Technical Paper

Using Feeder Trending as an Early Warning System

Using your loss-in-weight feeder's trending capabilities to track down external causes of feeding performance problems.

Introduction

As any veteran troubleshooter knows, often the biggest challenge in diagnosing a process performance problem is backtracking from symptom to cause. Sometimes the path leading from problem to cause is short and easily followed, such as when a motor fails and needs to be replaced. But when the trail is lengthy, indirect or unclear, the possibilities of cause and effect quickly multiply, often branching into a seemingly endless array of frustrating dead-ends.

When faced with an apparent loss-in-weight feeding problem the feeder itself rightly becomes the initial focus of troubleshooting scrutiny. But what if the feeder checks out yet the problem persists? If the feeder has passed muster, the problem's underlying cause must then lie elsewhere, whether with the operating environment, upstream/downstream conditions or equipment, or with the process material itself.

Today's sophisticated loss-in-weight feeders display many parameters associated with feeding performance and machine status, ranging from feed rate and motor drive commands to span settings, alarm limits and much more. While the primary purpose of these display parameters is to allow you to monitor and manage feeder operation, trending some of these parameters can provide valuable clues you can use to point the way to conditions external to the feeder that may be limiting its performance. It is this category of causes and the diagnostic capabilities afforded by display trending that form the subject discussed here. Sharpening your ability to track down process causes of feeder performance problems will reduce unplanned downtime, improve process efficiency and save money, too.

Working Out from the Feeder

This article focuses on the more elusive, performance-related problems as opposed to the often easily diagnosed, operational problems of 'the feeder won't run' variety. The cause of less-than-optimal feeder performance can take refuge in the oddest, most unexpected places, so a planned troubleshooting approach is needed to uncover them. Thus, we must begin with the feeder itself and the way it works.

To see how your feeder's trending capabilities can help identify an external cause to a feeding problem, it is first necessary to profile the feeder's operating principle. Most simply put, a loss-in-weight feeder's operation starts with continuously weighing the feeder along with its hopper and charge of material to be fed. The feeder's weight declines as material is discharged, and feeder speed is constantly adjusted to produce the desired gravimetric rate (equivalent to the rate of system weight loss). See Figure 1. This proven approach offers the advantages of high accuracy (even at very low rates), complete material containment, and maximum material handling flexibility. Any feed device suitable to the process material and required rate range may be employed such as a screw or vibratory feeder for solids, or a pump or valve for liquids.

As a direct result of its operating principle a loss-in-weight feeder requires two accommodations: first, periodic refill is needed to recharge its supply hopper, and second, isolation from the process environment to permit accurate and continuous weighing. Thus, as part of the larger process environment, a loss-in-weight feeder must perform a balancing act of sorts. On one hand it must connect to and interact with the process by receiving and discharging material, yet on the other hand it must be isolated from the process environment for maximum weighing accuracy.

This balance is effectively struck through combined measures taken in the design, application and installation of the feeder. As detailed later in this article these measures involve issues including mounting, process connections, material supply and the process environment itself.

In operation a loss-in-weight feeder continually circles the simplified control loop pictured in Figure 2 below, constantly attempting to drive mass flow error to zero. The time it takes to complete one loop represents the interval over which weight loss is measured and any required adjustment to feeder speed can be determined and applied. Using our simplified control loop as a template to organize the typical locations and causes of feeding problems, the right portion of Figure 2 separates the feeder from the process itself. Since it is the main mission of a feeder to control flow rate, trending measured mass flow is a prime indicator of a performance problem. However, it is the weight measurement itself that, when trended, will help most to narrow the diagnostic possibilities. Once

