FIELD TRIALS WITH THE NEXT GENERATION OF LUMBER DRYING CONTROL SYSTEMS

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WHY DRY LUMBER?

Companies planning on remaining in business are scrambling to find ways to increase their operational effectiveness and profitability. Some focus on automating their operations. Some focus on upgrading the skills of the people. The companies most likely to succeed will focus on both.

Those same companies at the same time are focussing on their customers. There's a rapidly expanding awareness of the key role that customers play in the life of any business. That is, with no paying customers there is no business.

Those customers are getting smarter every day, especially with the incorporation of computers in their offices. Customers have greater access to market information and spend more time searching out the most reliable and affordable producers.

The most profitable or desirable customers may not be the construction contractors that purchase large volumes of green lumber at the lowest possible price and profit margin, but furniture and millwork plants needing carefully kiln-dried lumber. Customers are likely to be ordering kiln-dried products for the European Community, the Pacific Rim, or developing countries. The key issue is that, even when there is a downturn in the U.S. construction market, these customers will usually continue to order products. This is because their customers, being less affected by the construction market, continue to do remodeling jobs, buy furniture, etc. That's a significant consideration given the effects the cyclical housing markets can have on lumber producers' profitability.

All these changes and opportunities force lumber producers to focus intently on the opportunities afforded by kiln drying. By kiln drying their lumber, producers open up vastly larger markets. And by kiln drying their lumber, producers add value to the lumber, value that equals increased profits.

IN THIS ARTICLE

This article is about ways to increase profit opportunities by increasing the operational effectiveness of lumber drying activities. This article describes the positive impacts an in-kiln, lumber moisture content sensing system has had on a lumber drier's operations. The sensor allows lumber driers to sense the moisture content of entire loads of lumber from the start to the finish of drying. The sensor allows lumber driers to know immediately how changes in their drying schedules affect the rate and timing of drying.

The sensor allows lumber driers to know immediately what effects changes in their equipment have had on drying throughout the kiln. The sensor helps lumber driers assure that their new or reconditioned equipment is operating as specified by the manufacturer.

BACKGROUND

Stewart Technologies' President (the author of this paper) has been working in the lumber drying field since 1966, helping lumber driers improve their productivity and profitability by many means. Stewart Technologies helps its customers improve their existing operations by repairing and maintaining the equipment. We do that in a number of ways. We monitor the functioning of the equipment and suggest ways to repair or replace it. We monitor conditions in the kiln and suggest ways to alter kiln schedules to improve the drying operation. We train operators and managers to use their controllers more effectively and efficiently.

That work is important and has helped hundreds of lumber driers improve the productivity and profitability. In spite of the tremendous gains achieved by some lumber driers through training, one key aspect of the process remained something of a mystery to them and to us. We all wanted to know what the moisture content of the lumber was during the entire drying process and how that moisture content changed in response to changing kiln conditions. We could measure how long it took to dry the lumber before and after making changes in equipment and practices. We could measure the (range of) moisture content of the lumber after drying. But we were not able to measure the moisture content of the lumber during the entire drying process and how that moisture content changed in response to changing kiln conditions.

BREAKTHROUGH!

All that changed last year. After several years of R&D, we introduced a device that allows our customers to monitor the moisture content of the lumber during the entire drying process. That device uses weight as the indicator. This paper describes some of the results achieved with customers using Stewart Technologies weight-based, lumber moisture content monitor.

KILN CONTROL OR LUMBER DRYING CONTROL?

There's a significant difference between **kiln** control and **lumber drying** control. That's the focus of the accomplishments described in this article. And that difference is going to be a **key** to profits and operating efficiencies in the **lumber drying** business.

Kiln Control

Softwood lumber driers typically use a time-based schedule, changing the conditions of the air in the kiln on a time basis. Little or nothing is known of the moisture content of the lumber during or even after drying. Some operators develop such an intuitive feel for their operations that it's often only a customer complaint that will cause them to get out their moisture meter and measure the lumber.

