DELTA T DRYER MOISTURE CONTROL SYSTEM COMPLETES TEN YEARS

Since Boise Cascade's initial purchase in 1986, Delta T system has improved drying efficiences in mills across the country.

BY JOHN ROBINSON

August 1996 marked the 10th anniversary of a significant improvement in plywood manufacturing—commercialization of the DELTA T veneer dryer/moisture control system by Drying Technology, Inc., Silsbee, Tex. Installation of more than 140 systems has resulted in significant improvements in production, quality, energy conservation and air emission reduction.

Boise Cascade Corp. purchased the first DELTA Ts for three jet dryers at its southern pine plywood mill in Florien, La. in August 1986. **Figure 1** is a graph of the drying time reduction for one of these dryers when switched from manual to DELTA T control. The graph shows that the veneer was being over-dried and the DELTA T reduced the drying time from 11.8 to 10.7 minutes for a production increase of about 9%. **Figure 2** shows the action of the DELTA T controller when switched to auto DELTA T mode.

Figure 3 shows that production rate was increased from 122 to 137.5MSF (⅜ in.) per deck-section (12.7% increase) when all three dryers were DELTA T controlled at the Florien mill.

As a result of the successful Florien installations, Boise's Oakdale, La. mill installed three DELTA T systems in January '87. Daryl Studeman, manager of both mills, was instrumental in giving this new technology a start. In July '87, three were installed at Boise's Medford, Ore. mill on longitudinal dryers. Concurrent with the Medford startup, three systems were started up at Gregory Forest Products, Glendale, Ore. Later, Terry Christensen, Div. Manager, Mid-Continent Div., Georgia Pacific Corp., made a one-time purchase of 27 DELTA T systems—one for each of his dryers—an obvious shot in the arm for a small, struggling company.

At the present time, more than 140 dryers are presently being controlled with the DELTA T. Some of the earlier systems are being upgraded using the latest PC based hardware. Orders for six new veneer dryer systems were received the first month of '97. The DELTA T can benefit both hardwood and softwood veneer mills. While veneer dryers paved the way for this technology, the DELTA T is being applied to many other industries.

MOISTURE CONTROL

Dryer/moisture control has suffered over the years from lack of timely moisture content (MC) data upon which to make control decisions. Consequently, feedback control was, of necessity, the control method used in controlling dryers. Feedback control, an "after-the-fact" type control method, uses data from a MC sensor located at the exit of the dryer as the basis for controlling the veneer MC inside the dryer. Such control systems are not very effective; in fact, it can be demonstrated that they make the right control decision only one time in three. For example, if a MC sensor at the dryer exit indicates that the product is wet, the feedback controller will increase the amount of heat to the dryer; or if speed is the manipulated variable, the speed will be decreased. However, such control decisions are based on "after-the-fact" MC data. The condition of the product about to exit the dryer may not be the same MC as that just exited. The MC inside the dryer could be one of three conditions:

- Dryer than normal
- Wetter than normal
- Just right

Since only one of the three possible conditions is correct, the feedback controller has one chance in three of making the right decision. These are not very good odds and demonstrates why such systems have a tendency to cause the MC to cycle.

DELTA T SOLUTION

There was a need for a MC sensor that could be located inside hot, dirty and space-limited dryers so that timely MC data would be available upon which to base control decisions. Attempts to place conventional MC sensors inside such atmospheres were not successful. However, the patented

