Improved Moisture Content Control Saves Energy

Traditionally, moisture control sensors are placed at the dryer's exit. Locating sensors inside the drying chamber reduces response time.

By Johnny Robinson, Drying Technology Inc.

Product quality is closely related to moisture content. Excess moisture in the product can cause problems, and too little moisture, in addition to reducing product quality, wastes energy and dryer capacity. Consequently, exiting product moisture control should be an important consideration in the design, operation and maintenance of dryers. Failure to properly control the moisture content can be costly in terms of lost production, excessive unit energy consumption and poor product quality.

Poor moisture content control produces a moisture content distribution with a relatively high exiting-product standard deviation. In most process drying applications, the mean target moisture content is held at two to three standard deviations below the upper limit of moisture content acceptability. The lack of good moisture content control systems forces most processors to overdry their products because as a rule, problems occur less frequently from overdried than from underdried product. The challenge is to develop more effective control systems capable of producing product with a lower moisture content standard deviation.

Most moisture content sensors are located at the end of the dryer or in a remote laboratory setting. However, this location is contrary to that needed to maintain good control. In general, the closer the moisture content sensor is to the dryer entrance, the smaller the dead time. (Dead time is the time required for the moisture content sensor to detect an entering disturbance.) A smaller dead time equals a more effective control system. The standard deviation of the exiting product moisture content — a measure of control system effectiveness — is directly proportional to the dead time. Given this, the location of the moisture content sensor with respect to the dryer entrance obviously is an important consideration, and one that affects efforts to maximize production, improve product quality and conserve energy.

The ideal situation would be to install a moisture content sensor inside the dryer. Conventional moisture content sensors — those based on a correlation between the moisture content of the product and some property of the product such as capacitance, conductivity or resistance — usually are not installed inside the hot, dirty, space-limited atmosphere of a dryer. A moisture content sensor capable of being installed inside a dryer has been developed.

The effectiveness of a moisture content control system may be evaluated by comparing the exiting product moisture content standard deviation before and after its installation. Figure 1 compares the exiting moisture content distributions from the same dryer using two different moisture content control methods. Poor control is represented by the curve with the widest moisture content distribution. In the example illustrated by figure 1, the standard deviation of the product was reduced from 1.25 to 0.625 as a result of installing a control system that included a moisture content sensor located inside the dryer.

Figure 1 also suggests three operating options are available for such a system:

- Continue to operate at the previous mean moisture content, which will result in less variation in moisture content and improved quality.
- Increase the dryer production rate (dryer speed) until the upper moisture content limit of the

Poor vs. Improved Moisture Control

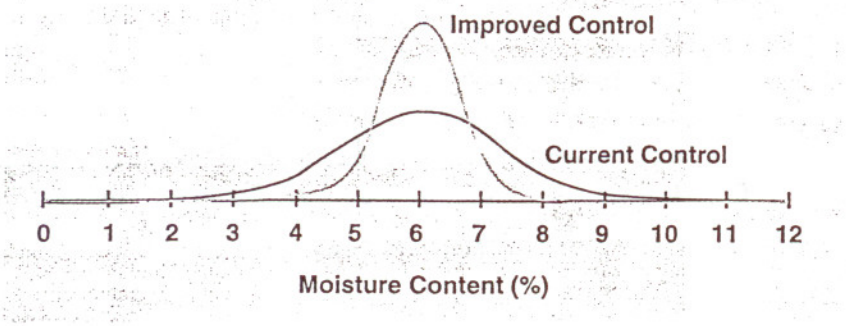


Figure 1. Using an inside-the-dryer control reduces moisture content standard deviation.

two are superimposed.

- Decrease the thermal energy input until the upper limits of the two distributions are superimposed.

The first option available to processors — continue to operate as before but enjoy less variation in product moisture content — provides a single benefit: improved quality. By contrast, processors employing the second option — increase the dryer production rate — enjoy two process benefits: increased production and decreased unit energy consumption. Likewise, processors employing the third option — reduce the thermal energy input — enjoy two process benefits: decreased unit energy consumption and improved quality. By employing the second or third option, the mean value of the moisture content will be increased.

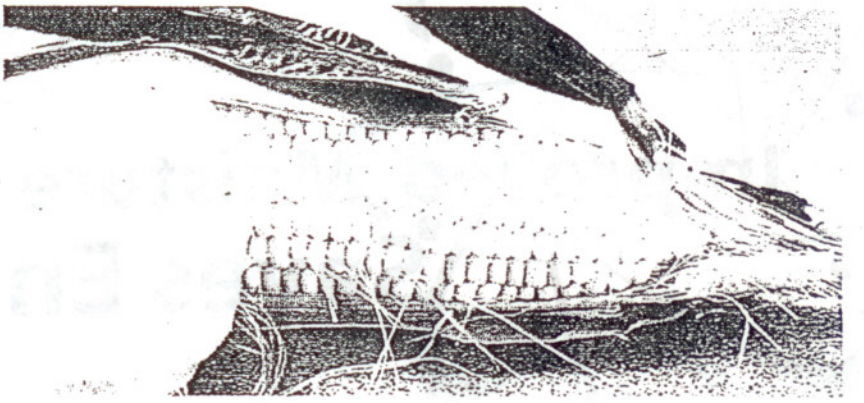
Figure 2 shows that the mean moisture content can be increased without exceeding the established upper limit of product moisture content, either by decreasing the thermal energy input or by increasing the feed rate.