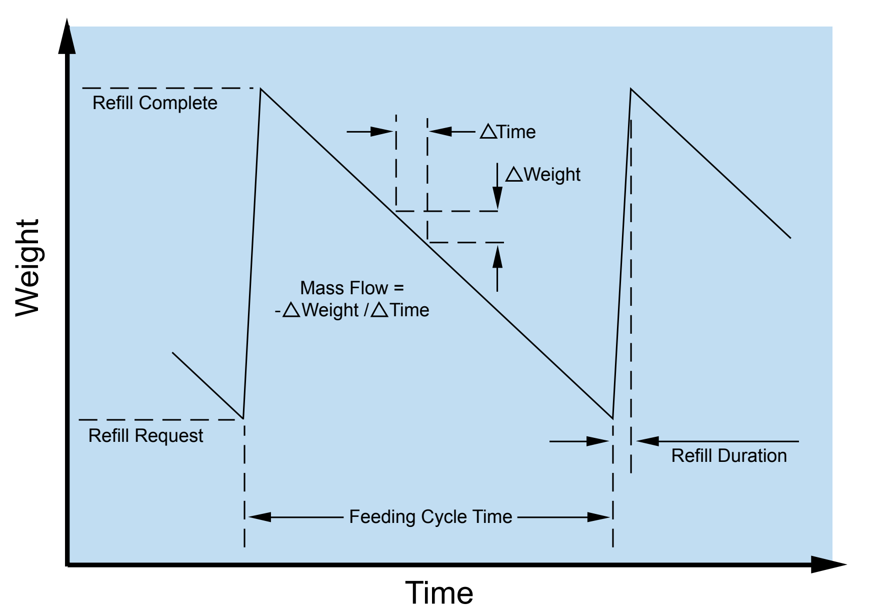


Fig. 1: Loss-in-Weight Operating Principle

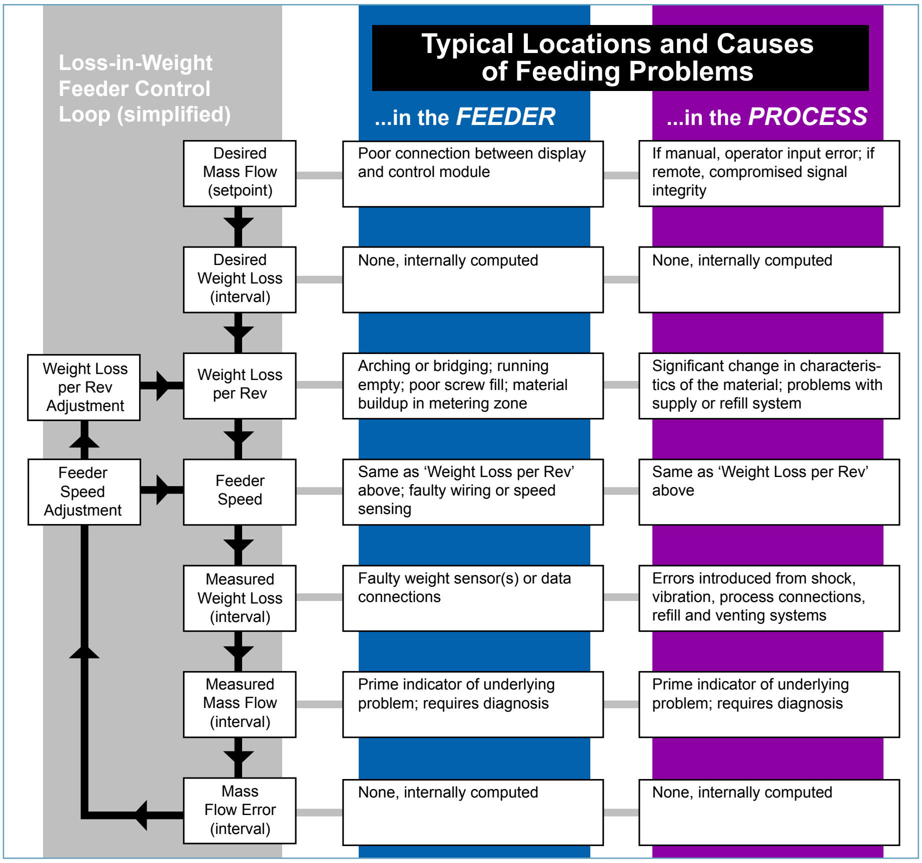


Fig.2: Feeding Problem Locations and Causes

the feeder has been checked out and, if eliminated as the problem's cause, attention must then turn outward to the surrounding process environment.

Alarm Alert

Likely the first alert to a feeding problem will be an alarm generated by the feeder's control system. Properly used, alarms are vigilant sentries on guard against feeding woes, and they comprise your first tool in detecting and diagnosing a problem whether inside the feeder or out. Able to detect violations of feeder motor speed limits, weight signal integrity and feed rate deviations among other things, performance-related alarms may tell you that something bad is happening, but they don't necessarily tell you what's causing the problem.