FIGURE 1

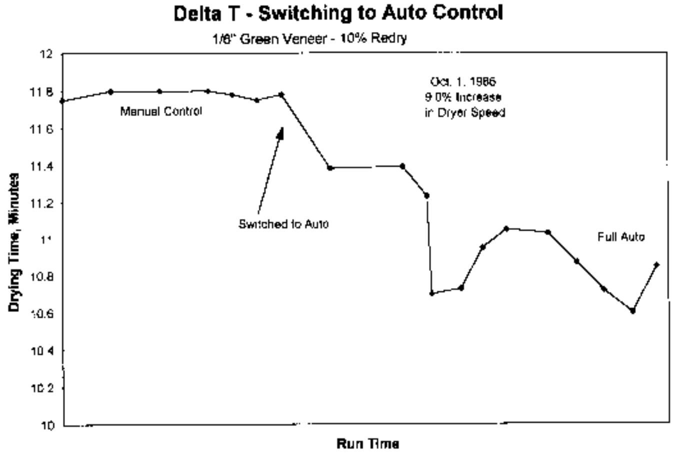


FIGURE 2

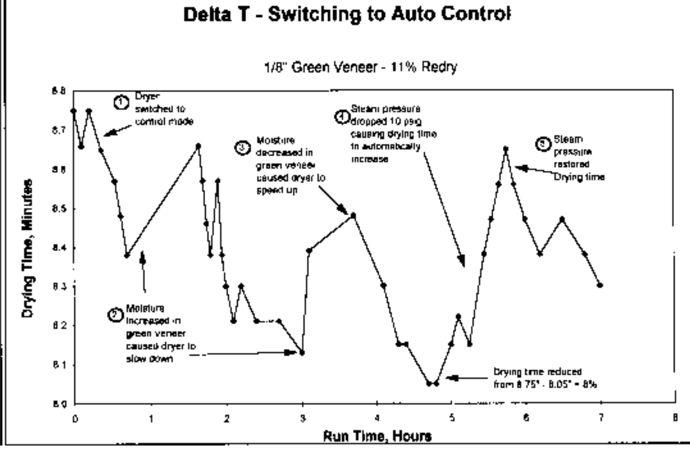


FIGURE 3

Production Increase

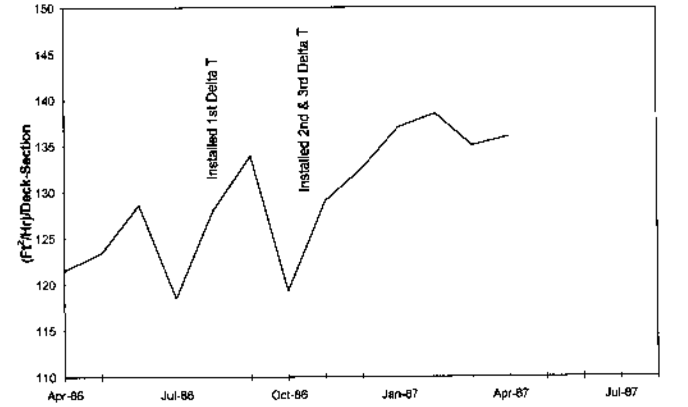


FIGURE 4

Drying Rate vs Moisture

Southern Pine

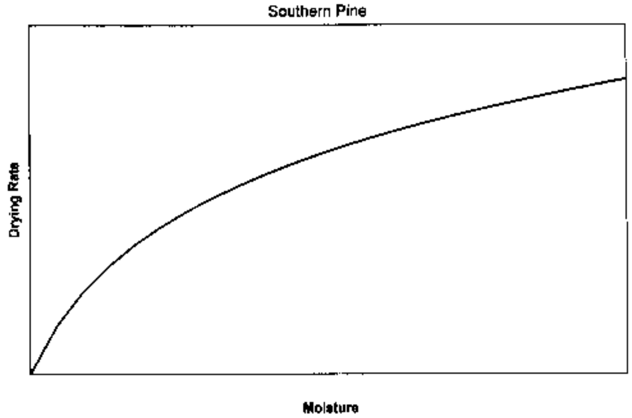
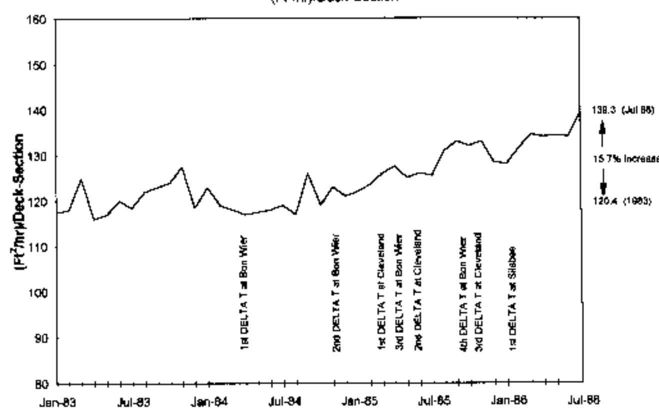