The **key** point is that only **kiln** conditions -- the temperature, humidity, and air flow -- are controlled directly. The condition of the lumber is "controlled"

in-directly. In reality it isn't "controlled" so much as simply affected.

Operators assume, based on past results, that the lumber will come out with about the same desired final moisture content as it did the last time the same schedule was used. Given the good ability of most operators to learn from their experiences, given the average drying character of lumber, and given the nature of the drying process, the result may be relatively uniform results from run to run. Granted, many operators have schedules for at least the summer and the winter, and for wood from particular locations.

To many operators, managing a kiln in the manner just described is like driving a car over the same road every day without ever looking at the road. Someone teaches them the route early on or they read about it in a book (Schedules for Commercial Species). They never know if they're going as fast as possible or as economically as possible. They always get where they're going (the lumber gets dry). Sometimes they run off the road onto the shoulder a little but their boss or customers usually don't complain unless "there's a flat" (the lumber comes out too wet, too dry, or with too much loss of grade).

But is that the way you want to dry lumber? Are the results optimal in terms of costs and time? If not, can you afford to keep operating like that in the long run? We doubt it. There now is an alternative.

LUMBER DRYING CONTROL

The alternative to kiln control is **lumber drying** control. In this case, operators measure what's important about the process, that is, the **moisture content of the lumber**, and base control of drying conditions -- the temperature, humidity, and (rate and) direction of air flow in the kiln -- on that.

Lumber driers have used weight to monitor moisture content since they started drying lumber in kilns nearly 100 years ago. Most hardwood lumber driers continue with this tradition today. A few sample boards are weighed periodically (daily, weekly) to determine how and when to change kiln conditions. To do that, lumber driers must make gross generalizations about the average (and range of) moisture contents of all the lumber in the kiln based on the average (and range of) moisture contents in 5 to 10 small sample boards. Because degrade caused by drying too fast, too slow, or too much is so costly, most hardwood lumber driers end up drying the entire load based on the condition of the most defect prone pieces, which are generally the slowest drying, pieces. The result is slow turn around and relatively high drying costs, though perhaps low costs due to loss of grade.

The advantage of periodically measuring the moisture content of sample boards is that control of drying is based directly on what's important about the process, that is, the moisture content of the lumber during drying, not just the condition of the air in the kiln. The disadvantages are that operators must shut down and enter the hot and humid kiln periodically, which can be dangerous or impossible if the kiln is too humid, and that control is based on measurement of already-dried lumber, not lumber in the process of drying.

Softwood lumber driers, with their often lower-valued and more forgiving product, gave up the sample-board, weight-based method for the time-based, "driving with your eyes off the road" method (though only after decades of diligent work by researchers and operators all over the country). However, factors such as

rapidly diminishing raw material supplies, increasing costs and decreasing supplies of fuel and electricity, and generally increasing costs of doing business, are causing most operators and managers to look around for ways to improve their operations cost effectiveness.

AUTOMATING THE LUMBER DRYING CONTROL PROCESS

Commercial lumber driers and kiln controller manufacturers have tried for decades to automate the weight-based, lumber moisture content monitoring process in order to allow for manual or automatic control of drying on a realtime, "moment-by-moment", basis. In 1975, in cooperation with the American Forest Products Company, Stewart Technologies President built such a system for one of their dry kilns. The were able to weigh all of the lumber on a kiln truck (equipped with load cells) and to base control of drying conditions on that. That system was used for three years and was taken out of service by a new, "old fashioned", kiln operator.

To our knowledge, all other attempts to create such systems have eventually failed in large part due to the high temperatures, acidic condensing moisture, and rough physical nature of the operations related to lumber drying. Another chief factor has been the inability of suppliers to incorporate the weighing system into the drying operations in a way that didn't cause frequent disruptions in the operations.

