Top Ten Frequently Asked Questions on Feeder Accuracy

An introduction to the principles and practices of bulk solids feeding

coperion K-TRON

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An Introduction to the Principles and Practices of Bulk Solids Feeding

Feeder accuracy is a concern of any processor who has to control the flow of bulk solid material. This handy guide attempts to answer the most common questions surrounding the area of feeder accuracy, and should serve to form a working knowledge of the basics of continuous feeding.

While applications can range from the simple regulation of a single material to highly complex and sophisticated, multi-ingredient blending systems involving many feeders and processing lines, this discussion will limit its focus to individual feeder accuracy.

By combining a presentation of the principles of feeder accuracy along with the practical aspects of their application to real world process operation, it is hoped a more useful and rounded understanding is achieved.

? one

"How is feeder accuracy defined?"

To fully define feeder accuracy it is necessary to address three separate and distinct areas of feeder performance: repeatability, linearity and stability. Repeatability reports how consistent the feeder's discharge rate is at a given operating point, linearity assesses how accurately the feeder discharges at the requested average rate over its full operating range, and stability gauges performance drift over time.

Repeatability

This measure of feeder accuracy, commonly termed precision, is the performance statistic most familiar to feeder users. It quantifies the short term level of consistency of discharge rate. Repeatability is of importance to quality assurance because it measures the expected variability of the discharge stream, and hence of the product itself.

The repeatability measurement is made by taking a series of carefully timed consecutive catch samples from the discharge stream, weighing them, and then calculating the ± standard deviation of sample weights expressed as a percentage of the mean value of the samples taken. The measurement is typically performed at the nominal intended operating rate of the feeder. (If the feeder is to operate over a wide range of rates, repeatability measurements may be taken at several points within the range.)

For example, owing to the random nature of repeatability errors, if sampling shows a standard deviation of ± 0.3% it can be said that 68.3% of sample weights will fall within the ±0.3% error band (1 Sigma), 95.5% will occur within ±0.6% (2 Sigma), and 99.7% will lie within ±0.9% (3 Sigma).

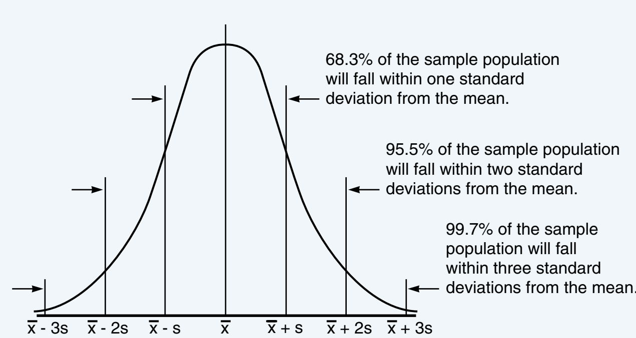
Traditionally, repeatability has been expressed at two standard deviations (2 Sigma) over minute-to-minute sample periods. However, due to the increasing demands of downstream processing equipment and end product quality standards, some processors are now specifying repeatability at up to 6 Sigma or sampling periods as short as several seconds. Where such short sampling periods are required, a corresponding lowering of precision is to be expected.

A complete expression of a repeatability statistic must contain the following elements: a ± percentage error value, the Sigma level, and the sampling criteria. For example, a repeatability performance statement might take the following form: ±0.5% of sample average (@ 2 Sigma) based on 30 consecutive samples of one minute, one kilogram, one belt revolution, or thirty screw revolutions, whichever is greater.

Linearity

Note that the repeatability statistic reveals nothing at all about whether the feeder is delivering, on the average, the targeted rate. Repeatability only measures variability of flow rate. Rather, it is the linearity statistic that reports how well the feeder delivers the desired average rate throughout the feeder's operating range. Perfect linearity is represented by a straight-line correspondence between the setpoint and the actual average feed rate throughout the feeder's specified turndown range from its design full scale operating point.

To perform a linearity measurement several groups of timed catch samples must be taken from the feeder's discharge stream. Typically, ten consecutive catch samples are obtained and weighed at each of the following flow rates: 5%, 25%, 50%, 75% and 100% of full scale. (The smallest tested flow rate should be at the feeder's maximum turndown—in this case the feeder's 20:1 turndown converts to 5%.) For each of the five data sets the average sample weight is calculated, and the difference between the computed average and the desired sample weight is taken. (Note that when a group's average sample weight is less than the desired sample weight, the difference will be negative.) These weight-based errors may then be expressed in terms of percent of desired rate by dividing each difference by its respective targeted sample weight and multiplying by 100.



Standard deviation

The result is a set of five error values, reflecting average feed rate performance over the unit's operating range.

To eliminate any bias that could be remedied by mere calibration, and to reduce this set of five error values to a single number that characterizes the feeder's linearity performance, the range of the error set is computed. The result expresses the feeder's linearity performance in percent of desired operating rate.

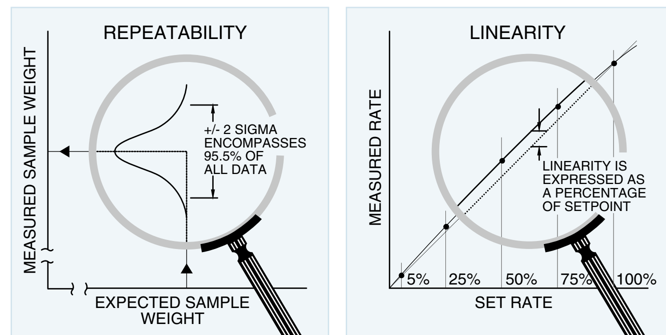
Linearity performance is thus correctly expressed only when it contains the following elements: a ± percentage error value based on set rate, the sampling criteria, and the turndown range from full scale. For example, a linearity performance statement might take the following form: ±0.2% of set rate based upon ten consecutive samples of one minute, one kilogram, one belt revolution, or thirty screw revolutions, whichever is greater, over a range of 20:1 from full scale. Note that the linearity curve depicted above right is exaggerated for illustrative purposes.