FIGURE 5

Corporate Dryer Performance

(Ft²/hr)/Deck-Section



DELTA T is capable of sensing and controlling MC while the product is still inside the dryer. It uses simple temperature sensors and the model for continuous dryers,

$$MC = K_1(\Delta T)^p - K_2/S^q$$

that relates the product moisture content (MC) to: (1)) the temperature drop (ΔT) of hot air after contact with the product; and (2) the production rate or dryer speed (S). The model is applicable for direct (hot air) and indirect (hot surface) type dryers. It also may be applied to batch dryer control, e.g., lumber kilns, by adjusting the model using a simple mathematical step. It is also useful in providing drying rates at specific points inside the dryer.

DEVELOPMENT

The DELTA T model was mathematically derived in 1975 by John Robinson, a chemical engineer, employed with Kirby Forest Industries, Inc., now a division of Louisiana-Pacific Corp. **Figure 4** shows construction of a drying rate vs. moisture curve for southern pine veneer. Similar plots for other products including other species of veneer, lumber, sawdust, petfood, textiles, paper, etc., gave the same shape curve thus proving that the drying rate vs. moisture for most, if not all products, could be modeled by a power curve. This greatly facilitated the mathematical derivation of the DELTA T model.

Following derivation of the model, an attempt at demonstrating its effectiveness was made at Kirby's Cleveland, Tex. mill. This proved unsuccessful because the delta t (DT) term in the earlier model was the temperature difference between the hot air supply and the veneer surface. It soon became evident that obtaining a representative veneer surface temperature was not practical. At that point it looked as if the model was of academic interest only and not suitable for controlling a dryer. Later, the model was extended mathematically to utilize, as the delta t term, the temperature difference in the hot air before and after contact with the veneer. The DELTA **T** was now in a highly practical form since it was composed of: (1) an easily obtained measured or process variable, (DT), highly correlated to MC, that lumped all of the variables associated with drying into one value; and (2) it contained dryer speed, a variable that was easily manipulated to effect a change in the process variable.

The modified DELTA T model was used as the basis for a prototype control system on a jet veneer dryer at Kirby's Bon Wier, Tex. mill in 1983, then managed by Bill Norrington. Frank Smith, dryer superintendent, and later Dave Walsh, dryer superintendent, were sold on the idea and helped tremendously in its initial and successful startup and operation. Later Frank and Dave obtained DELTA **T** control systems at other mills where they were employed. Following successful operation on one dryer, it was installed on all four Coe jet dryers. Patent applications were filed in 1984 and issued in 1987 and 1988 for both continuous and batch dryers. **Figure 5** shows the production increase achieved resulting from installation of eight DELTA T systems at Kirby Forest Industries, Inc.

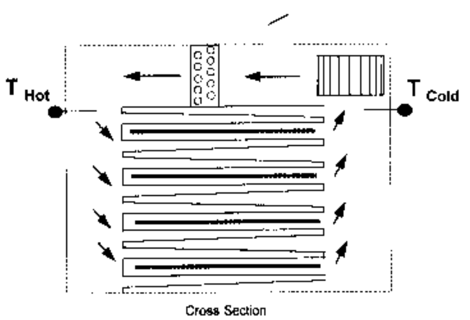
APPLICATIONS FOR ROTARY PEELED VENEER

A) Jet Tube Dryer

For rotary peeled veneer, the usual drying practice is to feed, manually or automatically, veneer to the dryer in various thicknesses and widths up to the normal 54 in. size. The normal jet tube dryer has four decks and usually three drying zones, with the majority having 10-26 drying sections and two or three cooling sections. A section is about 6 ft. long with an individual circulating fan. **Figure 6** shows a cross-section of a typical jet tube dryer with fan, heat source and location of temperature sensors for obtaining the delta t value.

As the circulating hot air contacts the wet veneer, it is cooled, then reheated by recirculation across the heating coils. For a constant air flow and hotside temperature, the DELTA T model states that the temperature drop across the veneer is a measure of the MC of the veneer at that

FIGURE 6



point. The DELTA T control system processes the delta t data using the model to produce an output value that is proportional to the MC of the veneer. This output signal is compared to a setpoint value, and the difference (error) is used to manipulate the dryer speed and/or the thermal energy input valve.

