DDGS MOISTURE CONTROL

Most ethanol producers fail to achieve a potential return of $1 or more per ton of dried DDGS product due to the inadequacies of their moisture control systems. These losses are caused by failure of existing control systems to reduce the moisture variation (standard deviation (s.d.)) of the product moisture exiting the dryer a potential 30 % to 45% below that presently achieved. The DELTA T moisture control system is capable of recovering these losses by reducing the standard deviation from 30 % to 45%. As seen in figure (1) below, this allows the moisture distribution curve for DELTA T control to be shifted upward until its upper specification limit (USL) is superimposed on the USL of the cure for the current control method. The resulting difference in mean moisture values for the two curves represent the economic gain in terms of production increase, unit thermal energy reduction, and improved product quality.

Figure (1) – Improved Vs Current Moisture Control

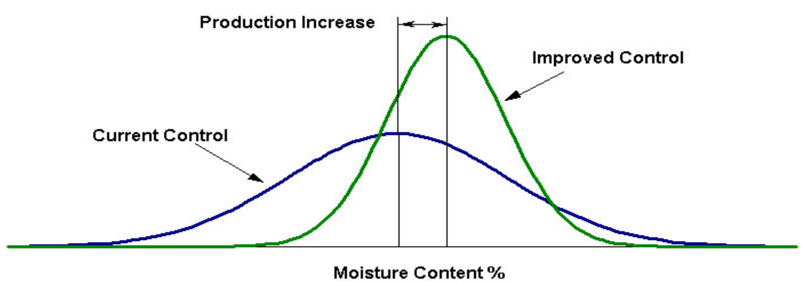


Figure (1), typical of many DELTA T installations, clearly demonstrates that current moisture control methods are failing to achieve the potential benefits of the best designed and maintained dryers.

THE CONTROL PROBLEM:

Four major problems present in current moisture control systems that adversely affect their effectiveness are: (1) use of the exhaust temperature as a surrogate for exit moisture for flash, ring, spray, and rotary dryers, (2) lack of an "inside-the-dryer" moisture sensor to significantly reduce the dead time (time to detect a disturbance entering with the feed) for fluidized-bed and conveyor dryers, (3) lack of a general moisture control model derived from first principles, and (4) lack of the ability to automatically adjust for disturbances entering with the feed.

Single-loop feedback control is commonly used for controlling product moisture exiting dryers. The loop may be closed (automatic) or open (manual). Many feedback loops are operated in manual mode because of the lack of confidence in conventional moisture sensors. A feedback loop accepts a moisture signal from a conventional moisture sensor or the results of a laboratory moisture sample and compares it to a setpoint target moisture value. The difference in the setpoint value and the moisture reading produces an error signal used by the controller to adjust the amount of thermal energy required to maintain the target moisture.

A. PROBLEM 1 -- DEAD TIME BARRIER:

As may be inferred by the term, feedback, there is delay (dead time), between the time a disturbance enters the dryer and its detection by a conventional moisture sensor which, by necessity, is installed at the dryer discharge or beyond. Since conventional moisture sensors cannot be installed inside the dryer for further reduction in dead time, the minimum dead time is fixed and is equal to the total time the product is in the dryer; the maximum dead time would be experienced if a conventional moisture sensor were installed beyond the dryer exit. Since the s.d. is directly proportional to the dead time, it is fixed also. If the conventional moisture sensor is located beyond the dryer exit, e.g., laboratory samples are used, the dead time is further increased.

Solution of this dead time limitation problem has been attempted using feedforward loops, for measuring incoming moisture and mass feed rate so that the evaporative load to the dryer could be calculated in real time and used as an anticipatory signal to bias the feedback loop for an incoming disturbance. In practice, such feedforward loops are not effective because of the uncertainty in the accuracy of the added sensors and because of the maintenance and investment expense.