This paper is about an improved and successful weight-based, lumber moisture content monitoring system. This system is capable of weighing entire loads of lumber continuously during the entire drying process. The system has been in continuous operation for 8 months in commercial dry kilns. Based on our work with several lumber driers, we'll describe the benefits this system has provided, or could provide, and how the system could be used by any lumber drier regardless of the type of controller or dry kiln they have.

MONITORING KILN CONDITIONS AND LUMBER MOISTURE CONTENT

The following are some the variables typically measured during drying. We do this with the help of the operators in order to calibrate their kiln controllers, monitor the functioning of the major mechanical components in the kiln, and to track the rate and timing of moisture loss by the lumber.

Dry-Bulb, Wet-Bulb, and Vent Temperatures

Thermocouples (fast-acting, electronic, temperature sensing devices) are attached the wet and dry bulbs, the steam heat pipes, and at least a couple of the vents, to monitor how these systems work together to control kiln conditions directly, and lumber drying indirectly. Outputs of these sensors allow the operators to calibrate the controllers at any time during drying simply by adjusting the controllers to match the thermocouples. The outputs allow the operators to monitor how the heating, (de)humidifying, and air circulating systems are working at all times. And the outputs allow us to compare the relationships among those

conditions and the rate and timing of moisture content loss by the lumber.

Lumber Weight

Portable, electronic weighing devices are placed under the drying lumber to measure weight loss. The weighing devices can be moved around the dry kiln by the operators to allow them to track drying as well as the functioning of the mechanical systems in any part of the kiln.

Lumber Moisture Content

Moisture content typically is expressed as a percentage. This percentage represents the weight of a piece of lumber compared to its "oven-dry" weight. (This is so because the way to achieve it is to oven dry the lumber.)

NOTE: To determine the moisture content of their sample boards, hardwood driers will cut the ends off the boards, weigh each sample immediately, dry the samples in an oven for a specified period of time, or until the samples no longer lose weight. The difference between the weights is the weight of the water in the piece. That weight, divided by the weight of the oven-dry sample, is the moisture content of the sample. The average of the two samples is considered the moisture content of the larger board. That moisture content allows operators to determine the oven-dry weight that the sample board would achieve if it were dried in an oven (oven dried). Knowing the oven-dry weight of the board, it is possible to calculate the current moisture content of the sample board simply by weighing the board.

Operators can approximate the same process to determine the current moisture content of entire loads of lumber. They use good measurements of the volume of lumber in the load, published values for the average density of that lumber, and measurements of the final moisture content of the lumber using electronic moisture content meters. Based on those data they can develop accurate measures of the moisture content of entire loads of lumber based on its current weight.

Kiln Equipment and Schedule Changes

The accompanying figures illustrate results achieved by the operators at a cooperating mill using the sensing devices just described. Their dry kilns are fairly typical of those found at many other softwood mills. Results from tests in a double-track kiln are used because they illustrate some points more dramatically than would have the results from tests in a single-track kiln.

A key issue that is demonstrated clearly in these figures is, if operators can only measure the condition of the air -- dry- and wet-bulb temperatures -- in a kiln, they might not necessarily get a good indication of what's happening to the lumber. That is, there **might not** be a clear connection between the condition of the air and the condition of the lumber! If that's the case and operators don't know what the condition of the lumber is at all times during drying, how can they be expected to do as good a job as they might in drying the lumber properly!? They can't!

That's no longer necessary, however. With the equipment described in this report they now can track the progress of drying during the entire process regardless of the moisture content, dimensions, or species of lumber. They do that

by tracking the change in weight and moisture content of entire loads of drying lumber (Figure 1).

Figures 2 and 3 show dry- and wet-bulb temperatures oscillating up and down. These oscillations are in response to changing weather conditions (especially outside air temperature changes from cold mornings to warm afternoons), changing boiler fuel conditions (wet bark vs. dry planer shavings), other kilns being brought on line, etc. The oscillations may occur with changes in setpoints and with fan reversals. Most older kilns, especially those controlled by filled-system bulbs, show these sorts of conditions. Some new ones do too.