Essentially, the DELTA T control system measures the MC of the veneer inside the dryer and makes necessary changes in operating conditions to produce a veneer at the proper MC at the dryer exit. A brush-type MC sensor is located at the dryer exit to detect and mark high moisture spots that would create problems in gluing and pressing. The number of wet sheets (marked) out of 100 sheets is the percent redry.

Figure 7 depicts the two-loop, cascaded DELTA T control system. A delta t value is obtained, usually in the third zone and used in adjusting the speed of the dryer and/or the heat input valve. Normally, if steam is used as the heat source, the valves are wide open and the dryer speed is manipulated.

In the inner or primary loop of Figure 7, a delta t value is established that produces the desired percent redry and/or MC. As the actual delta t value departs from the setpoint value, the control system adjusts the dryer speed and/or the hotside air (supply) temperature. The delta t setpoint is adjusted for changing hot air supply temperature, e.g., through pressure swings of the steam supply header. The controller gain allows about 0.1 minute change in drying time for each degree of delta t departure from the delta t setpoint. The maximum change in drying time allowed is limited to about ±1 minute.

The secondary or outer loop maintains the percent redry. A setpoint value is established and if the actual value falls outside the limits, a small adjustment is made in the delta t setpoint which, in essence, shifts the delta t limits accordingly. The adjustments are designed such that the delta t loop is always able to adjust the dryer speed in response to a change in delta t. This ensures that the variation in the average MC of the veneer exiting the dryer is minimized while the percent redry does not get out of control.

A better method of controlling veneer dryers is to control to an average MC and allow the percent redry to vary. An average MC could be established that would keep percent redry within limits but on a longer time basis than the usual 100 sheets of veneer. **Figure 8** shows the improvement in control when average MC of the veneer is controlled rather than percent redry.

B) Longitudinal Dryers

The DELTA T has been applied to single and multi-zone longitudinal dryers with equal success. A minimum of four temperature sensors are required for obtaining the delta t data. Some have been controlled using the complete zone delta t; others measure the delta t over a shorter portion of the zone. The control scheme is essentially the same as for a jet dryer.

C) Screen Dryers for Sliced Veneer

The DELTA T has been applied in the control of sliced red oak veneer using a screen dryer. A 20% production increase was reported at Weyerhaeuser's mill in Pennsylvania as a result of improved control that eliminated over-drying of expensive oak veneer.

D) In-Line Veneer Dryers

Razz Carter of the Weyerhaeuser Co. was instrumental in gaining approval for installation of the DELTA T on all in-line veneer dryers and two conventional jet dryers at its U.S. mills. Steve Higdon, Mill Manager at the Millport, Ala. mill, reported a 12% production increase. Razz later installed a DELTA T at Mannington Wood Floors in Livingston, Ala.

ADVANTAGES

Conventional control of veneer drying is based on controlling to a percent redry target. For example, if the target is 15%, the dryer is either manually or automatically controlled by counting the total sheets of veneer and the number of wet sheets. If the number of wet sheets exceeds 15 out of 100 total sheets, the dryer speed is decreased. Likewise, if the actual count in 100 sheets is less than 15, the dryer speed is increased. This type control has a tendency to cause the dryer to cycle and produce more over- and under-dried veneer than necessary. As previously mentioned, such systems make the right decision only one time in three, therefore, if this type system is employed, it is probably best to operate in manual mode to reduce the number of bad decisions made by automatic percent redry based systems.

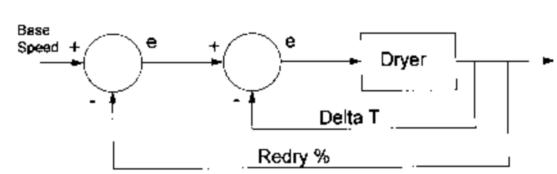
In contrast, the DELTA T senses when the veneer average MC is changing inside the dryer and begins to change the drying time accordingly. As a result, the medium and long-term trends in MC are essentially eliminated by the control action of the DELTA T. Drying Technology, Inc. has measured about a 33% reduction in redry (15% to 10%) as a result of better control by the DELTA T. This redry goes directly into acceptable production and in this case would result in a production increase of 5.9%. Some mills continue to operate at the original 15% (target) redry value, therefore, the dryer speed must be increased to maintain the percent redry target. As a result, production is increased significantly. Overall, our customers have reported production increases ranging from 4-20%, and in all cases the veneer quality was improved. At the latest installation, Columbia WV Plywood, Buford King, plant engineer, reported an 8% production increase.