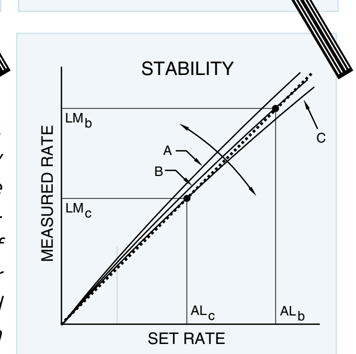
Stability

A perfectly performing feeder is worth little if it can't maintain its performance over the long haul. Many factors can potentially contribute to performance drift such as feeder type, control and weigh system stability, the handling characteristics and variability of the material, the feeder's mechanical systems, maintenance, and the operating environment itself.

Drift is detected by calibration checks, and is typically remedied by a simple weight span adjustment. In the stability diagram above right, line A illustrates a condition in which the feeder has drifted far out of calibration. Nowhere throughout the feeder's operating range does the measured rate equal the set rate. By adjusting the feeder's weight span setting the linearity curve is rotated so that perfect correspondence between set and measured rate can be established at any given point (e. g. 90% full scale for line B, or 50% full scale for line C).

The user will ultimately determine the appropriate frequency of calibration checks based on operational experience, but the question of stability is worth considering when purchasing a new feeder. Significant and ongoing cost savings in maintenance labor, off-spec product, and potential process downtime can be realized by selecting a feeder designed for stable, drift-free operation. See Question #3 for more information on calibration.





Feeder 'accuracy' is the combination of three performance parameters: repeatability, linearity, and stability. Repeatability describes flow rate variability at a given rate setting, the linearity measurement reports the range of average flow rate error over the full operating range, and stability gauges total system drift over time.

Repeatability and linearity performance are a function of the feeder's overall design as well as the material and process environment. Stability, or performance drift, is corrected by the process of periodic catch sample calibration checks. Errors in average feed rate are eliminated through span setting adjustment that essentially rotates the machine's linearity curve to re-establish a one-to-one correspondence between set and desired rate.

? two

"How do I translate process requirements into feeder accuracy specifications?"

Bridging the gap between feeder-related performance and end product quality begins with an analysis of quality standards and specifications. On the basis of that data, appropriate feeder performance specifications can be determined by simply working backwards.

Recognize that the formulation standards for an end product are typically expressed relative to the totality of the product's desired composition, and that a feeder's performance is expressed relative to its individual flow rate.

Translating process demands into feeder performance requirements must also include a careful consideration of process timescales. For example, in plastics compounding the timescale of feeder performance may be specified as the residence time during which mixing occurs within the extruder—less than seven seconds in some cases.

Factors affecting feeding accuracy within this brief timescale include feeder selection and sizing, weighing resolution, control responsiveness and environmental dynamics such as vibration and shock. For example, at a given feed rate, a smaller diameter feeder screw will rotate faster than a larger diameter one, minimizing the effect of discharge stream pulsing. Shifting to a twin screw also minimizes pulsing. A high-resolution weighing system will more finely discern weight changes, making it possible to execute more control corrections over a short interval with the result of improved short term performance. And a weighing system designed to suppress the effects of vibration will minimize signal contamination, enabling a higher level of moment-to-moment feeder performance. A fuller discussion of this important consideration is contained in a technical paper entitled "Short Timescale Feeding in Critical Process Applications" (document T-900010), available from Coperion K-Tron upon request.

The material itself also figures strongly into the equation. By their nature some materials can be fed very accurately, and others pose definite challenges. Some can be fed accurately in one physical form, and not in another. Questions such as the following need to be considered when forming realistic process and feeder specifications: What are the material's physical and handling characteristics? Can it be fed as accurately as required? Do its characteristics vary with storage conditions, time, environmental changes, or supplier? Most feeder manufacturers will be happy to perform material tests to determine optimal feeder configuration and realistic performance levels.

? three

"How do I decide whether to choose volumetric or gravimetric feeders?"

By definition, gravimetric feeders measure the flow's weight in one fashion or another, and then adjust feeder output to achieve and maintain the desired setpoint. Volumetric feeders, again by definition, don't weigh the flow. Volumetric feeders operate by delivering a certain volume of material per unit time which is then translated into an inferred weight-based flow rate by the process of sampled calibration.

As such, volumetric feeders, while simple and relatively inexpensive, are open-loop devices in the sense that they cannot detect or adjust to variations in the material's density. For materials whose density does not vary significantly, volumetric feeders may perform to the required accuracy. However, the density or flow properties of many if not most materials varies significantly enough to warrant gravimetric feeding if accuracy requirements are at all demanding. Most feeder manufacturers have the resources to determine whether a given material can be fed volumetrically at the required accuracy, or if a gravimetric feeder is required.

Since, as mentioned above, volumetric feeders are open-loop devices from the viewpoint of discharge rate, headload variations and material buildup on the flights of a feed screw change the volume-per-revolution relationship, throwing off calibration without any outward sign. Gravimetric feeders automatically detect and adjust to these conditions.

Data capture/communications is becoming an increasingly important consideration in many processes as automation and plantwide integration become more the norm. Gravimetric feeders hold the edge here in that they actually measure the flow rather than inferring it, and most feeder manufacturers now offer full-featured PC-based communication interfaces compatible with PLCs and other plantwide data acquisition or monitoring systems (SCADA).