Figures 2 and 3 also show the rate and timing of moisture content loss of loads of lumber in response to some or all of the conditions just mentioned. In most situations, because of the interacting nature of the kiln conditions -- heat, humidity, and air flow -- the operators were not able to detect any obvious, repeating relationships among single factors and lumber drying. At times there seemed to be a relationship between changes in the dry-bulb temperature and at times not (Figure 2). The same held for the wet-bulb temperature (and its analog, the wet-bulb depression), but at times not (Figure 3 and 4).

Researchers have shown clearly from studies in the laboratory, that there are direct and clear-cut relationships between the rate of loss of moisture from lumber and the temperature, humidity, and rate and volume of air flowing over the lumber. That's in the laboratory. These figures show clearly that those relationships aren't always so clear in commercial practice. In fact, few (if any) operators know with a high degree of certainty what the conditions of the air are at any particular time, let alone in general.

The only thing really clear about what was happening to the drying lumber was what was shown by measuring what was happening to the drying lumber. By doing that operators could determine how the system as a whole was operating and could make changes in the different parts of the system to achieve the desired affect. That is described next.

ACHIEVEMENTS AND OTHER BENEFITS

Diagnostic and Troubleshooting Tool

The operators noticed from the weights of loads of lumber on one track of a double-track kiln, that the load being weighed lost moisture content when it was on the entering-air-side of the double-track kiln and gained moisture content when it was on the leaving-air-side (Figure 1). Based on these data the operators surmised that since the loads seemed to gain and lose weight with changes in fan direction (none of the other relationships (Figures 2-4) were nearly as clear), the kiln probably was not venting all the moisture that it should be.

We installed thermocouples in the vents to monitor how often they opened and for how long they remained open (Figures 5 and 6 constitute an entire run). The operators kept the vents closed for about the first 6 hours to keep the moisture and heat in the kiln ("heating up and through" stages). Once the vents were allowed to open, they opened up (indicated by a large difference between the entering-air (lower) and exiting-air (higher) temperatures) and remained open for most of the rest of the run. The vents closed at the end when equalizing and conditioning were done.

