LOADMASTER - WEIGHT-BASED KILN CONTROL

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Background

In the summer of 1992 Delmhorst Instrument Co., a manufacturer of portable, resistance-type moisture meters and Dr. Robert Little, then a professor of wood technology at the University of Tennessee, collaborated to research and design a weight-based dry kiln control system. The concept of using the weight of multiple, individual sample boards inside the kiln to continuously measure moisture content and derive wetbulb and drybulb setpoints accordingly is one which offers the kiln operator tremendous flexibility and control. The result of this project is the LOADMASTER, a system which offers a practical solution to the problem of obtaining accurate moisture content measurements from any initial moisture content down to conditioning levels.

Drying for Quality

One of the most dramatic changes in the lumber business of the 1990's has been the increased emphasis on drying quality. The accelerated demand for high quality lumber, whether it be high value cherry or oak for the furniture market or SPF for construction, has never been greater. More and more customers, both at home and abroad are demanding a bright, flat, high quality product at the right moisture content. Premium dried woods are a most valuable commodity due to escalating prices of a diminishing resource, the high cost of degrade, and ever-increasing world competition.

Drying practices vary from one mill to another, even more so between the hardwood and softwood industries. These variations can be due to the requirements of a specific market or perhaps a hard to break reliance on a "tried and true" method that always seemed to work. Also contributing to this may be the fact that the drying process has not always been viewed by management as a top priority when it comes to capital expansion.

Mill management has now come to realize that poor drying equipment and techniques can only be a profit drain which minimizes the value added opportunities available. Advances in dry kilns and dry kiln controls enable us to control kiln conditions so well that it is the variability in the lumber itself that presents the greatest challenge to the quality-conscious drying operation.

To help overcome this variability during drying we must rely on control systems that better monitor the lumber's behavior and use the *drying rate* as the basis for control. Most techniques in use today all have some merit, depending on

the operation and the end use of the product, and all have some inherent limitations, as well.

The use of real-time, in-kiln weight measurements best enables the operator to overcome some of these limitations because it is a direct method of measuring moisture and gives the ability to dry lumber with precise control.

Early Development

Dr. Little's approach was in part, based on past developments in the field, which had patents dating as far back as 1925 as well as many of his own ideas which he and his colleague, Bill Moschler shared. The two had extensive first-hand experience with a weight-based control system which they had installed at the University's forest products lab in the mid-1980's. This system utilized a "pancake" style load cell, designed to weigh the entire package at once.

While this approach worked well in a 700 bd.ft. research kiln we all agreed it would not be practical to apply to commercial kilns upwards of 50,000 bd.ft. or more . A primary disadvantage is that while the average MC of an entire pack would be obtained, the operator would not be able to determine slow drying areas from those drying at a faster rate since he would not have a reasonable representation of MC at various points throughout the kiln. So Bob began to look at the possibility of weighing individual sample boards - a practice which all hardwood lumber kiln operators were quite familiar with. The unique aspect of this approach was that the samples were to hang *vertically*, in the plenum area of the kiln. Conventional wisdom requires that multiple samples which are periodically removed to measure weight (moisture) loss, be repositioned within the lumber charge horizontally, or parallel to the air flow.

The main reason for placing the samples vertically on the kiln walls instead of inside the pack is to avoid potential inadvertent damage to the electronic load cells by the lift operator when switching charges. If the samples were placed in the charge, some would simply not be visible.
This approach intrigued us and merited further investigation even though we had been advised that many drying experts had outright rejected the idea. We saw some distinct advantages:

1.) An operator would have the ability to dry high value lumber from any initial MC level, whether it be dead "green", pre-dried, or air-dried.

2.) Another advantage would be the ability to use schedules which incorporate small, gradual changes rather than sudden "jump" changes, characteristic of step schedules. The use of real-time weight measurements would enable the operator to overcome the inherent limitations of time-based schedules (drying characteristics change from one charge to another) or indirect electrical methods which have limited reliability above fiber saturation point. This is where we believed that a weight-based scheme could really lend itself to minimizing degrade. Setpoint changes are made constantly throughout the drying cycle, not just at pre-determined intervals. The weight-based

approach results in a schedule with a gentle, smooth curve, making changes in small, one degree increments, precisely when the MC levels call for them.

3.) The kiln operator would no longer have to spend much of his time pulling sample boards for intermediate weighings *outside of the kiln.* When samples are removed from the kiln environment, given an opportunity to change within the control room environment, and then weighed, errors and inaccuracies are bound to occur.

The Heart of the System

The key to such a system would have to be the actual load cell and the apparatus which held the cell itself and the sample board affixed to the kiln wall. Considering the range of conditions present in the dry kiln, it was imperative that the load cell be extremely durable. To ensure this dependability, we tested many types and brands of load cells in both the test kiln and a steamer. The steamer proved to be the ultimate test as some units simply melted after a short time. We finally settled on a hermetically sealed unit, well-suited to its intended environment.

Some other concerns to be addressed in using load cells inside the kiln included how the air flow might affect the cell, the effect of changing temperatures, and interference from other electrical devices. Another issue was whether the load cell would maintain a constant output for a given input over time.

Once the proper load cell for the application was identified, the next challenge was to design the sample holder. Leaving the sample to hang freely was an initial thought which later proved unreliable due to extreme "buffeting" . The holder is designed so that the load cell will read only the direct weight of the sample, and not suffer the effects of buffeting. Construction is entirely aluminum, stainless steel, and teflon. It's durable, and most important it isolates the sample from outside forces such as vibration from fan motion or air flow.