Sensing Moisture Content

There are several methods of determining the moisture content level. With an inside-the-dryer moisture control sensor, moisture content is measured by calculating the temperature difference (ΔT) between two key process variables. This method of predicting product moisture content is based on mathematical models relating the product moisture content to:

- The temperature drop of hot air (convective drying) after contacting the wet product.
- The temperature difference between the temperature of the drying medium (conductive or convective drying) and the temperature of the product immediately following contact with the heating medium.
- The dryer speed, production rate or total drying time.

The most common moisture content control system is feedback control, in which the moisture content sensor is located at the exit of the dryer or at some point thereafter. With this setup, if the product's moisture content at the sensor departs from the target value, the feedback control assumes that this condition is caused by a disturbance entering the dryer, and appropriate changes in operating conditions are made. If these disturbances are random and exist for periods of time less than the dead time, there will be over or undercontrol. In this situation,



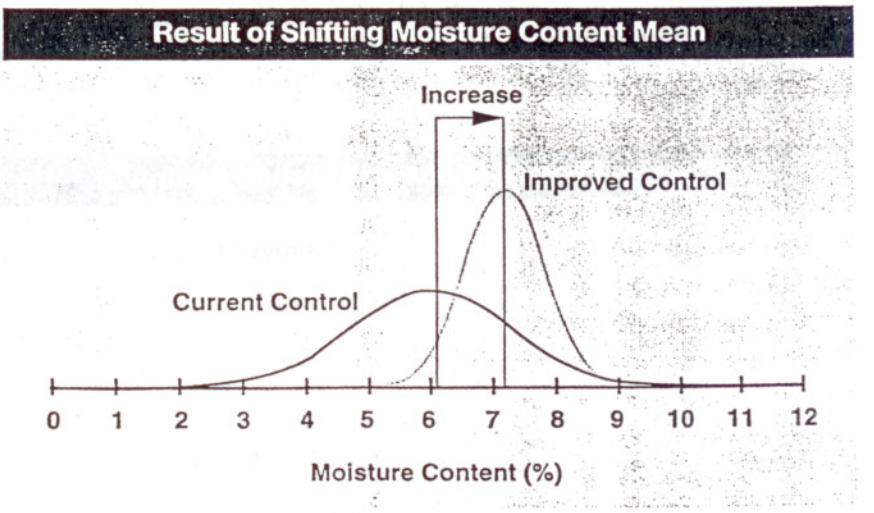
Inside-the-dryer moisture control sensors are used in many process applications, including drying corn gluten.

the exiting moisture content will tend to cycle, the standard deviation of the exiting moisture content will be larger than usual, and operation at a lower than possible moisture content will be the result. If the disturbance lasts longer than the dead time, the production for the period of time equal to the dead time plus the lag time will be produced before proper control is established. Control systems utilizing inside-the-dryer moisture content sensors are capable of producing shorter dead times.

Improving dryer control by reducing the standard deviation of the exiting product moisture content can improve the drying operation. By placing the moisture content sensor inside the dryer, the dead time is reduced, which reduces the standard deviation of the exiting product moisture content. A reduction in standard deviation allows the mean moisture content to be increased without exceeding the established upper limit for moisture content. If the mean moisture content is increased, less unit energy is consumed because of less water to evaporate. Additionally, the production rate, if presently dryer-limited, can be increased.

Figure 3 compares the product moisture content vs. time in the falling-rate zone of a typical

Figure 2. Because the moisture content standard deviation is reduced, the moisture content mean can be increased.