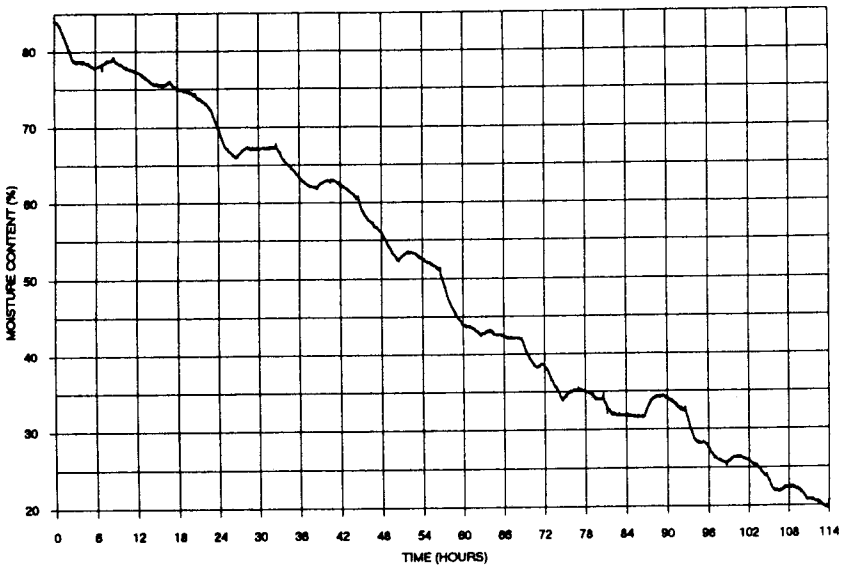

Figure 1. Moisture content before modifications

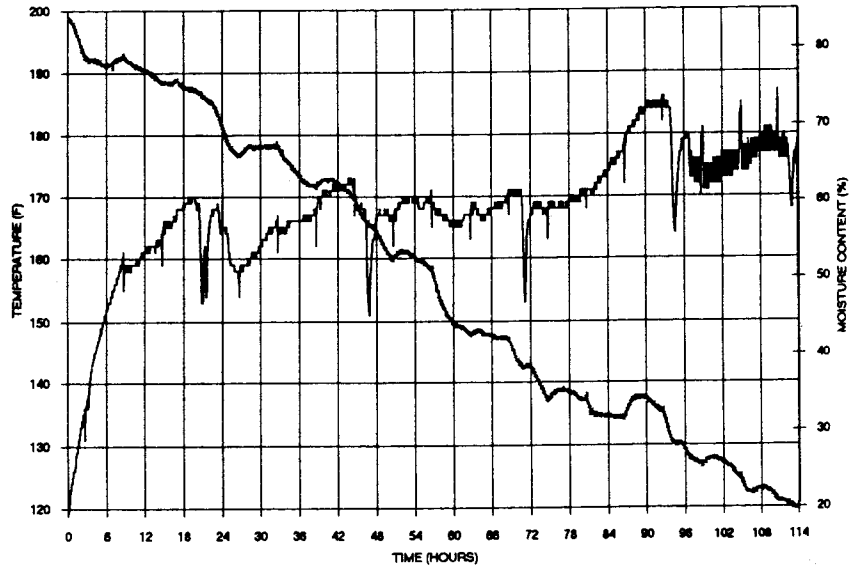

Figure 2. Dry-bulb temperature and moisture content.

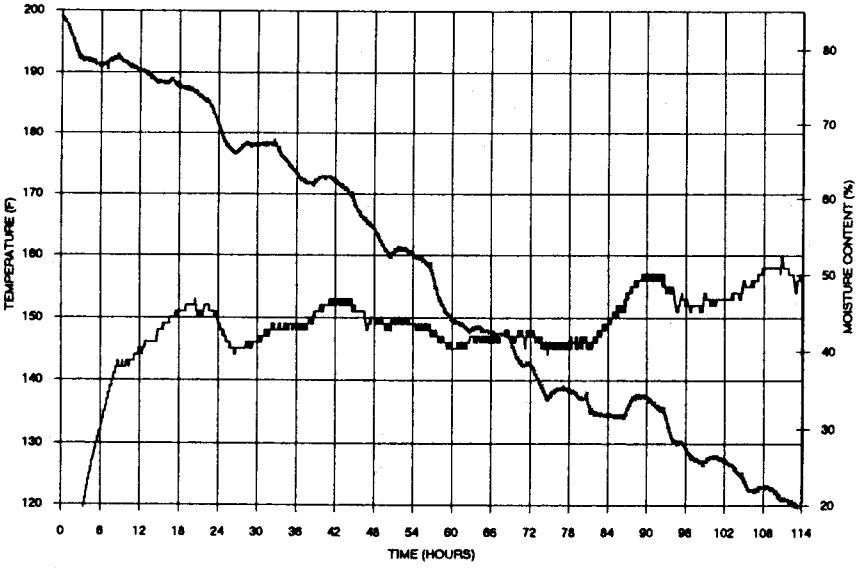

Figure 3. Wet-bulb temperature and moisture content.