? four

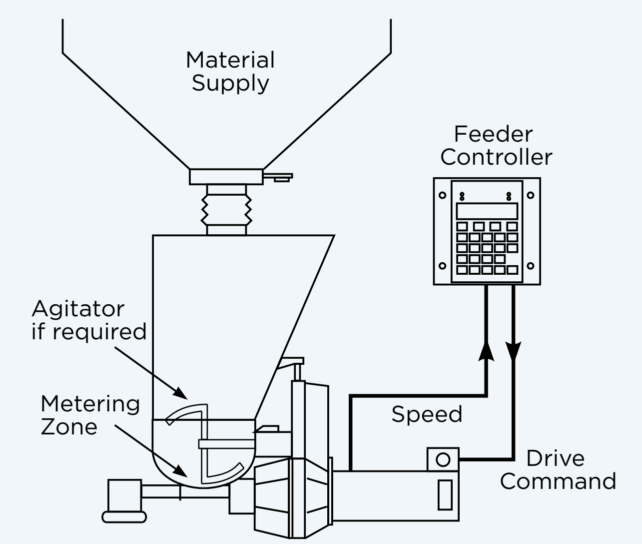
"What factors determine the accuracy of a volumetric screw feeder?"

As mentioned above, volumetric feeders operate by delivering a certain volume of material per unit time. Flow rate changes are accomplished by altering screw speed. A range of screw designs, sizes and geometries as well as agitation systems are available to optimize feeding the given material.

Volumetric screw feeders represent an economical solution to many process feeding applications where high accuracy is not a crucial concern and where direct flow measurement is not required. Basically, three factors affect screw feeder accuracy: the consistency of delivered volume per screw revolution, the accuracy of screw speed control, and material density variability.

Understandably, the highest accuracy can be attained on free flowing materials that fill the screw consistently and whose density is reasonably constant regardless of hopper level, such as plastic pellets. In that case the volume of material delivered per screw revolution can be quite constant.

When fed on a single screw feeder, more challenging materials such as highly floodable powders, or sticky or hard-



Typical volumetric feeder

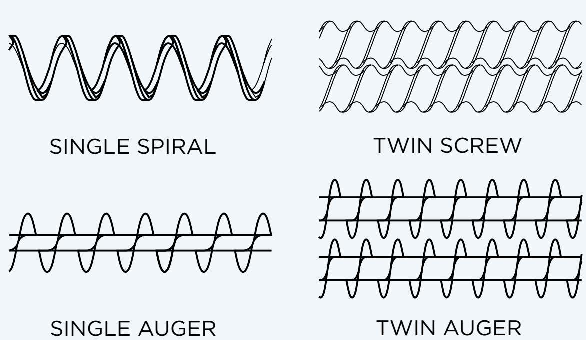
to-flow materials can cause volume per revolution to change drastically and unpredictably. For sticky materials, buildup on the screw lowers the volume-per-revolution relationship, throwing off calibration. Floodable powders, when aerated, can flow uncontrolled through the screw, rendering volume per revolution meaningless. And friable or other materials whose density can vary greatly limit the potential for high accuracy when fed on a volumetric screw feeder.

For any volumetric feeder partial or complete material blockage upstream of discharge is likely to remain undetected for some time unless the feeder is outfitted with a no-flow detector. Similarly, flood-through can also remain undetected since the feeder has no way of 'knowing' the out-of-control condition. Most gravimetric feeders can automatically detect and alarm to these conditions.

When considering a volumetric feeder the prudent approach is to work with the feeder supplier who should be able to recommend the best feeder configuration for the material, advise on agitation or other options to promote flow and minimize density fluctuations, and determine achievable accuracy.

Speed control, the other half of the volumetric equation, is less of an issue but still deserves attention because an error in speed control translates directly into a feed rate error (i.e., a 1% error in speed control results in a 1% feed rate error). Today however, most feeder manufacturers employ speed feedback control (either analog or digital) on their volumetric feeders in order to maintain closer control than in the past when open-loop control was more prevalent. Nonetheless, the prospective purchaser is well advised to inquire as to the type, accuracy and long term stability of speed control employed.

Two screws are often better than one



Traditional single screw feeders, whether using an auger or spiral screw, don't work well with many of the more difficult-to-handle materials. Thus, in the 1970s Coperion K-Tron introduced the twin screw feeder. By employing two self-wiping closed-flight screws intermeshed side by side, sealed pockets are formed to capture and transport floodable or hard-to-flow materials to discharge.

To optimize feeding performance on specialized materials such as fibrous, clumpy or friable substances, design variations of the classic twin screw, such as the twin auger, have been developed. Today, the twin screw family of designs is acknowledged as the optimum choice when feeding most difficult materials.

? five

"How does a loss-in-weight screw feeder work and what issues affect its ability to perform accurately?"

The concept is simple, but the execution is challenging. A loss-in-weight feeder consists of a hopper and feeder that is isolated from the process so the entire system can be continuously weighed. As the feeder discharges material, system weight declines. The loss-in-weight feeder controller adjusts feeder speed to produce a rate of weight loss equal to the desired feed rate setpoint.

Owing to their high gravimetric accuracy, strong material handling capability, innate material containment design, and ability to feed precisely at very low rates, loss-in-weight screw feeding has become the preferred feeding method in a broad range of industries and applications.

