A UNIQUE DRYING MOISTURE CONTROL SYSTEM

Drying, the process of removing water or organic solvents from wet products, is used extensively in the manufacture of wood veneer, pulp and paper, textiles, carpet, foods, minerals, animal kibble, pharmaceuticals, coal, corn gluten, and many other products. Moisture or solvent content of the finished product is the variable most widely used to evaluate the effectiveness of the drying operation. Product quality and value are directly related to the moisture distribution in the product as it leaves the dryer. Dryer control improvements that could produce narrower moisture distributions might save billions of dollars a year from increased production and reduced energy usage (see Figure 1).

CONVENTIONAL DRYER CONTROL SYSTEMS

The problem with most dryer control technology in use today lies in determining product moisture inside the dryer. Conventional moisture sensors are not suited to the hot, dirty, corrosive atmosphere inside most dryers; furthermore, interior space is limited, and only a small amount of product can be accommodated. Although some dryer control systems incorporate sophisticated computers, most collect "after-the-fact" data, i.e., the moisture sensors are located on the product line following the dryer. Moisture content data are fed back to the control computer and a variable such as dryer speed and/or energy input is manipulated in an attempt to control exit moisture content to some setpoint value.

Many dryer control systems use exit product or exhaust vapor temperature as the controlled variable, an approach that can be effective if system noise, loop errors, and system changes are minimized.

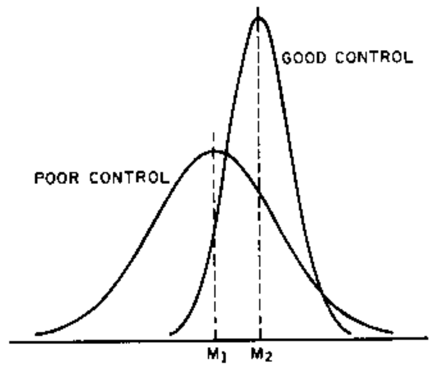

Figure 1. *Good dryer control will maintain a moisture content setpoint (M_2) and narrow the moisture distribution to the desired levels.*

This is not the typical case, however, and a wide moisture content distribution can be the result. It is therefore clear that a method is needed to sense moisture near the end of the drying process so that adjustments can be made before the product exits the dryer.

THE DELTA T SOLUTION

The patented Delta T method for dryer control made by Drying Technology, Inc., provides a way to sense and control moisture inside dryers. For continuous dryers it is based on the mathematical model:

$$M = K_1(dT)^p - K_2/S^q \qquad (1)$$

where:

- M = product moisture
- dT = temperature drop of hot air after contact with the wet product
- S = production rate or dryer speed
- K_1, K_2 = constants unique to a system and product
- p,q = exponents unique to a system and product

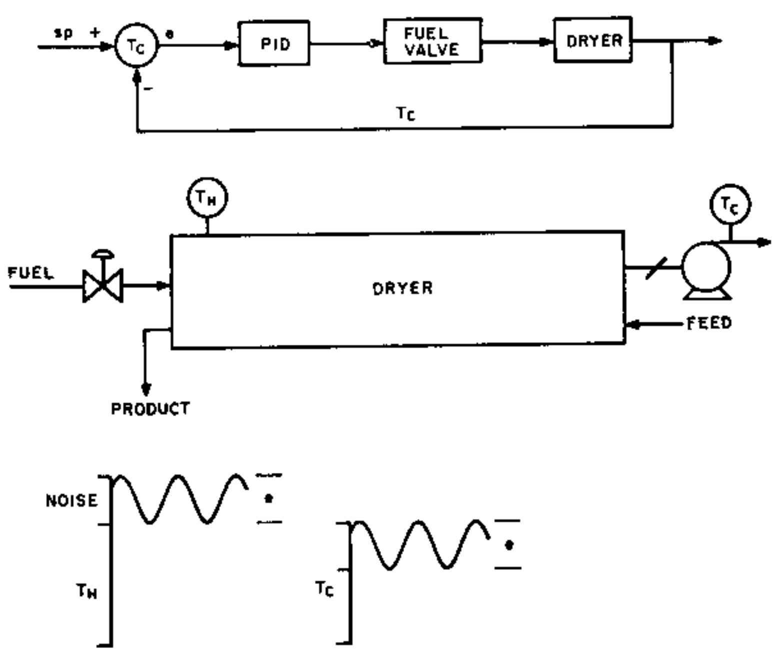

Figure 2. *The cold-end temperature will not relate to moisture content when noise and loop errors are transferred from the hot end.*

