feeding accuracy, especially over short intervals. For these materials available options include the use of an arch breaker agitator in combination with the horizontal agitator, full vertical agitation (which eliminates the horizontal agitator) or the new ActiFlow bulk solid activator which reliably prevents bridge-building of cohesive bulk materials with no material contact.

9 Single Source Systems Solutions

Individual feeder accuracy is only part of the performance puzzle. The entire material handling system must work together to achieve a quality end product. Coperion K-Tron offers seamless feeder refill by integration of Coperion K-Tron vacuum loaders into SmartConnex feeder controls. SmartConnex feeder controls offer easy communication to most plant PLCs via SmartLink boards included in the feeder's Coperion K-Tron Control Module (KCM). In addition, the Coperion K-Tron Systems Engineering Group can supply the complete material handling system.

Recent surveys have shown that processors prefer to purchase an integrated solution over buying discrete pieces of equipment that require engineering to function together. Coperion K-Tron goes beyond feeders and vacuum conveyors to engineer, deliver and warranty complete material handling systems.

Processors can select the level of integration they prefer:

- Feeder line integrated into plant PLC via the SmartLink solutions offered in the SmartConnex Coperion K-Tron Control Module (KCM)
- Integrated Feeder refill with self-contained or single central Coperion K-Tron vacuum conveyors controlled via feeder SmartConnex controls
- A complete material handling system designed and delivered from the Coperion K-Tron Systems Engineering Group

Coperion K-Tron's systems engineering group can help you pull together all the pieces to your feeding system puzzle. With over 35 years experience providing complete feeding systems to the full spectrum of the process industries, Coperion K-Tron is the single source supplier of feeding systems. From storage hoppers to support structures, and from FIBCs to PLCs, if it's part of your feeding system, Coperion K-Tron can deliver quality engineering and full customer support with single source economy and responsibility.

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