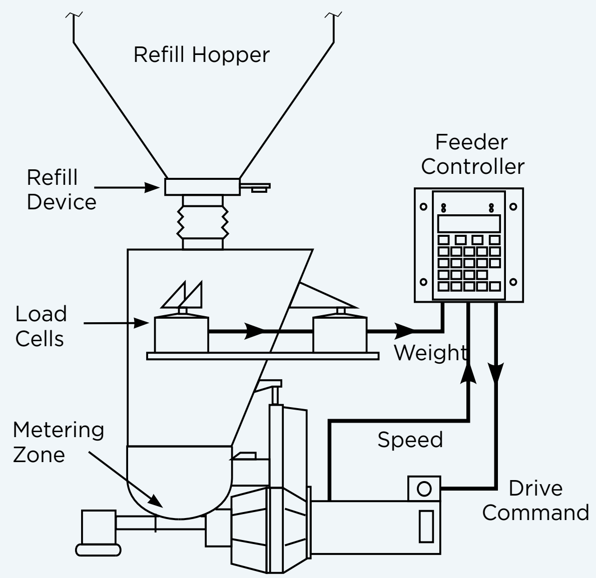
Assuming a properly selected and sized volumetric feeder, accurate performance hinges on several factors. First is the weighing system. To achieve high accuracy on a moment-to-moment basis, the weighing system must be able to quickly detect very small changes in total system weight. This requires a very high resolution yet stable weighing system that is unaffected by environmental variations. Since weighing is performed continuously, the weigh system also has to be highly responsive and display negligible hysteresis and creep. See Question 7 for more information on weighing.

A second factor centers on the process environment itself. In-plant shock and vibration can corrupt the weight measurement, destroying the basis for feed rate control. Flexible connections and the possible use of shock mounts help to isolate the feeding system and filter out much but not all of the accelerations associated with the ambient plant environment. As a result, both the weighing and control system must be designed to discriminate between meaningful weight readings and spurious components associated with shock and vibration. See Question 8 for more information on the subject of shock and vibration.

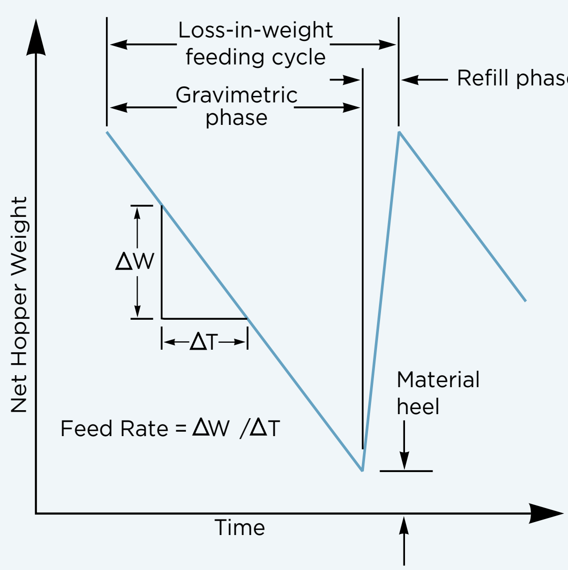
A third factor focuses on refill management. During hopper refill (either manual or automatic), system weight increases and clearly cannot be used as a basis for feed rate control. Early loss-in-weight feeders simply held feeder speed constant during refill until replenishment was completed and a declining weight was sensed, at which time feeder speed would be controlled again.

Two problems are associated with this approach. First, during refill the feeder acts as a volumetric feeder. Second, upon re-entry to true loss-in-weight control, abrupt changes in feeder speed can occur resulting in a (sometimes extended) period of off-spec flow until the feeder settles at the new, proper speed. These abrupt speed changes occur due to the facts that screw fill efficiency changes during refill, and material density at the bottom of the hopper can be somewhat higher than it is prior to refill owing to the increased headload.

To remedy these problems it is sometimes necessary to invoke control measures during refill to smoothly compensate for the increasing density or headload of material about to be discharged. This can be accomplished by gradually altering feeder speed in such a manner as to precisely mirror the effects of increasing density and headload. To determine the appropriate speed at any given material level in the refill process, the relationship between flow rate and feeder control output (termed

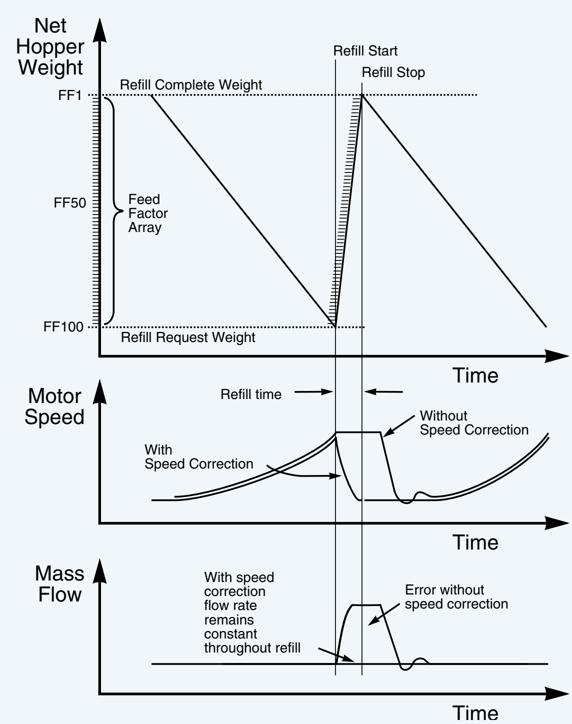


Typical loss-in-weight feeder



Loss-in-weight refill principle

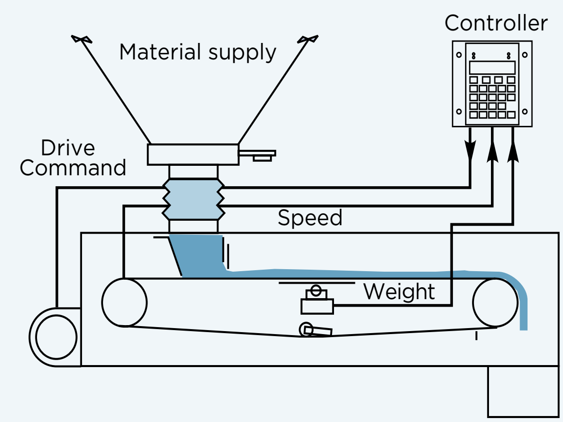
Optimizing loss-in-weight feeder performance during refill