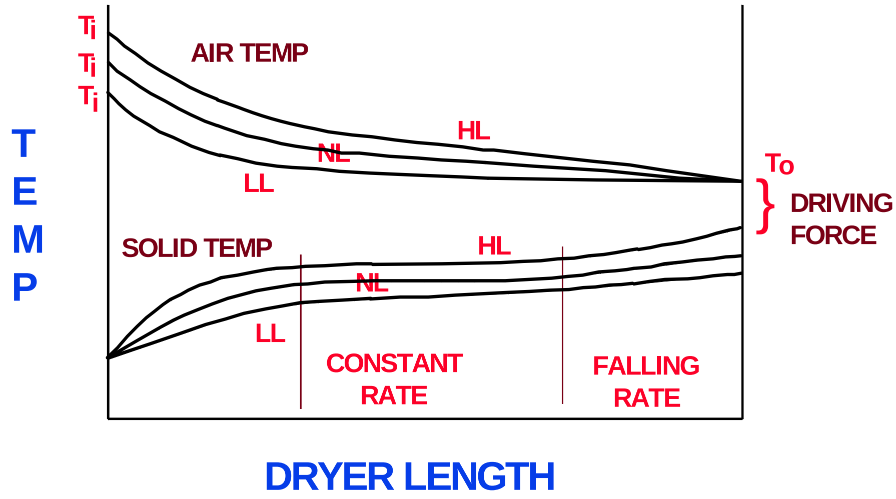
B. PROBLEM 2: EXHAUST TEMPERATURE CONTROL

It is common where rotary, flash, ring, and spray dryer are employed to find that the moisture control system is based on the use of an exhaust temperature value as a surrogate for exit moisture. This is not good practice because as soon as evaporative load changes enter the dryer, the established exhaust temperature setpoint is no longer valid for producing the target moisture content. Unfortunately, there are no simple, automatic, and continuous methods for adjusting for such disturbances; consequently, the dryer operator must continually search, in an “after-the-fact” manner, for a new exhaust temperature setpoint. Needless to say, the s.d. of the product produced by the exhaust temperature control method is significantly higher than if it were operating under a control system using the improvements recommended above.

Sometimes a moisture sensor located downstream from the dryer entrance is used as a feedback signal to adjust the setpoint for the exhaust temperature control method. However, this introduces another loop that must be tuned, calibrated, and maintained; and it introduces another source of long dead time.

This weakness of the exhaust temperature method of moisture control for co-current flash, rotary, ring and spray dryers is further explained by figure (2). It shows, for a co-current dryer operating at high load (HL), normal load (NL) and light load (LL), the temperature of the air and product as they progresses through the dryer.

Figure (2) – Weakness of the Exhaust Temperature Moisture Control System



The exhaust temperature, To, is held constant (setpoint) when using the exhaust temperature control method. If, for example, the drying load changes from a light load (LL) to a heavy load (HL), the driving force for drying (difference between constant exhaust temperature and the temperature of the product surface) is shown to decrease when in fact it should be increased to evaporate the extra water load to the dryer. In order to correct the problem introduced by the exhaust temperature control system, the operator must search for the correct exhaust temperature setpoint in an "after-the-fact" trial and error manner. This causes an unnecessarily higher product moisture s.d.

C. MODEL-PREDICTIVE CONTROL:

Sometimes, a highly-sophisticated model-predictive moisture control system is suggested.   It is based on empirically-derived model(s) generated over relatively long periods of time for on-line learning of the process dynamics of a specific dryer system. These systems require time and specialized engineering talent to train and adapt to a particular dryer. They are probably more appropriate for more complex processes. However, to be successful, they too require effective moisture sensors.

<u>THE CONTROL SOLUTION</u>:

Significant reductions in moisture s.d. can be realized if the following criteria are included in the moisture control system design: (1) base the control system on a general moisture control model derived from first principles that does not require calibration or training time. The DELTA T was not empirically obtained by correlating variables to the moisture content, but was mathematically derived as a general moisture model; (2) use a moisture sensor that can be installed inside the dryer that enables further reductions in dead time thus enabling a 30% to 45% decrease in s.d; and (3) use a control system that has the capability of automatically adjusting the setpoint to accommodate evaporative load swings to the dryer

The patented, award-winning DELTA T moisture control system is a highly successful and simple moisture control system that is presently controlling the moisture from over 300 dryers, including installations on ring and rotary dryers in the wet corn milling industry. It is designed according to the criteria listed immediately above for direct and indirect, batch or continuous dryers. There is significant economic advantage to be gained from a moisture control system based on a general dryer moisture model that can be on-line, in less than five days, and has a simple pays back of the investment in less than six months.