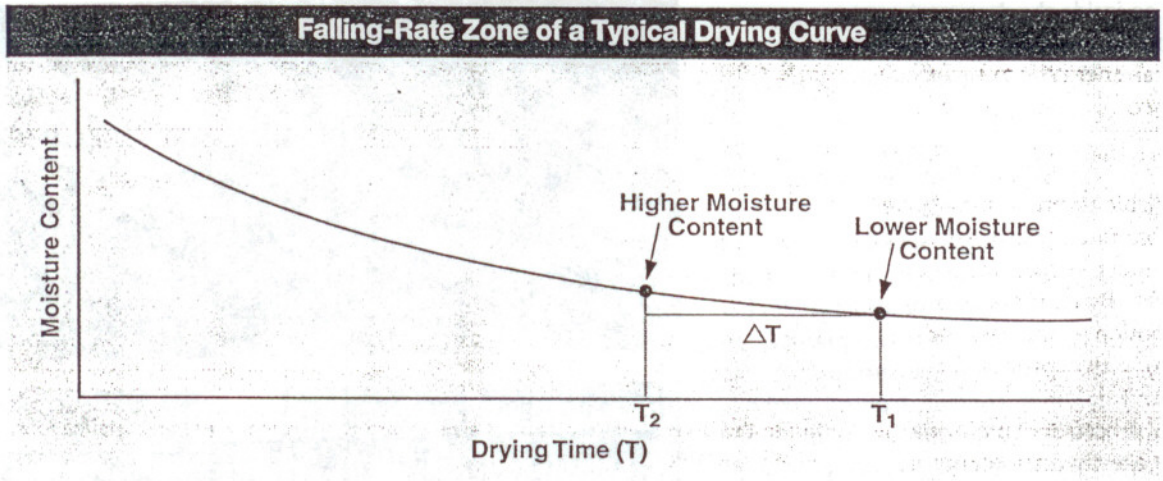


Figure 3. Because the inside-the-dryer-sensor allows processors to raise the mean product moisture content, production output is increased.

drying curve. It may be used to calculate the production rate benefits derived from increasing the product mean moisture content by using of an inside-the-dryer moisture content control system.

The production increase that results from raising the mean product moisture content is demonstrated by figure 3. In this example, the initial target mean moisture content operating value is located at the longer drying time (T_1) on the curve. The new target mean moisture content is located on the curve at the lower drying time (T_2). The calculation for the production increase resulting from improving moisture control, takes the difference between the drying times for the two conditions (T_1 minus T_2), divided by the original drying time (T_1), multiplied by 100 to give the percent production increase resulting from improved control.

$$\frac{(T_1 - T_2)}{T_1} \times 100$$

Replacing a feedback control system with one

utilizing an inside-the-dryer moisture content sensor can produce cost/benefit ratios. This improvement is primarily the result of the ability to place the sensors inside the dryer.

Because of the limits on where they can be located with respect to the dryer entrance, conventional moisture content sensors may result in longer dead times and larger standard deviations from the target moisture content. Adding a feed-forward input such as evaporative load changes has not been widely accepted on the plant floor because of the problems in measuring feed rate and entering moisture content. Control methods are available where the moisture content sensor can be installed inside the dryer, reducing the dead time. As a result of using the inside-the-dryer moisture content sensors, standard deviations of the exiting product moisture content have been reduced. |PH|

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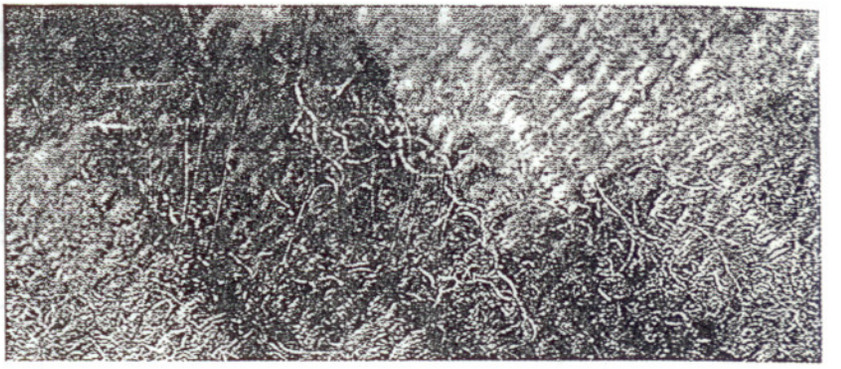

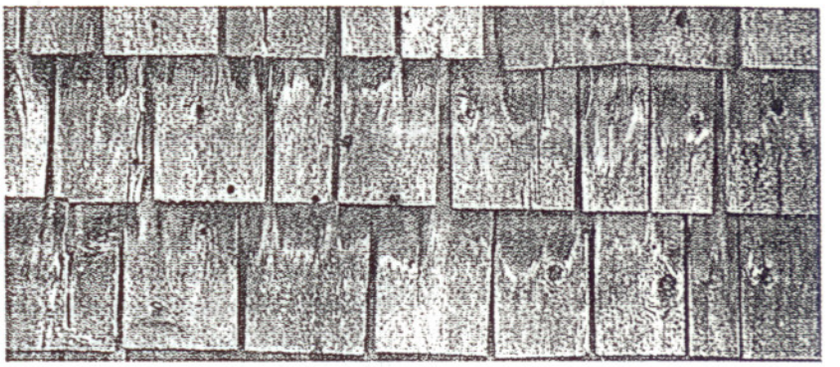

Other processes that can benefit from inside-the-dryer moisture control include textiles and forest products.