Also, since alarms are triggered by an event (i.e. crossing an alarm limit), the cause of the alarm may be either a condition that lingers long enough for diagnosis, or an isolated, momentary event that passes before the cause can be identified. This is where trending comes in. By tracing through time it is often possible to correlate events and conditions inside the feeder with events and conditions in the external process environment, even in the absence of a triggered alarm.

Time to Trend

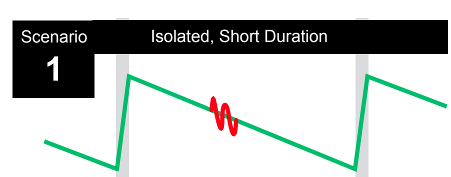
While trending can reveal much about problems inside the feeder, the most useful trending parameter in locating causes outside the feeder is measured weight. As an example, consider that a loss-in-weight feeder operating at a modest 6 kg/hr rate and a not-all-that-impressive accuracy of +1% must maintain its average per-second discharge rate between 1.665 and 1.668 grams. Also consider that it must do this with a weighing system that is the only support of a relatively massive operating assembly (the feeder, hopper and material) which is physically connected to the upstream and downstream process. This should serve to adequately underscore the need to effectively isolate the feeding system from the influence of the outside world.

Most modern loss-in-weight feeding systems have been designed from the outset to combat performance-erosive influences faced in typical process environments. But given the need to reliably discern exceedingly small weight changes in hostile process surroundings, these design measures sometimes prove insufficient. Trending analysis can help reveal the source(s) of process influences that do make it past feeder's defenses, allowing the problem be identified and solved.

The figures in the following scenarios present the familiar sawtooth trendline of net hopper weight in green overlaid by various weight disturbance scenarios shown in red, each suggesting a different cause, or at least significantly narrowing the set of possibilities. Indicated disturbances are grossly exaggerated for clarity. Today's sophisticated feeder weighing systems usually employ a low-pass filter to screen out most environmental contamination, but, in practice, even with a problem-free feeder, its trendline trace of net hopper weight will reveal small but acceptable bumps, noise and other irregularities. For the purpose of this article they have been ignored to focus on the subject at hand.

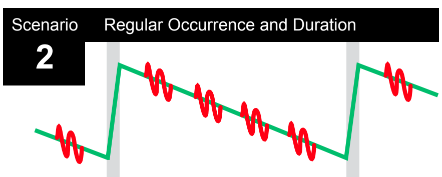
Scenario 1: Isolated, Short Duration

Isolated, short-duration weight disturbances may be caused by a passing plant worker bumping the feeder, placing a cup of coffee on it, or some other form of momentary disturbance. This type of disturbance is not the problem it might appear to be. Most loss-in-weight feeders are programmed to recognize a brief disturbance and ignore it or, depending on the disturbance's actual duration and/or severity, quickly determine if it should compensate for any resulting excess or shortfall in discharge. While a disturbance of any kind will tend to reduce overall measured feeder accuracy, the harm inflicted by isolated, infrequent disturbances is typically not significant.



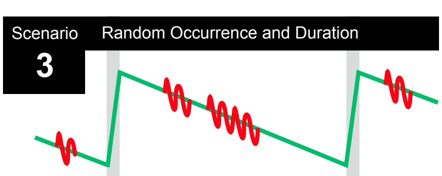
Scenario 2: Regular Occurrence and Duration

Such is not the case when the feeder is asked to perform in a more disturbanceprone process environment. The cumulative effect of ongoing disturbances can degrade overall feeder performance. If your feeder's weight trending displays this disturbance pattern the likely cause is shock or vibration transmitted to the feeder from some nearby piece of equipment or even the plant structure itself. If multiple sources of regular disturbance are at play, the trace's pattern may appear random (as in the next scenario), but closer inspection should reveal its composite character. The frequency and duration of regular disturbances can help direct you to the offending equipment, but the particular remedy depends on the situation.



Scenario 3: Random Occurrence and Duration

No shortcuts here. If, upon analysis, disturbances are found to be truly random in their occurrence and/or duration, the troubleshooting ante is raised. Without any direct evidence to infer a cause, the problem solver is forced to retreat to the 'divide-and-conquer' strategy of methodically eliminating all potential causes. Is the feeder being buffeted by rogue air currents? Do the disturbances occur when the rest of the process is shut down? Is something odd going on inside the feeder? Are the feeder's process connections okay? One by one, possible causes must be nominated, assessed and eliminated until the culprit (or culprits) are identified. This is where a troubleshooter really earns his keep. Fortunately, a continuing series of random disturbance is relatively rarely encountered.