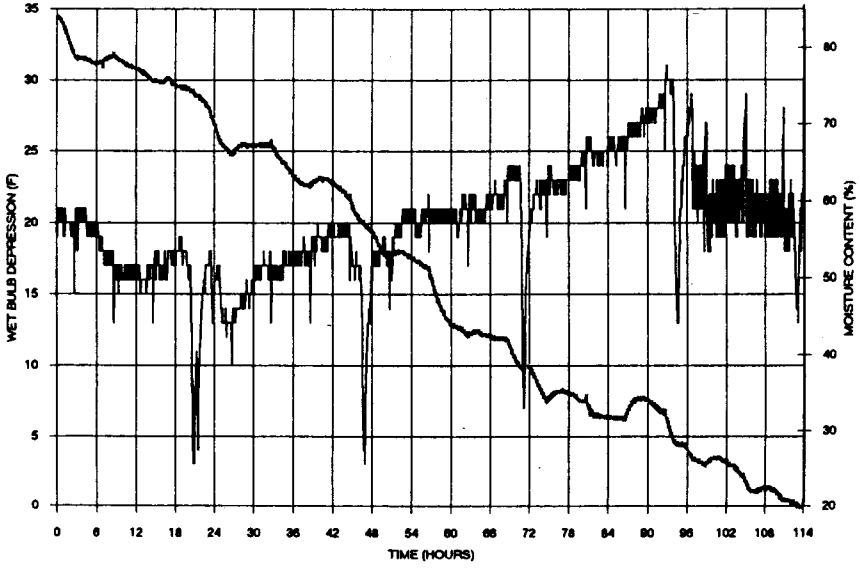

Figure 4. Wet-bulb depression and moisture content.

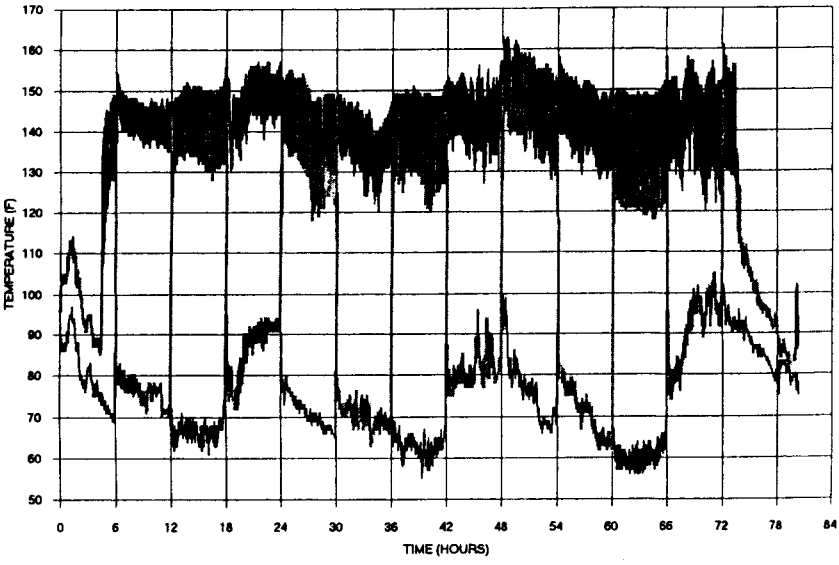

Figure 5. Vent temperatures.

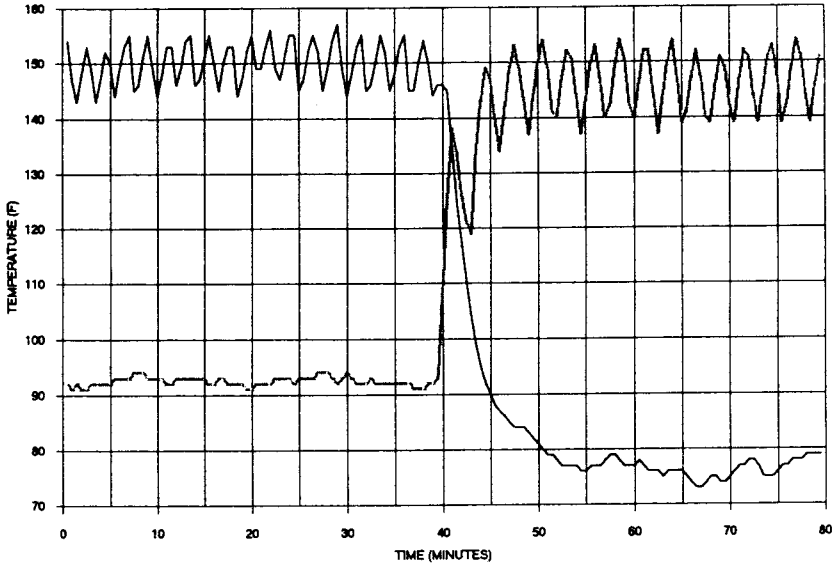

Figure 6. Vent temperatures on expanded time scale.