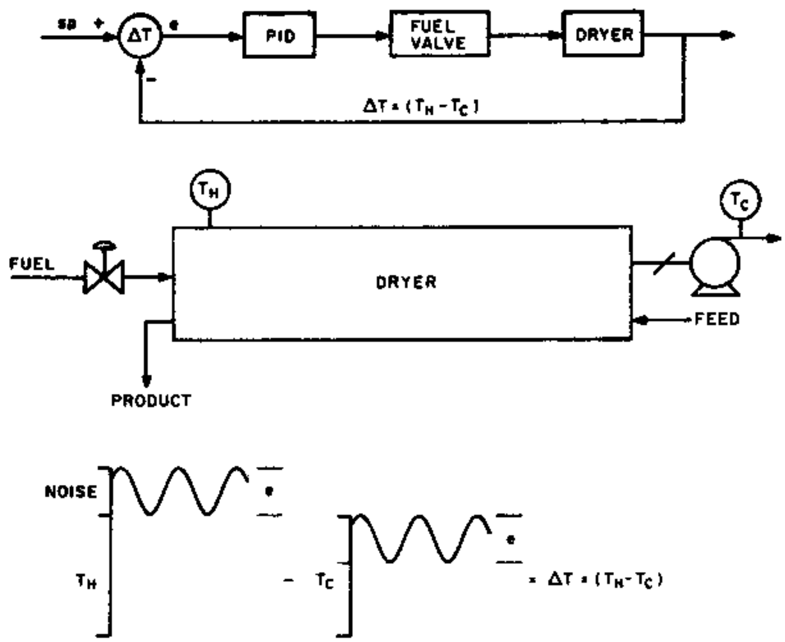

Figure 3. *The majority of the noise and loop errors are eliminated as a result of the subtraction step in calculating the ΔT value.*

The above form is applicable to dryers using both convective and conductive heat transfer. For batch dryers, dryer speed is converted to drying time (D_t) and the model becomes:

$$M = K_1(dT)^p - K_3(D_t)^r \qquad (2)$$

As previously noted, the majority of convective dryers are controlled by maintaining a constant cold-end (exhaust) temperature. Unless hot-end temperature (T_h) is constant, cold-end temperature (T_c) is not a good predictor of exiting product moisture content. Figure 2 is a schematic of cold-end temperature control and the problems encountered with noise and loop errors transferred from the hot end to the cold end.

As shown in Figure 3, the Delta T system eliminates noise and loop errors and, to a great extent, erroneous signals caused by upset conditions that result from the subtraction step in calculating the ΔT value.

In after-the-fact dryer control, product moisture is measured either by grab-sample or by an on-line sensor, and the information is used later to make corrections in dryer operating conditions. The problem here is that once product is out of the dryer it is too late to correct for moisture; by the time the pertinent information is available, product entering the dryer has characteristics that differ from those of the previous batch and corrections would only exacerbate the situation. It can be shown, in fact, that this type of control makes the right decision only 33% of the time.

During the drying process, evaporation of water or solvent from the heating medium (usually hot air) causes a temperature drop in the medium. As may be seen from the above models, product moisture is related to temperature drop. This important relationship may be used to measure product moisture at almost any location in the dryer using a minimum of two temperature sensors. By experience we have found that a change of 0.5°F in the ΔT value is significant, so we use RTDs because of their accuracy and repeatability.

An increase in ΔT indicates an increase in product moisture content; similarly, a decrease in ΔT indicates a decrease in moisture content. Therefore, installation of ΔT probes at any point along the dryer provides a rugged sensor for determining the moisture content at that point.