Scenario 4: Correlated With Refill

An often under-appreciated requirement of loss-in-weight feeding is the need to return to acceptable weighing conditions as soon as possible after refill completion, allowing the feeder to resume gravimetric operation. A refill is a major disturbance to the feeder's weight, so a settling time is required after refill. This is to allow the feeder's scale system to stabilize and begin to collect the correct weight loss data.

Several external process factors can contribute to disturbance following refill. Although a required element in a fully automated loss-in-weight feeding system, the refill system itself is not weighed, and is thus considered to be part of the process environment. Any unintended post-refill leakage from the refill device, such as less-than-complete shutoff, will corrupt the feeder's weight measurement until the leakage has ceased. In at least one unusual case where the refill device had been positioned some distance from the hopper because of limited headroom, a post-refill weight disturbance was found to be due to the protracted trailing off of flow produced simply because of the length of the transit. The fix is obvious: check your refill device for proper operation, and confirm positive shut-off.

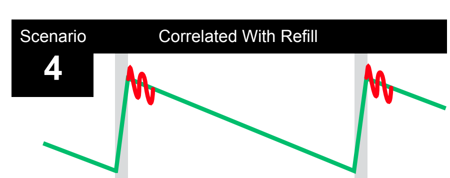
Venting of the feeder's hopper is another potential cause of post-refill weight disturbance. Proper venting permits the air displaced by incoming material to escape, and facilitates material de-aeration and settling. The venting issue lies partway between being an internal issue and an external cause, depending on whether venting is passive or active. If passive, air is left to exit on its own accord, impeded only by the aperture provided and the resistance presented by any sock or filter. An improperly sized vent or a clogged filter can delay complete venting, temporarily pressurizing the hopper and inducing stress on flexible connections. At worst it can pressurize the feeder's hopper enough to force material out through the discharge. These conditions will produce a perceived weight disturbance, feed rate error, and/or an abnormal motor speed trendline. The fix here is simply to clean or replace the filter, and, if needed, increase vent size.

Qualifying as a potential external cause, active venting and dust collection uses suction to encourage air's exit, which clearly involves forces that can compromise weighing. If active venting is too aggressive, the low pressure in the feeder's hopper can induce stresses on flexible connections that directly register as weight disturbances as well as providing a path for the transmission of vibrations from the process environment. In such a case, check all connections (inlet, vent and discharge) for full flexibility during active venting and correct as necessary.

Before moving to the final weight disturbance scenario it is important to note one possible refill-related cause internal to the feeder. It has to do with the fact that a loss-in-weight feeder's weighing system is not available to control feed rate during the brief refill operation. This is understandable, since during that time material is being quickly added to the feeder as the hopper is recharged. To avoid interruption of the discharge stream, traditionally feeder speed has been held constant during refill at the rpm value occurring just before refill, temporarily placing the feeder into a volumetric operating mode. After refill (and its ensuing settling delay) the feeder re-enters gravimetric operation, and speed is again allowed to vary as required.

Mainly depending on the compressibility of the process material, this traditional approach may or may not generate a sensed weight disturbance as the feeder returns to gravimetric operation. For a readily compressible material whose density changes appreciably as a function of headload, feeder speed just before refill is somewhat higher than it should be just after refill when the material being fed has been compressed due to the applied weight of newly added material. As a result, when feeder speed is held constant at this higher speed, progressive overfeeding occurs during refill and a rather abrupt reduction in feeder speed occurs when gravimetric operation resumes. However, some feeders avoid this shortcoming by memorizing the feeder's recent weighing history and using that information to smoothly reduce feeder speed during the short refill period. If your feeder does not have this capability and you spot an immediate post-refill weight disturbance, look at your feeder's speed trendline to see if there is a significant difference between speed values just before entering refill and just after the apparent disturbance has passed. If there is, and if you have already eliminated all other possibilities (and if you can't live with this particular disturbance) you may need to consult your feeder supplier to resolve the difficulty.