Note: The operators also correctly surmised that such gains and losses of moisture content were probably causing the surface of the lumber to shrink and swell repeatedly, which could lead to the development and deepening of surface checks!

To (temporarily) correct the situation the operators adjusted the vents to open more. During the winter several years before, they had adjusted the vents to not open wide in order to keep heat in the kiln, thus helping maintain boiler pressure. When they allowed the vents to open further, most of the up-and-down cycling of the weight disappeared immediately (Figure 7). The operators were able to fine-tune adjust the vents to the point where they were able to allow the kiln to vent the required amount of moisture and yet keep the heat in the kiln.

While the operators were never able to get their dry- and wet-bulb temperatures totally under control, they were able to achieve a relatively uniform rate of moisture content loss, which was the desired result. Given that the lumber now loses moisture content at a uniform and continuous rate, it appears that the lack of control of temperature might not be that serious a matter from an operational standpoint. That was a key finding from the operators' standpoint since they then had one less thing to worry about all the time. (They are pursuing other means of gaining some control of temperature.)

When used in this manner, this weight-based system constitutes a powerful diagnostic and troubleshooting tool for kiln operators and maintenance personnel at any mill. Other examples of how knowledge of the rate and timing of moisture content loss could be used to detect and correct problems in lumber drying operations are as follows.

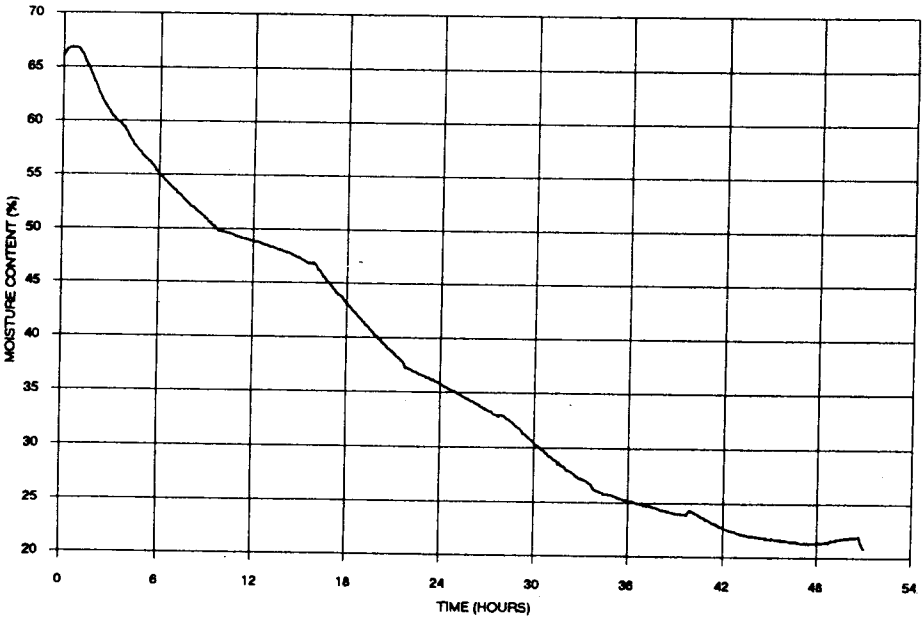

Figure 7. Moisture content at end of study.

Many operators are familiar with things they can do to check out new and existing equipment and analyze the current state of operations. They can use existing equipment and hand-held devices to calibrate dry- and wet-bulbs, and they can use air velocity meters to diagnose and repair the fan and baffle systems.