Hardware and Software

The focus of development now shifted to the remaining hardware which would enable the load cell signal to be interpreted. We determined early on that a PID distributed control approach would provide the redundancy hardwood lumber manufacturers demanded. While a PC would be necessary for operator interface, downloading, and supervisory control, we wanted to be sure that in the event of central computer failure or a problem within the control room, the operator could control each kiln independently. This is accomplished by mounting a control box on each kiln containing UDC controllers and the signal transmitters for the load cells and RTD's. The controllers at the kiln relay their information through a gateway to the computer. The software reads these values, makes calculations based on the weight with respect to MC, and returns set points for the drybulb and wetbulb temperatures as well as controlling the physical hardware inside the kiln.

The LOADMASTER software application is a highly customized adaptation of a commercial process control package. Detailed graphical interfaces had to be created from scratch along with associated "drivers" which would allow the computer user to interact with the control box on the dry kiln.

Commercial Test Phase

After over two years of development work, we installed the first test system at Averitt Lumber in Clarksville,Tennessee in May, 1995. A second system was installed the following month at Havco Wood Products in Vonore, Tennessee. Running the system from these test sites for six months enabled us to better evaluate the LOADMASTER 's performance under actual commercial conditions. Both systems were placed on 50,000 bd.ft. masonry package kilns.

Averitt is an operation with a total annual production of over 35 million bd.ft. of various local hardwoods, including an average kiln inventory of over 1 million bd.ft. In addition to selling high grade lumber, Averitt operates a dimension mill, as well as making edge-glued panels and mouldings. Havco manufactures flooring for tractor trailer trucks, utilizing a radio frequency press to glue the truck flooring assembly.

Personnel at both plants were aware of Bob Little's earlier work with the weight-based concept and had expressed interest in acting as beta sites for a new system. The nature of their operations was ideal for testing as both rely heavily on narrow, strict tolerances of moisture content.

Testing revealed that our initial concerns about placing the sample boards in the plenum were not warranted. Early data from Averitt confirmed that the expected difference in average air flow rates between the plenum and inside the lumber pack or bolster where the operator would typically place a sample was not appreciable enough to affect the drying rate. More significantly, Averitt indicated a 10%-15% decrease in drying time for 4/4 and 5/4 red and white oak. The largest decreases were realized with charges in which initial moisture contents ranged from approximately 50%-70%. Pre-dried and partially air-dried charges showed smaller decreases. Considering that part of the early testing was spent becoming familiar with the software and tweaking components, we believe these figures can be further improved upon, especially since Averitt has installed a second LOADMASTER on a prestressed concrete kiln which has better overall drying control conditions than the older masonry kiln. Most important, Averitt's lumber continues to show no visible signs of degrade and has excellent color, while reducing drying time.

Data from Havco showed another advantage of weight-based control. The kiln operator keeps records of every charge which include the standard deviation of the average MC after drying was completed. A much "tighter" curve (smaller standard deviation) is evident when they switched to the weight-based controller, meaning better overall uniformity in drying.

We have since placed three more systems in service including the second one at Averitt.

The Loadmaster System - Operation

One of our goals was to develop a system which would enable a kiln operator with little or no computer experience to learn to operate it within a short time. To this end, we simply decided to automate already familiar procedures. So starting a charge is virtually identical to starting a kiln charge manually. An easy to follow Windows based graphical interface allows for input via a mouse or keyboard. Onscreen slider controls, pop-up number pads and windows, and "touch" push buttons make it even easier.

Sample boards are carefully selected and moisture sections are cut, weighed, dried and re-weighed - just as usual. Instead of placing the kiln samples inside the lumber pack, the operator then places them in each of the sample holders. The hardware can accommodate up to six samples per kiln. The individual sample moisture contents are displayed within graphic representations on the specific kiln's main screen. At this point the operator chooses to control the kiln off of either a single sample, the average of the wettest half, or the overall average. This selection can be changed at any time during the charge.

Controlling off of a sample refers to the software's ability to determine the most efficient setpoints for drybulb and wetbulb temperatures, based on current level of moisture content. If operating in automatic mode, this information is being updated constantly. Changes occur exactly when they are called for. If the moisture content calls for a one degree drop in wetbulb temperature at 1 AM, it happens automatically.

Auto mode offers the operator the ability to set a desired *moisture content loss rate per day*. The LOADMASTER program will automatically adjust setpoints, advancing or slowing the schedule down to achieve the desired rate. Auto mode allows the operator to auto-equalize the charge at the end of the drying cycle, using setpoints that have been input, and running until either the MC of the wettest sample and the desired MC is less than an operator's determined percentage, or for a specified length of time.

We felt it would be important to be able to easily switch from auto mode to manual mode, in case the operator wanted to make his own adjustments at a given point in the schedule. In manual mode, any setpoint can be entered, spray can be left in auto or locked off, vents can be popped open or left to run automatically. Once a desired "manual" change has taken place, the operator can switch back to "auto" and let the charge continue to dry normally.

The system's charge history feature provides real-time graphs of drybulb and wetbulb temperatures and their setpoints. This system data is updated every 15 minutes, giving immediate access to the kiln's history. Each graph can be expanded or reduced, depending on the level of detail desired. They serve as an excellent troubleshooting tool to help pinpoint events such as a fan controller acting up or a boiler malfunction. Most important, the graph shows what the result was in the kiln itself, and subsequently its effect on the lumber.

Finally, we felt it critical to add the ability to *check* the functionality of the kiln's components. From within the maintenance screen the operator can turn

components off and on and check to see their response. This is extremely handy when installing a new heat valve or vent motor.

Conclusion

LOADMASTER is a *lumber drying* control system based on the original language familiar to all seasoned kiln operators. Through current technology the operational program has been brought to a high level of sophistication, sensitivity, and flexibility which results in shorter schedules, higher quality and increased profits. LOADMASTER is available commercially through Delmhorst under protection of the University of Tennessee Research Corporation patent.