A manually refilled loss-in-weight feeder can by its very nature experience disturbance problems due to human error and intereference. Any disturbance over a long period will cause a feeder upset. As mentioned above, the feeder's control system will ignore some brief disturbances but any long-term disturbance outside certain limits will be acted on by the controller and the feeder's speed will change accordingly. Here again, weight trending allows you to identify the problem.

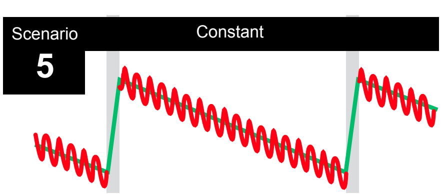


Scenario 5: Constant

This most visually intimidating weight disturbance category is also the most performance-damaging. Our final scenario depicts weight measurement swamped with constant contamination. Once possible internal causes have been eliminated (electronic noise, static, binding of scale flexures or pivots, etc.), clearly the process must have found some direct route, some point of least resistance, to manifest its contaminating influence on the feeder's weighing environment. While the condition warrants immediate correction, its diagnosis is often rather simple and its solution usually apparent.

Common causes turn out to be poor mounting practice where the feeder is installed without adequate consideration to the transmission of shock or vibration through the feeder's base or other supports, stiff or stressed installation of flexible inlet, venting and discharge connections or electrical wiring and cabling. Even a broom left leaning against the feeder has been found to provide a path for weighing contamination.

A final potential cause of this sort of contamination is when inletting or discharging to pressure or suction, or feeder purging. Because the feeder's inlet and discharge experiences a pressure differential, there is a net force applied to it. Theoretically, if that force is truly constant, there is no problem because a loss-in-weight feeder operates off of sensed differences in weight, not absolute weight. However, even small variations in differential pressure can influence the feeder's sensitive weighing system. Case by case consultation is required to resolve this type of contamination with pressure balanced inlet, discharge and vent connections.



The Material Factor

The material being fed is the only part of the external process invited to cross the feeder's defensive line. Once inside, however, the material doesn't always behave as a well mannered guest should. Familiar difficulties include bridging, arching and other 'flow-through-the-feeder' problems such as material caking, clumping or buildup on the feed screw, tube or agitator (if used). These problems are best anticipated, addressed and resolved during feeder selection and testing, or at worst, in pre-op shakedown. However, actual process conditions can