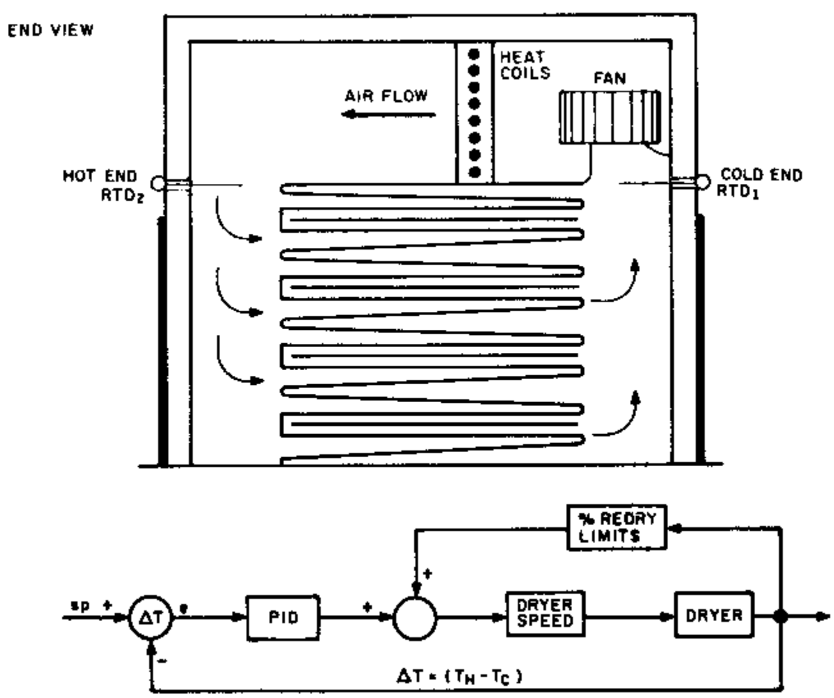

Figure 4. *RTDs are typically located on the hot and cold ends of a wood veneer dryer with transverse air flow. Control is based on the Δ value and the % redry limits.*

APPLICATIONS

Delta T technology has been applied to the control of over 75 wood veneer dryers operating on both impingement jet and longitudinal air flow drying techniques. Figure 4 shows RTD location in a typical installation using transverse air flow.

The system improves the management of rotary drum dryers that are at present controlled only by exhaust temperature (see Figure 5). When used to dry products from the wet corn milling industry such as gluten, feed, and germ, the ΔT value may be the difference between the cold-end temperature and the product exit temperature or the temperature difference between the incoming and outgoing air.

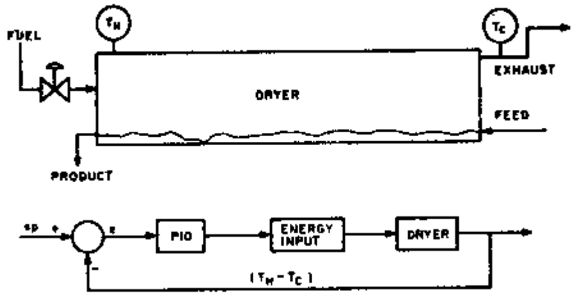

Figure 5. *In rotary drum applications, the temperature drop through the dryer is used to control energy input.*

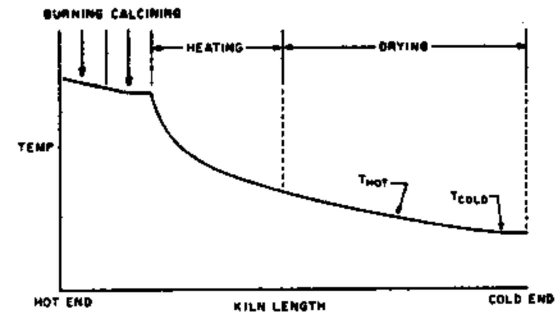

Figure 6. *Most lime mud kilns have four zones. Drying takes place in the cold end; heating, calcining, and burning occur in the hot end.*

In a **lime mud kiln**, mud consisting mostly of calcium carbonate from the kraft pulping process is converted back to calcium oxide. Lime mud at ~65–70% solids is fed to the cold end of the kiln. Fuel enters and is burned at the opposite (hot) end. At least four zones are present in the kiln—drying, heating, calcining, and burning (see Figure 6). Most control systems for lime mud kilns use two main loops, hot-end and cold-end. Hot-end control maintains a constant temperature in the burning and calcining zones and the cold-end loop controls drying. Again, loop errors and noise are transferred from the hot-end loop to the cold-end loop. They may be eliminated by using ΔT rather than cold-end temperature as the controlled variable (see Figure 7).

Dryer systems used on **textiles and carpets** offer one of the best opportunities for improvement in moisture control. Most if not all carpet dryers use hot air in multiple stages as the drying medium (see Figure 8), for which Delta T technology is easily adapted.