Without special control measures during feeder refill, predictable flow rate errors occur due to material dynamics and transition out of refill. By measuring and memorizing feeder output vs input during the preceding gravimetric phase, motor speed during refill can be controlled to compensate for these effects. Additionally, under this approach abrupt changes in motor speed are avoided when refill is completed and the feeder resumes full gravimetric control.

feed factors) is memorized during the entirety of the preceding gravimetric phase of operation. Then, during refill, reference is made to this array of feed factors, and the appropriate motor speed can be applied based on sensed system weight as the hopper is filled.

By taking this more sophisticated approach it is possible to smoothly exit the refill phase and return to true gravimetric operation. Additionally, by controlling feeder speed during refill based on the most recent performance history, reverting to volumetric performance is avoided and gravimetric accuracy is essentially preserved.



Typical weigh belt feeder

? six

"When should I choose a weigh belt feeder and what do I need to know about its performance potential?"

Due to their operating principle weigh belt feeders are often a good choice when feeding relatively free flowing materials not requiring containment. Weigh belt feeders 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. Unlike most loss-in-weight feeding systems whose physical size must typically be increased to accommodate higher flow rates, weigh belt feeders can achieve high rates while remaining compact, simply through a combination of manipulating material bed geometry and operating at higher belt speeds.

Factors affecting the performance potential of a weigh belt feeder include the consistency of the material bed (formed as incoming material is sheared past an adjustable inlet gate), the resolution, responsiveness, and environmental sensitivity of the weighing system, and the effectiveness of the feeder's various mechanical and electronic systems designed to permit accurate weighing through the belt.

Regarding material bed consistency, it is clear that a stable, properly formed bed minimizes the need for corrective belt speed variation, resulting in improved overall accuracy. Based on the material's properties and intended range of flow rates, the feeder manufacturer typically determines the proper bed geometry and range of permissible inlet gate adjustment.

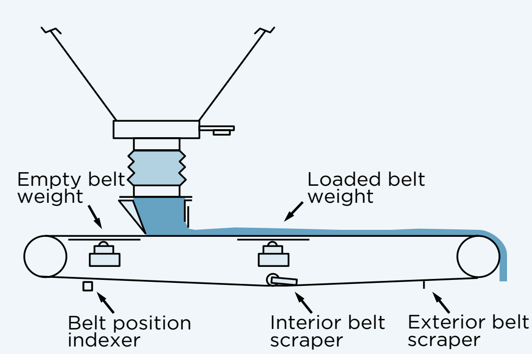
Weigh system resolution must be high (though not as high as in loss-in-weight feeding), especially at higher belt speeds where material may pass over the short weigh section in a small fraction of a second. The system must also be able to accurately weigh in a process environment where unknown levels of shock and vibration occur. (See the following question for more information on this important concern.)

Precisely weighing material through a moving belt requires that belt tension be maintained within limits at all times. Variation in tension produces a weighing error due to a catenary effect and may also result in belt slip. While static belt take-up tensioning devices may still be found on some feeders, the preferable solution is a dynamic tensioning device that applies constant tension regardless of belt load, wear and stretch.

A second measure taken to assure accurate weighing through the belt acts to maintain consistent tracking of the belt. Automatic belt tracking keeps the belt centered and prevents it from drifting to one side, corrupting the weight measurement through contact with the feeder's side skirts.

Thirdly, taring or zeroing is a major concern when weighing through the belt 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

Continuous automatic on-line belt taring

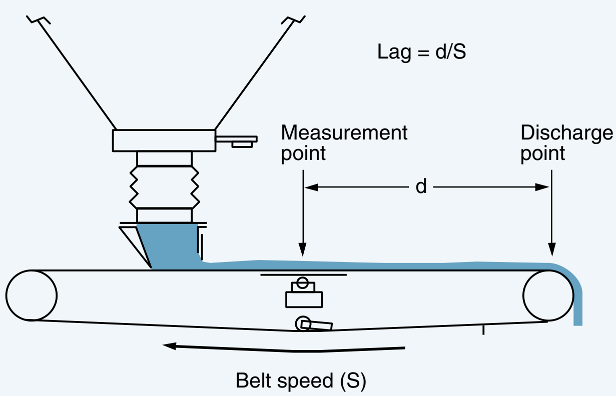


By adding a second weight sensor upstream of material inlet it is possible to continuously tare the belt on-line, without operator intervention.

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.

Sensitive to this issue, some feeder manufacturers helped automate the taring procedure by including a self-tare feature that would, upon user demand, cycle the (empty) belt feeder through a single belt revolution and automatically compute a tare value correction. While this feature was one step in the right direction, another more refined step soon followed. To account for variations in belt weight along the length of the belt, an indexing feature was added so belt weight could be measured and recorded inch-by-inch along the belt's length. During process operation, these indexed belt segment tare values would be applied in order as the corresponding belt segment passed over the weighing section.

Transportation lag compensation



By appropriately delaying corrective changes in belt speed, flow rate is controlled at the point of discharge rather than at the point of measurement — an important consideration when proportioning to variable or uncontrolled flows.