<u>BENEFITS FROM IMPROVED MOISTURE CONTROL:</u>

Tangible benefits from an improved moisture control system are: (1) increased production, (2) reduced thermal energy consumption, and (3) improved quality by eliminating over and under-dried product.

A. PRODUCTION INCREASE:

Current moisture control produces wider moisture variation (higher s.d.), therefore, the mean product moisture content must be controlled to a lower moisture content to prevent wet product. Such operation costs the producer in terms of: (1) loss of water sales (must evaporate more water), (2) higher unit thermal energy consumption to evaporate more water, and (3) product quality (color, palatability, mold growth, etc) often suffers. Figure (1) illustrates how the production rate may be increased by leaving more water in the product without exceeding the established upper moisture specification limit. The value added to the product per 1% increase in moisture content is about $1/ton when DDGS is sold at $100/ton (figure 4).

If the dryer is energy-limited, additional and significant production capacity can be obtained by drying more feed using the energy saved by increasing the mean moisture content. This is accomplished after improved control reduces the s.d. by simply increasing the feed rate until the total thermal energy consumption is back to the amount used prior to improved control.

B. THERMAL ENERGY CONSERVATION:

Thermal energy requirements are directly related to the amount of water left in the finished product. Each one percent increase in moisture content of finished DDGS product reduces unit thermal energy cost by about $0.50 per dried ton of DDGS.

C. INTANGIBLE BENEFITS:

Other important benefits from this improved moisture control system, not readily quantifiable, are realized because of the use of a patented general model for moisture control that enables a more thorough knowledge of .the process, and eliminates long periods of time for calibration and training. In fact, it uses a cruise-control method, similar to that of an automobile, for quickly getting on-line. The system is started in manual and when the moisture content is on target, is switched to auto mode. It takes over and controls to the target moisture content in spite of disturbances entering the dryer with the feed. If a new product is introduced to the dryer, all that is necessary is to repeat the cruise-control procedure. This capability is extremely important for gaining acceptance of new technology by plant operators. Some of the intangible benefits are: (1) no calibration required; (2) operator-friendly, cruise-control startup; (3) product consistency from shift-to-shift; (4) uses reliable temperature sensors and a mathematical model to sense moisture, (5) usually requires only software with no downtime required, (6) pays back investment in less than six months, and (7) moisture control system is universally applicable to most dryer-types and products.

D. OPTIMIZATION:

Dryer optimization with respect to maximized production, minimized thermal energy consumption, and improved quality is now possible. Figure (3) depicts actual data from the optimization process of a dryer as it transitions from current control with higher moisture s.d. to improved control where the s.d. was gradually reduced such that mean moisture content was gradually increased without exceeding the upper specification limit. Note that there is room for further optimization by increasing the mean moisture content from this dryer.