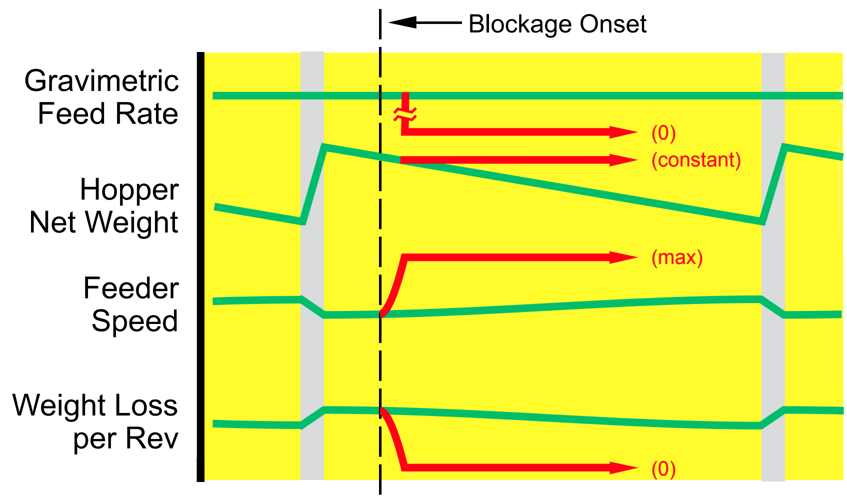


Fig. 3a: Material Blockage

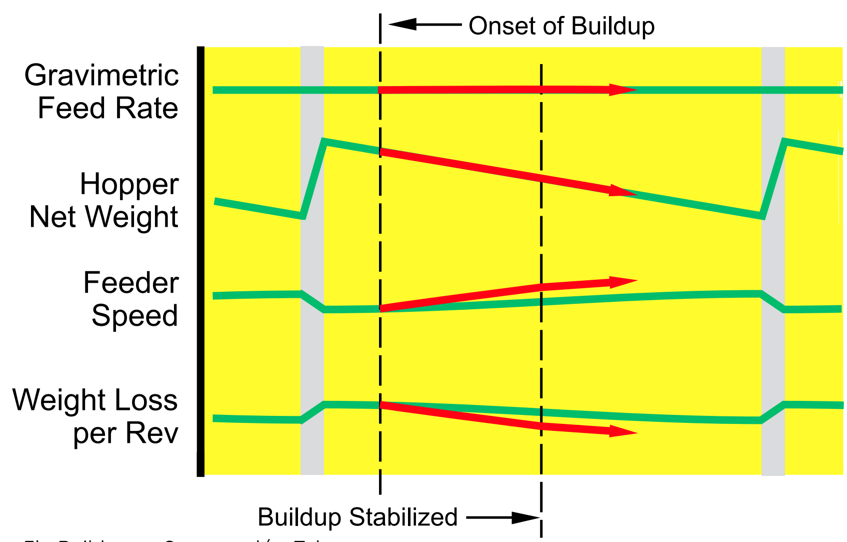


Fig. 3b: Buildup on Screw and/or Tube

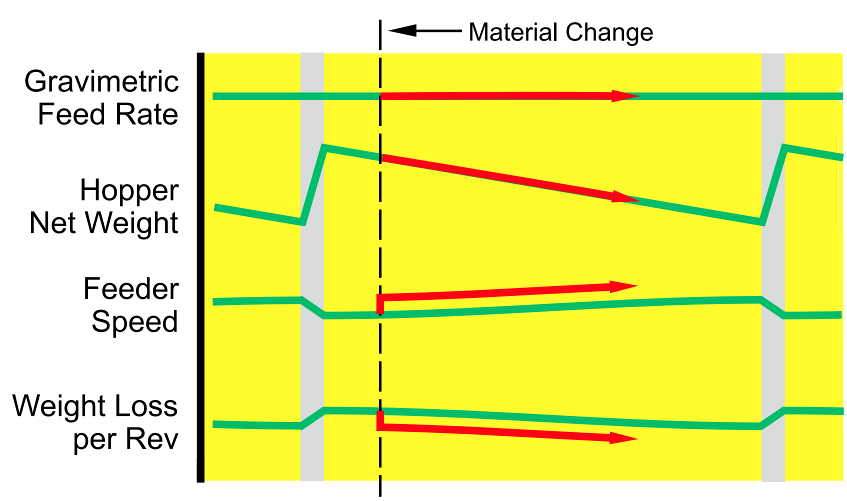


Fig. 3c: Material Properties Variation

and do change, and the character of the material can vary as well. Such changes can result in the return of old flow problems or the emergence of new ones. While such problems will almost certainly cause one or more alarm conditions, monitoring a feeder's performance variables through display trending can help identify and diagnose emerging concerns.

The trendline patterns shown below are associated with typical material related problems. Figure 4a depicts the condition where material suddenly becomes hung up due to arching, bridging or some other form of blockage in the hopper. After the feeder empties material below the blockage, feed rate quickly falls to zero, hopper net weight remains constant, feeder speed maxes out in its futile attempt to dose material that is no longer available, and weight loss per rev drops to nil.

Figure 4b displays the trendline pattern typical of material buildup on the feed screw. Here, weight loss per screw rev declines more than expected over time as material builds up on the metering element(s). In response, feeder speed increases to compensate for the reduction in the screw's efficiency. If buildup stabilizes and is not severe, feed rate and hopper weight remain on track. However, too much buildup will eventually trigger an alarm condition related to feeder speed or violation of weight loss per rev limits.

Figure 4c shows a trace pattern signaling an abrupt change in the material's density or handling characteristics. This condition could arise from any of several causes ranging from a different material supplier or changes in storage or transport practices to mistakenly introducing the wrong material. Illustrated here is the condition where the density of the material abruptly falls to a slightly lower-than-expected value. Feeder speed increases in step-like fashion to adjust for the sensed reduction in weight loss per rev (the opposite would occur if density increased). Feed rate and hopper weight are shown to remain on target in this example, but if the change in material properties or handling characteristics is too great the feeder may not be able to accommodate and an alarm of one sort or another would be sounded.

Conclusion

Troubleshooting is tough enough on its own, especially when the cause of a problem may not lie where the problem manifests itself. Putting your feeder's display trending capabilities to work can provide valuable clues to tracking down some of the more elusive causes of feeding performance problems, letting you take some of the drama, pain and mystery out of keeping your process operation running smoothly.