With the introduction of its Smart Weigh Belt Feeder, Coperion K-Tron has taken what may be the final step in conquering the problem of belt taring—Continuous On-Line Automatic Taring. By adding a second SFT weigh sensor upstream of the material inlet, the belt can now be continuously, accurately and automatically tared 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 assure the highest possible weigh belt feeding accuracy.

Finally, the phenomenon of transportation lag has relevance in some weigh belt feeding applications. Since there necessarily exists a short conveying distance between the weighing and discharge points, belt feeders with a transportation lag compensation feature invoke an appropriate delay in required belt speed adjustments to produce the desired flow rate at the point of discharge. This feature is important in proportioning to variable or wild flow material streams.

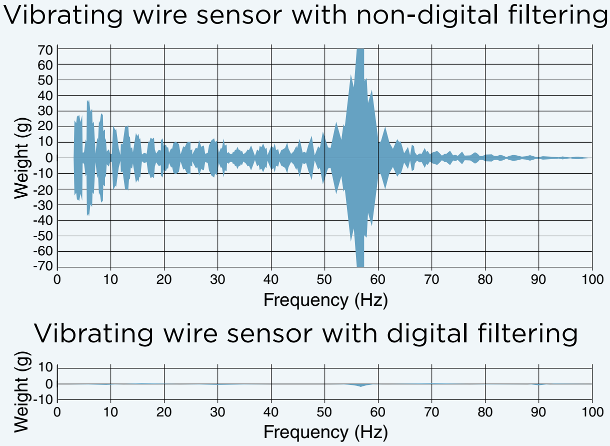
? seven

"Compared to other process weighing applications how does a gravimetric feeder's weighing system differ?"

The performance demands placed on a gravimetric feeder's weigh system far exceed those required of a static weighing system. To illustrate, consider the following scenario. A loss-in-weight feeder handles a powder and is to feed at a maximum rate of 100 kg/hr with a turndown range of 20:1. The feeder and hopper together weigh 100 kg and can accommodate 50 kg of material. Assume the measurement range of the feeder's weigh system to be 200 kg and all sources of feeding error apart from weighing are ignored. To achieve a 2 Sigma weighing accuracy of $\pm$0.25% at the feeder's maximum rate of 100 kg/hr over a 5-second interval the weigh system has to detect an expected weight loss during that period of a little less than 140g with a standard deviation of only 0.17g! At maximum turndown where the feeder operates at a rate of only 5 kg/hr the weigh system must measure an expected 6.9g weight loss during that same period with a standard deviation of less than nine one-thousandths of a gram.

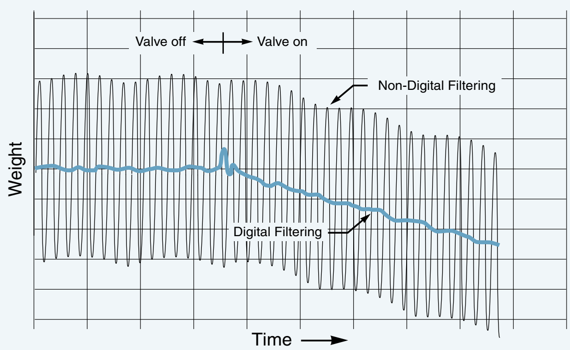
Weighing performance such as illustrated above requires the highest possible measurement resolution. And when it is

Vibrating wire sensor with non-digital filtering



Compared to conventional non-digital weight filtering techniques, digital filtering is highly effective in suppressing the effects of vibration throughout the full range of frequencies encountered in a typical plant environment.

Dynamic weighing response with digital filtering vs. non-digital filtering



In vibration-prone environments digital filtering permits accurate detection of even small variations in weight, where conventional filtering techniques fail to discriminate between the forces induced by vibration and actual weight changes.

realized that weighing must take place in a process environment frequently hostile to such precision, the true scope of the weighing challenge becomes clearer.

In both loss-in-weight and weigh belt feeding, weight measurements must also be taken very quickly. This need underscores the importance of a highly responsive weigh system that does not rely on deflection and that exhibits no significant hysteresis or creep. Also, it must display strict linearity if it is to perform accurately over its full operating range. And finally, a weigh system appropriate for application in continuous feeders must also display a very high level of measurement stability to avoid drifting off calibration, regardless of temperature, humidity or other environmental factors.

A fuller presentation of the issues, solutions and technologies surrounding continuous weighing is contained in an eight-page brochure entitled Smart Force Transducer - Setting New Weighing Standards in Process Feeding & Batching available upon request from Coperion K-Tron.

? eight

"How can the effects of shock and vibration be minimized in gravimetric feeder applications?"

As if the challenges described in the previous question were not enough, the impact of shock and ambient plant vibration on a continuous feeder's weigh system deserves separate treatment. At first glance it may seem fruitless to even attempt precision weighing in a plant environment where vibration is the rule and occasional bumps, hits, and jostles can likewise be expected.

However, in this age of smart machines, the traditional measures of flexible connections and shock mounts are being augmented by innovations in sensor design and powerful real-time signal processing techniques that are able to reliably extract meaningful data even in an apparently chaotic weighing environment.

Advanced weight sensor technologies designed to minimize signal contamination during the measurement are combined with highly sophisticated post-measurement processing techniques to minimize the effects of shock and vibration transmitted to the feeder from its environment. While beyond the scope of this presentation, two examples should suffice to illustrate the power behind these innovations.

In the comparative example illustrated above left, 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. One scale employed non-digital filtering; the other scale employed digital filtering. 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 and resonance effects associated with the sensor employing non-digital filtering. In contrast, the lower plot illustrates the effectiveness of 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.