Figure (3) – Dryer Optimization

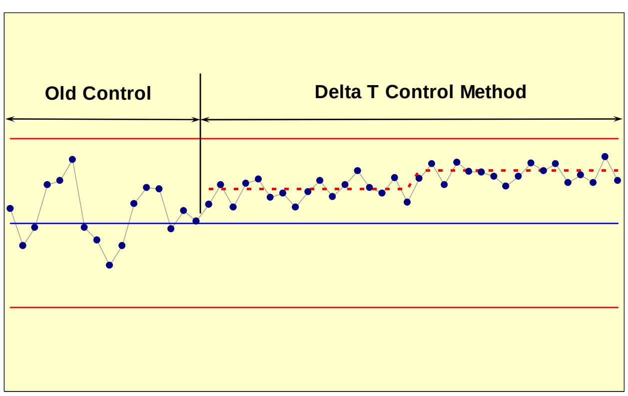
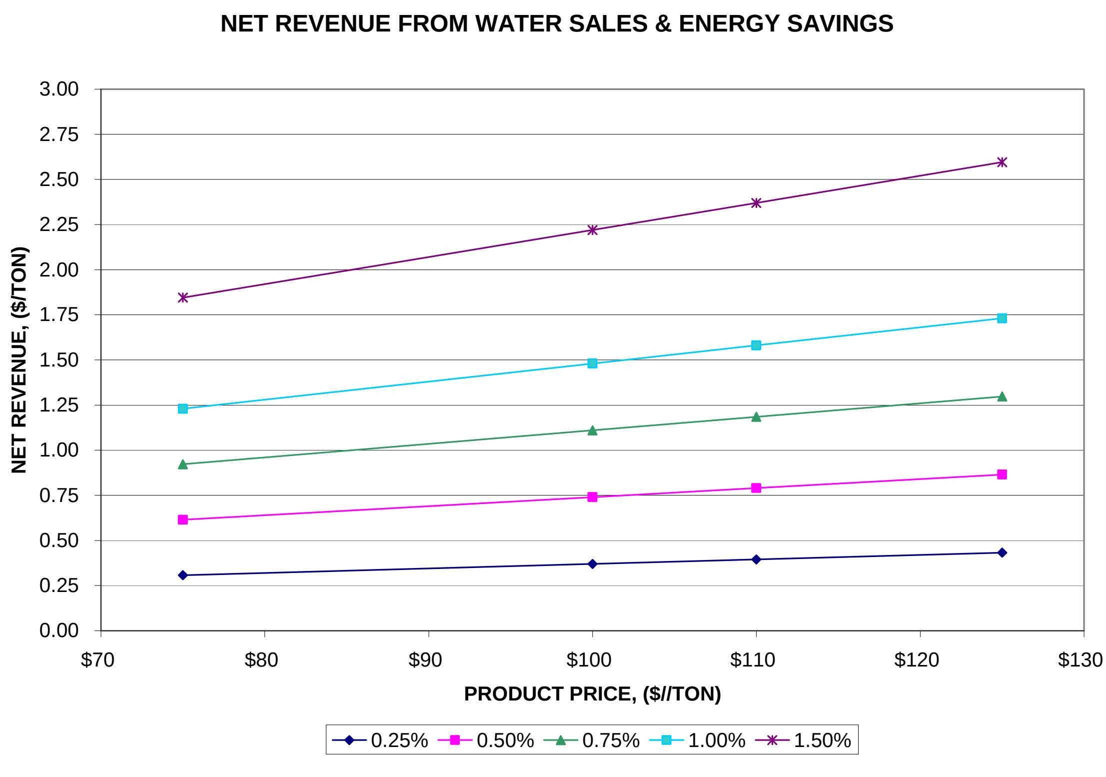


Figure (4) estimates the savings derived by improving moisture control for a dryer at various production rates and product wholesale prices. Annual net revenue is calculated by selecting the wholesale price in $/ton of dried DDGS, then proceeding upward to the appropriate % increase in mean moisture line, then proceeding to the left side to read the net additional revenue in $/ton dried product. This value multiplied by the annual tonnage gives the total net revenue for the year. For example, if the mean moisture is increased by ¾ % and the wholesale price of DDGS is assumed to be $100/ton, the net revenue is about $1.11 per ton DDGS produced. The total net annual revenue (from sale of water and energy savings) for each 100,000 tons/yr of DDGS produced would be $111,000. Total savings from a 100 Mgy ethanol plant would be about $320,000.

Figure (4) – Net Revenue From Water Sales & Energy Savings



SUMMARY & CONCLUSIONS:

The effectiveness of a dryer optimization system is totally dependent upon the capability of the moisture control system to reduce the moisture s.d. Since s.d. is directly proportional to dead time, any control system that has any chance of improving current moisture control must remove the barrier to further reductions in dead time by installing the moisture sensor inside-the-dryer to detect disturbances much earlier, and where applicable, replace the ineffective exhaust temperature control method with the DELTA T system.

An improved patented moisture control system is now available that reduces the s.d. by 30% to 45% over that produced by current control systems. It includes the following design criteria: (1) an “inside-the-dryer” moisture sensor; (2) has the capability for automatically adjusting the setpoint for disturbances entering with the feed; and (3) is based on a general moisture control model derived from first principles that requires no long training or calibration time. This new control system has been proven in over 300 installations, including installations in the ethanol production industry, to increase production by ½ % or higher and to significantly reduce unit thermal energy consumption.