OPTIONS AVAILABLE

If the DELTA T operator station is to be located at the dryer, a hardened PC is used that combines the computer and the operator station. **Figure 9** shows a typical industrially hardened DELTA T system for location at the dryer. Some plywood mills construct small plywood control rooms near the dryer for accommodating the use of desktop PC. Up to four dryers have been controlled from the same computer.

Martco installed three DELTA T systems on its new plywood mill in

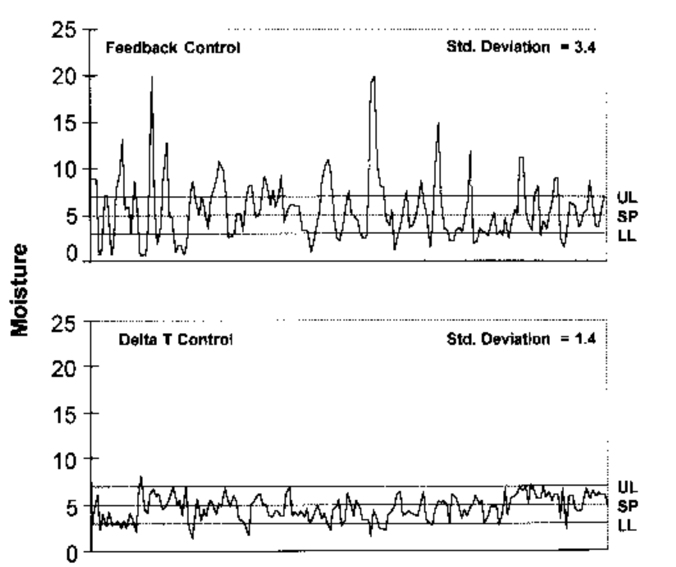
FIGURE 7



Chopin, La. during 1996. These were equipped with a series of delta t sensors throughout the length of the dryer sufficient to display the drying curve for the entire dryer. It is the intent of Jerry Buckner, VP at Martco, to use the drying curve to measure the extent of "squeezing" the constant rate portion of the drying curve into a shorter length by adding more heat in this heat transfer controlled portion of the curve. This would leave more dryer length for the time dependent falling rate portion of the curve. The result would be increased production. Additionally, it is the intent to study the effect on the drying curve of manipulating the dampers in several ways —one mode being to force more moist air toward the dry end. Since the heat capacity of moist air is significantly higher than dry air, this should enhance drying. It should have negligible effect on drying since the relative humidity of the air could never exceed 10% at operating temperatures above 250° F.

Several options are available with the DELTA T. These are: (1) Cooling Fan Control—controls the veneer temperature by manipulating the cooling fan speed. (2) Redry Origin—provides a computer screen showing the amount of redry produced from each of the 12 dryer positions (front, center, back x 4 decks). (3) Percent Filled—digital display at dryer feed station displaying the extent to which the dryer is kept full of veneer. (4) Width Control of 54s—measures and marks or directs narrow width 54s to the proper bin. (5) Modem communication capability for trouble-shooting and optimizing the system from manufacturer's office. Each of these options has made significant improvements in veneer recovery and product quality.