What they can't check out very easily is whether reconditioned or new equipment is capable of doing the job specified, which is to remove a certain amount of moisture in a certain period of time. Most kilns and their mechanical systems are designed based on that criteria (in addition to other factors like heat-up time, physical dimensions, load capacity, etc.). A lumber drier wants to know that all the systems are functioning and that they will meet specs. Only by measuring the actual rate and timing of moisture loss is that possible.

Manual Control of Drying

It's probably clear by now how manual control of drying could be improved significantly with the use of weight-based, monitors of the moisture content of the lumber. No other changes might be needed in the operations.

By placing weighing devices on both sides of a double-track kiln operators could measure how well their heating, dehumidifying and air circulating systems work, especially in the different fan directions. By weighing loads along the length of the kiln operators could find out what effects (if any) the colder temperatures nearer the doors had on drying. Knowledge of those factors would allow operators to vary temperature (and humidity) settings in different zones in the kiln based on the actual rate of drying in the different zones, not just on differences in air temperatures in those zones.

It's difficult for operators to improve on old schedules or develop new ones, especially for species or dimensions they've never dried before, lumber of a known species but with a different drying character, etc. For example, an operator might be able to dry 4/4 through 8/4 lumber of a particular species without a complaint, year after year.

But what's the operator supposed to do when one of the salespersons brings in an order for a new species or dimension from one of those new customers overseas!? The operator can call up a friend, a researcher at a university, or even a consultant, and perhaps find out the secret. But suppose the "secret" is to not dry it faster than 2.5% per day. If the operator doesn't know what the moisture content of the lumber is, how is he or she supposed to do that? A weight-based system would allow them to do that for any species or dimension.

Sometimes in the fall, operators notice a slowdown in drying and think it might be related to a change in the weather. As a result, they might change from their summer to their winter schedules. But was the change in the weather the cause of the slowdown or was it a malfunction of one of the kilns components? It might be due an increase in the moisture content of lumber from logs from a different drainage. It might be due to a change in the condition of the boiler fuel. With the means to measure the weight of the lumber, operators need no longer be bothered by those unanswered questions.

Automatic Control of Drying

The jump from manual control to automatic control of lumber drying is a straightforward one. What needs to be done is to place the weight sensing devices

under the load, calculate the approximate oven-dry weight of the load, and program the controller to regulate the heat, humidity, and air flow to achieve the type of drying desired.

Operators could program the controller to dry the lumber in a certain number of hours. They could program the controller to dry the lumber at a certain rate.

Operators could program the use of steam heat and electricity to optimize or minimize those costs. Operators could program the controller with an eye on the other parts of the production process -- planer schedule, availability of forklifts, etc. -- to achieve the desired overall production goals. The possibilities are limited only by the imaginations of the operators and managers.

CONCLUSIONS

Evident in our work with operators everywhere is that there's no substitute for well trained, and thoughtful operators. Smart operators are key to any profitable and productive lumber drying operation. The most "high-tech" kiln and control system available is no better than the operator who uses it. An operator who understands how lumber dries, who maintains his or her equipment in good condition, and who strives to improve the drying operations continuously through all means available, is often able to dry lumber more cost effectively and with better grade retention with a 30-year-old, manual, circle-chart controller than can an operator who doesn't understand how lumber dries, though they may have the latest equipment.

There is a significant difference between kiln control and lumber drying control. Operators who understand that difference and act to achieve the latter will help their companies be more productive and profitable every time.

Just measuring the temperature, humidity, and amount of air flow in a dry kiln is not necessarily sufficient to do a good job of drying lumber regardless of the type of kiln or controller used.

Only by knowing the current moisture content of the lumber, and by measuring the rate and timing of moisture content loss, can an operator, using either a manual or automatic controller, optimize the lumber drying operations. Only by using lumber moisture content as the basis of control can an operator make the drying operations and his or her company as productive and profitable as possible.