To illustrate the dynamic weighing responsiveness to small changes in loading while in a vibration environment, consider the following experiment. Here again, the weighing performance of two vibrating wire scales is compared, one with digital filtering and the other with conventional non-digital filtering. On each scale is a container of liquid fitted with a tap set to drip the liquid off the scale drop by drop. Both scales are mounted on the same vibrating table. Sensor output of each scale is shown in the illustration above right. The scale employing digital filtering clearly reports the small drop-by-drop weight loss, while the output of the scale with non-digital filtering is completely swamped by the forces induced by vibration.

? nine

"How do I measure feeder accuracy in my plant?"

Whether performed automatically or manually, precise sampling is crucial to accurate performance measurement. Today, realizing the importance of sampling accuracy, more and more processors are automating the sampling procedure. Automated sampling eliminates human errors associated with manual sampling such as inconsistent sampling durations, and streamlines the process of data handling. Automated sampling involves the use of a precision scale with output to a computer. Software controls the acquisition of weight data as the feeder discharges material onto the scale.

The sampling procedure Coperion K-Tron employs exclusively is called differential dynamic sampling. This highly accurate method involves outputting the weight reading as frequently as once per second, and automatically computing the difference between successive 'micro-samples'. These values are then totalized over the desired sampling size or period to form a single 'macro-sample'. This process is repeated until the desired thirty macro-samples (for repeatability measurements) or ten macro-samples (for linearity measurements) are obtained.

Note that automated sampling is the only means available to reliably determine feeder accuracy over timescales shorter than one minute. When taking short duration samples, human error in timing the samples becomes too great a factor to produce a meaningful result.

While the trend is toward automated sampling, manual sampling is still frequently employed when calibrating a feeder in the operating environment. Tools include a watch, two containers, a sampling scale, a record keeping worksheet, and a calculator. Whether testing for linearity or repeatability, the procedure is basically the same. With the desired setpoint value dialed in and the feeder running under gravimetric control, material flow is channeled from the process by a flap-type flow diverter (or similar means) into one of the containers. At the start of the timed catch sampling period the sampler quickly slides a clean, empty container into the material stream, positioned so that all material is discharged into the container. At the end of the timed sample interval the sampler cycles the other container into position and, while it is receiving material, records the weight of the contents of the first container. The sampler proceeds in this fashion, weighing one sample while the next is being obtained, until the desired number of consecutive samples is taken. Conventional statistical computation is then performed to determine repeatability performance (standard deviation) or linearity (average sample weight).

To minimize errors in manual sampling several safeguards must be observed:

1) Since there will probably be a difference, however small, between the weight of the two empty catch sample containers, each container should be tared separately. If the scale being used to weigh the samples does not have provisions for storing two tare values, the heavier container should be tared out and weights affixed to the lighter one to bring its weight up to that of the heavier one.
2) The sample weight must be large enough to make human error in sampling negligible. Most feeder manufacturers specify that samples should be a minimum of one minute in duration or one kilogram in weight, whichever is greater. Other limitations may apply.
3) To minimize variations in sampling technique, the same individual should catch all samples.
4) Samples must be taken consecutively.
5) The resolution of the sampling scale must be one order of magnitude greater than the smallest sample deviation. Thus for example, if samples are to be measured to 0.01g, the resolution of the sampling scale should be 0.001g.

Experience will dictate the required frequency of calibration checks for any given feeding application. Thus, it is recommended that processors consider the use of run charts to trend calibration data over time.

? ten

"What are the most common feeder troubleshooting and maintenance issues?"

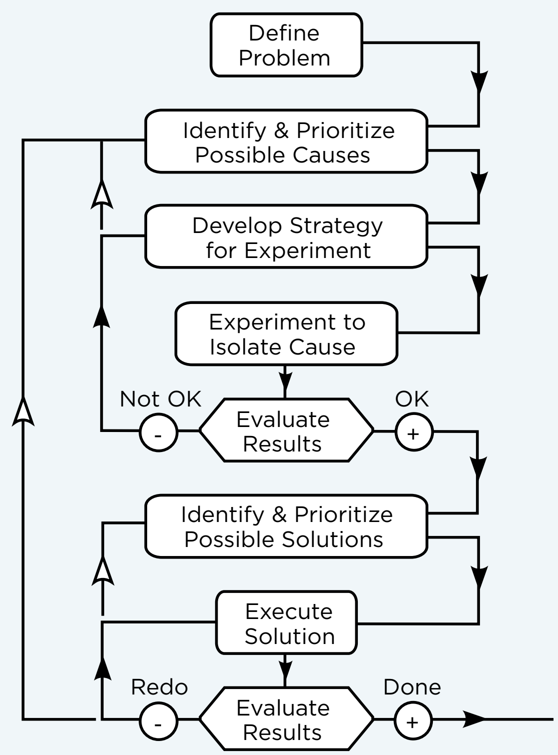
Assuming the feeder was properly selected and engineered for the application, and that upstream and downstream equipment is operating properly, most problems arise from improper installation, inadequate maintenance, lack of training of operating and maintenance personnel, and changes in the process material, or operating conditions and requirements.

Thus, many problems can be avoided at the outset simply by assuring proper installation, and thorough training of operating and maintenance personnel. Especially for more complex feeding systems, contracting for installation service is cheap insurance against potentially costly problems and start-up delays. And operator/maintenance training not only familiarizes plant personnel with the equipment itself, but also can be invaluable in improving problem solving skills through exposure to the methods and practices of troubleshooting.

Given the fact that a feeder is engineered and configured to handle a specific material over a specific range of rates, changes in the process material and/or operational requirements are also significant sources of unanticipated problems. In more than a few cases, merely changing the material supplier has resulted in feeder problems due to subtle differences in the physical characteristics of the new material.