FIGURE 8



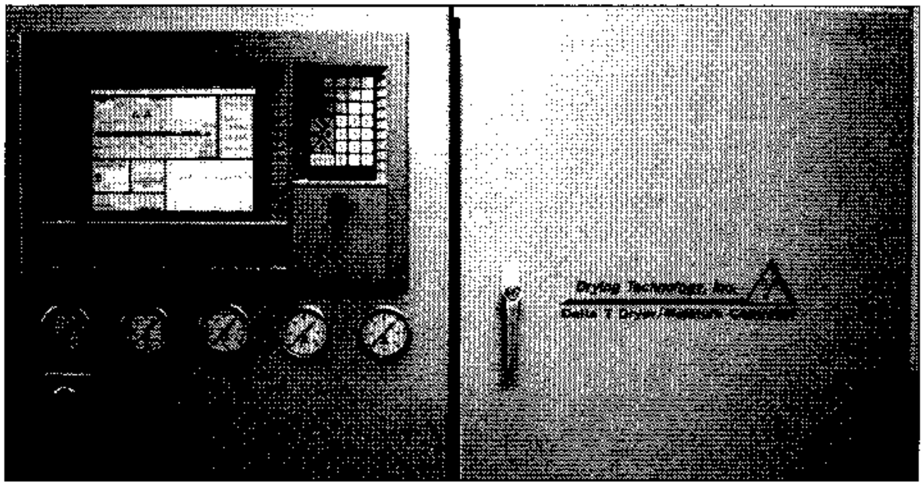


Figure 9: Delta T dryer/moisture controller hardware and software

The average production increase to be expected from a DELTA T installation is about 7% which results in a reduction in unit cost of about $4.40 per MSF (⅜ in.). Additionally, significant savings not readily calculable are: improved veneer quality, improved gluing, less breakage, fewer blows, fewer field complaints, and cooler drying which should reduce volatile organic emissions.

CONTROL OF OSB DRYERS USING THE DELTA T

A) Rotary Dryers

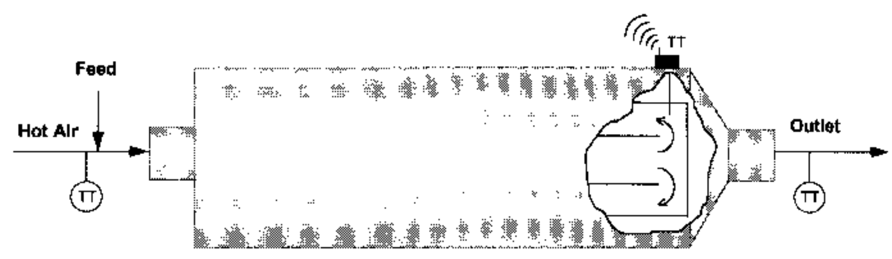
Rotary dryer control presents a challenge. By necessity they were originally installed with feedback type MC control using either an exit MC sensor or the exhaust temperature as the controlled variable. Most of these control systems were based on controlling to an exhaust temperature setpoint due to the inability of exit side MC sensors to perform satisfactorily. As previously mentioned, feedback control systems based on exhaust temperature or exit MC as the controlled variable, on the average, make the right decision only one time in three and are not very effective. This problem is exacerbated by a lag time (time a disturbance enters the dryer until its result exits the dryer) of about 15 minutes.

Operation of a control system with exhaust temperature as the controlled variable assumes that the exhaust temperature setpoint represents (correlates) the exiting MC. This is a reasonable assumption if there are no disturbances entering with the feed or with the ambient air. Since there are frequent disturbances such as fluctuations in entering MC, feed rate and ambient air, the operator must tinker with the exhaust temperature setpoint in an "after-the-fact" manner because there are no available automatic methods for compensating for such disturbances.

The initial DELTA T control system for rotary drum dryers used the total temperature drop across the dryer as the delta t (controlled variable) term in the model. This value is indicative of the evaporative load in the dryer. Any change in this value requires an appropriate and timely change in the heat input. In contrast to the control method using exhaust temperature as the controlled variable, a method for automatic compensation of delta t setpoint has been developed and is applied in order to correct for the continuously changing operating conditions inside the dryer. The DELTA T has been applied to triple pass rotary dryers and has reduced the MC standard deviation by 25-50%. Barriers to further improvements in control of rotary drum dryers above that presently achieved using the overall delta T value are: (1) the presence of a lag time of about 15 minutes, and (2) large heat sink resulting from the amount of metal that must be heated and cooled in a short period of time. A reduction in the lag time would significantly reduce the standard deviation of the exiting MC.

The next installation of the DELTA T on rotary dryers will address the excessive lag time by including wireless temperature sensors at various points inside the dryer (**Figure 10**).