Yankee Hood dryers are used to dry **tissue paper**. The process involves placing the tissue on a rolling drum that passes under a hood. Hot air is forced into the hood and across the paper. The

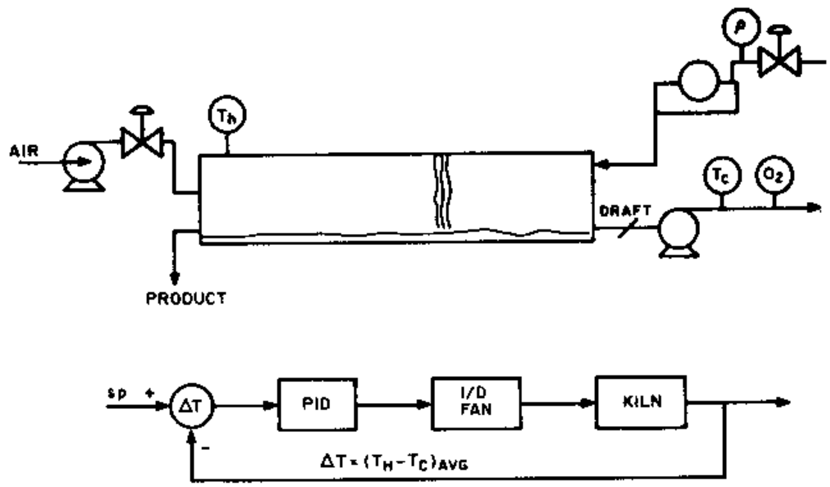

Figure 7. *The control scheme used in this lime mud kiln uses the ΔT value as the control parameter to maintain constant hot-end temperature and to control air flow.*

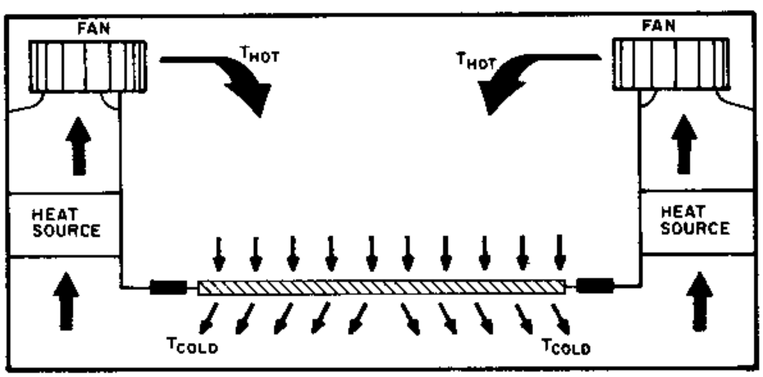

Figure 8. *In a flow-through carpet dryer, RTDs are used to measure hot-end temperature (T_{hot}) and cold-end temperature (T_{cold}). The resulting temperature drop is used as the process measurement to relate to moisture content. A change in conveyor speed or energy input can be made based on the temperature drop.*

temperature difference between the hot air entering the hood and the exhaust air is used as the ΔT in the hood model that controls the paper's moisture content (see Figure 9).

The Delta T drying model can be applied to many other types of dryers such as flash, fluidized bed, paper mill can, lumber dry kilns, and most other dryers using conductive or convective heat transfer.

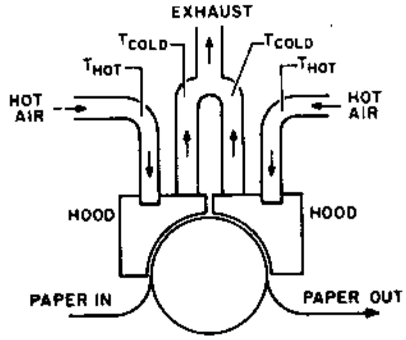

Figure 9. *In the Yankee Hood dryer application, RTDs are used to measure the temperature of the hot air (T_{hot}) entering the hood and of the exhaust air (T_{cold}). Several options are available on this system to adjust for changes in the moisture content of the paper.*

SUMMARY

The Delta T principle has been validated by over 80 installations to date. Strong evidence suggests it to be universal in application, i.e., all dryers using hot air or hot surface contact as the heat transfer medium should be amenable to control by the Delta T system. Its ability to use RTDs to measure product moisture content inside the dryer is a significant advantage, as is the elimination of noise and loop errors associated with interaction between hot-end and cold-end temperature control loops.

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