And, if a feeder is required to operate at rates outside of its initial design range, performance difficulties should not be unexpected. Some feeders have been designed to be easily re-ranged in the plant—a fact worth considering at purchase if such a need can be anticipated. Also, if process conditions such as ambient or material temperature, or vibration levels change significantly and a change in feeder performance is noted, it is prudent then to consult with the manufacturer.

Certainly, not all problems can be attributed to the causes addressed above. Aside from mechanical or electronic failure of feeder components, some problems arise from the feeder's operating principle itself. Since volumetric, loss-in-weight and weigh belt feeders operate on different feeding principles, each will be treated separately.



Troubleshooting flow diagram

Volumetric Feeders

Simplest in principle, speed-controlled volumetric screw feeders are usually the most easily diagnosed when problems arise. Again assuming a correctly configured feeder for the application, the most likely causes of problems are the integrity of the speed control and a change in the volume-per-revolution relationship.

If the feeder's speed sensor does not perform accurately (or at all), control is not possible. Depending on the specifics of the sensing mechanism, cleaning or replacement is required according to the manufacturer's recommendation, but first confirm that the problem is not with wiring or electrical connections.

If screw speed control is not the problem, a change in the feeder's volume-per-revolution relationship is the likely cause. Such changes typically occur due to material buildup on the screw or a blockage above the screw that prevents a consistent supply to the screw. Immediate but temporary remedies include cleaning the screw, discharge tube, and/or hopper. A permanent solution to repeated episodes may require a change in screw design, bin design or agitation, or other measures.

Loss-in-Weight Feeders

Typically employing a screw feeder to handle bulk solid materials, the problems addressed above in regard to volumetric feeders also apply to loss-in-weight units. Note, however, that since a loss-in-weight feeder controls primarily to declining system weight rather than screw speed, screw buildup or partial blockage will be compensated for automatically until, at some point, the feeder reaches an alarm condition. If this condition is observed, first check for buildup or blockage.

Since loss-in-weight feeders rely on an accurate weight measurement of the entire feeding system, it is important that the system be isolated from the process's vibration environment. While mainly an issue to be dealt with at installation through stable mounting, avoidance of strong air currents in the feeder's vicinity, and the use of shock mounts and flexible connections, difficulties can arise due to causes ranging from the installation of new equipment near the feeder to improper refitting of flexible connections during maintenance. If repeatability problems appear to be correlated with the operation of nearby machinery, or performance erodes after maintenance, increased vibration may be reaching the feeder. Note that some weighing systems available today provide built-in vibration protection.

The weigh system, arguably the most critical element in a loss-in-weight feeder, can also be the source of performance problems. Great advances in weighing technology have been made over the last twenty years, but there continues to exist a real diversity in the quality and capabilities of weigh systems in use today.

Thus, in light of this diversity, issues such as resolution, stability, responsiveness, weigh signal integrity, sensitivity to vibration, reliability, and data communications must be carefully evaluated by the processor before committing to equipment purchase. After installation, a program of regularly scheduled calibration checks is the best way to monitor system performance and reveal problems such as drift as early as possible.

A final source of typical loss-in-weight performance problems has to do with conditions at inlet and discharge. At inlet, if refill is performed automatically through the use of a refill feeder, any leakage in the shut-off device will produce a feeding error. And when discharging to a non-ambient pressure environment, any leaks or pressure pulses reaching the feeder will likewise produce a feeding error. These problems are usually easily fixed but may be difficult to detect. The best solution is to periodically check for positive and complete sealing.

Weigh Belt Feeders

Assuming a properly applied weigh belt feeder, most of the typical problems encountered with this type feeder center around the mechanical systems associated with managing the belt itself—keeping it clean, tracking properly, and in constant tension. Each manufacturer takes a somewhat different approach to achieving these ends, so a complete presentation of remedies to potential problems is beyond the scope of this paper. However, it is important to mention that, regardless of the systems employed, most problems stem from lax maintenance, cleaning and monitoring of belt management systems. The best solution here is prevention through regular monitoring and replacement as required according to manufacturer's recommendations.

For proper feeder operation the inlet gate of a weigh belt feeder is set to produce a material bed of a certain height and width for the given material. If a different material is handled, or if the density of the original material is changed significantly, adjustment to the inlet gate geometry is usually required to a) avoid material spilling off the belt or coming in contact with the channeling side skirts, and b) establish the proper belt loading (e.g., kg/m) value. Ignoring this consideration sets the stage for problems.

Belt slip occurs when insufficient frictional force exists between the belt and its drive pulley. Slip causes a direct error in feed rate, and is due to insufficient belt tension and/or the accumulation of process material on the inside of the belt. Proper maintenance of the belt and tensioning system will help avoid belt slip, but if the condition persists the feeder may have to be re-configured to operate at a lower belt speed. Belt slip detection is available from most if not all manufacturers.

Finally, due to their operating principle of weighing material through the belt, accurate and frequent taring is a concern. As discussed in Question 6, continuous, automatic, on-line taring is now available. However, until it is the norm, processors must make weigh belt taring a regular activity.

? what else?

Today misformulations, wasted material, and rejected product are too expensive to be called unpreventable. Ensuring feeder accuracy is central to guarding against these process pitfalls. And developing a familiarity with feeding's principles and practices is a good first step. But what else does the user need to guarantee a correct, reliable and cost-effective solution to his feeding problems?

The answer lies in selecting the best supplier, and making the fullest possible use of available support services, both before and after purchase. Check out the supplier carefully, gather references and talk to current customers. Evaluate the supplier's experience, application expertise, and systems engineering capabilities. Learn about the supplier's testing program, service and spare parts programs.

In short, communicate and investigate early on in the process. The time and effort invested will surely pay handsome dividends for years to come.

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