FIGURE 10



An RTD (temperature device) is inserted at, for example, the entrance to the third pass in the dryer. An FM radio transmitter connected to the sensor and powered by an induction generator rides the rotating shell of the outer drum. Lag time would be reduced up to 67%, and when coupled with the DELTA T control should reduce the MC standard deviation additionally.

B) OSB Conveyor Dryers

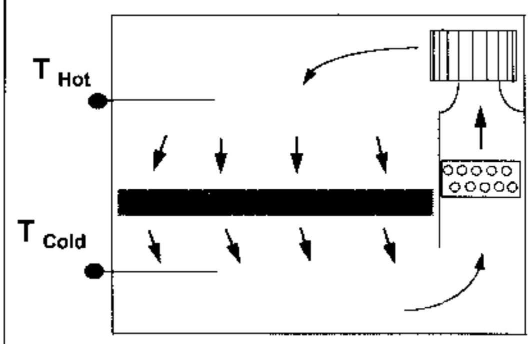
In recent years, flow-through conveyor dryers, usually configured as three 120 ft. stacked or in-line tiers, with three zones per tier, have been used for drying OSB strands. **Figure 11** shows a cross-sectional view of this type dryer.

Manufacturers of these dryers claim advantages such as less damage to the strands due to the elimination of the tumbling encountered in rotary dryers; less particulate matter due to the filtering effect of air flowing through the bed of strands; and fewer volatile organic carbon emissions due to lower operating temperatures.

Initial installations of OSB conveyor dryers have been designed with feedback or feedback/feed-forward type control systems that utilize IR or NIR MC sensors at the feed and at the end of each tier. The atmosphere around and inside an OSB dryer has not been conducive to the successful use of these MC sensors. Failure of these MC sensors resulted in failure of the control system. Model Predictive Control systems have also been employed; however, they are expensive and not flexible enough for this type operation Again, there is a need for a simple and reliable MC sensor that can be placed inside the dryer.

According to Drying Technology, Inc., application of the DELTA T control system would be ideal for controlling the MC from these dryers since it's possible to obtain the MC in each of the nine zones using simple temperature probes and the DELTA T model. Knowing the MC inside each zone/tier would allow control to commence in the first zone/tier and continue throughout the dryer length. The detrimental effect of lag time and heat sink would be eliminated. Disturbances entering with the feed would be detected at an early stage and proper adjustments in operating conditions would continue to be made as the strands traveled through the dryer. The end result would be a product with a significantly reduced MC standard deviation.

FIGURE 11



Cross Section

CONTROL OF OTHER PANEL PRODUCT DRYERS

A) MDF

Flash or suspension dryers are used in the production of medium density fiberboard (MDF). Drying times are quite short, perhaps 5-10 seconds in some cases. Therefore long lag times are not a problem as in rotary dryers. Temperature sensors would be installed at various points along the tube. The delta t value for the model would be the difference between a representative pair of temperature sensors in series along the drying tube.

B) Wet Process Fiberboard/Hardboard

Such dryers are usually multi-deck longitudinal dryers and should present no problem in applying the DELTA T in controlling exit MC. The lag time in these dryers is measured in hours, and the ability of the DELTA T to measure MC inside the dryer at any location is highly advantageous in controlling the exit product MC to a very tight standard deviation. It's also possible to monitor the internal MC in the vertical and cross-machine directions in order to correct any air distribution problems that might be present. This on-line ability could result in significant improvements in production rates by reducing the standard deviation of the exit product MC.

C) Miscellaneous Products

It appears that the DELTA T is universally applicable to all dryer-types and products. The MC of other board products, dried with rotary, conveyor, flash, etc. type dryers could be controlled using the DELTA T method much more efficiently than with the usual feedback or feedback/feed-forward control systems.

The DELTA T has been proven in numerous installations over the past 10 years to reduce the MC standard deviation of the product exiting the dryer. This allows the average MC to be increased without exceeding the established upper limit. This increase in average MC translates into increased production, reduced unit energy consumption and improved quality. Additionally, over-drying, which adversely affects production rate and quality, is eliminated. In addition to its use in the forest products industry, its universality has enabled DELTA T technology to be applied in the food, petfood, fibers, carpet, textile and chemical industries. ■

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