POST SORTING OF HEM-FIR: A MILL STUDY

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Final moisture content (MC) variation after lumber drying is often in a normal or log-normal distribution. However, some species exhibit a binodal moisture content distribution with a large node near or below the mean MC and a small node at the upper end of the distribution, usually well above 20% MC. Hem-fir exhibits this pattern as do some cedars and oaks. For most species the MC distribution is narrowed to an acceptable range by using an equalizing step in the schedule. For hem-fir this is not an economical approach because of the long time required and the overdrying that will occur.

Slow-to-dry pieces need to be sorted out, either before drying so they can be dried in a separate kiln or after drying so they can be sold as green or redried to the correct MC. Efforts to identify which pieces will be slow to dry has been met with marginal success when the wood is green, particularly with automated equipment. Sorting after drying with an in-line moisture meter can positively identify the pieces that are still wet.

Milota et al. (1993) obtained drying rates for individual pieces of hem-fir in a lab study, then modeled postsorting to show how it would benefit a mill. Here we extend the lab study to the mill environment and examine drying time, MC distributions, grade recovery, and the labor and time required to handle and machine the redried lumber.

Background

A diagram showing postsorting and redrying the wet pieces is shown in Figure 1. This approach offers several advantages over trying to presort. The first is that prior to drying it is difficult or impossible to tell which pieces are going to be wet when they come out of the dryer. Presorting based on the green density (often called weight sorting) is used effectively for some sorts, such as separating pine sapwood from heartwood. With hem-fir, however, the boards which will be wet at the end of drying are in the middle to upper part of the weight range. They are not readily sorted by weight from the sapwood boards or other heartwood boards in the same weight range.

[1]Dr. Wu was a Research Associate at Oregon State University at the time this study was done.

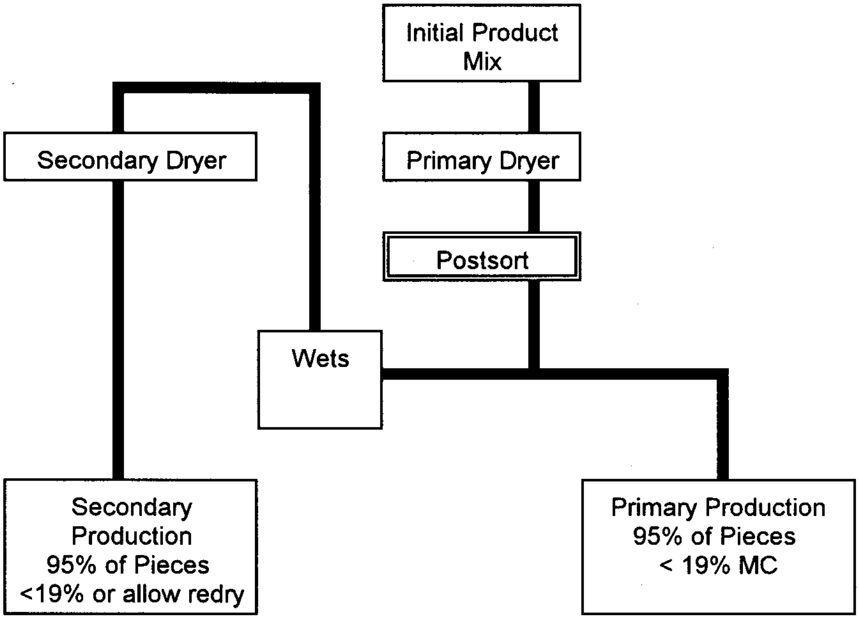

FIGURE 1. Schematic of how redry would work. Typically there would be 70 to 90% of the production in the primary path and 10 to 30% in the secondary path.

Berry (1969) first suggested that redrying would be an efficient way to reduce drying time and narrow the final MC distribution. He showed that white fir could be dried in 20% less overall time if 25 to 40% of the pieces were redried. He further considered the handling and stacking costs, additional sales to Eastern markets, and additional production that would be possible and found that the mill's profit was maximized at approximately a 20% redry rate. Berry did not consider the grade of the lumber in his calculation. His calculations were based on final MC measurements in normal production rather that actual charges to be redried.

Similarly, Bassett (1973) found that drying time and cost were both minimized for Douglas-fir dimension at an 18% redry rate; however, there is nothing in this paper to indicate that they actually measured grade recovery for redried lumber, but rather assumed a degrade cost of $1.25/mbf per %MC based on previous Weyerhaeuser studies. Never-the-less this paper does illustrate that redry may be an effective tool to reduce the variation in final MC. One would expect hem-fir to have a higher optimum redry rate than Douglas-fir (Berry obtained 20%) because of the greater number of wet pieces.

Milota et al. (1993) determined the drying rates for individual boards of western hemlock, mountain hemlock, white fir, noble fir, grand fir, and Pacific silver fir. They then modeled the effect that presorting by species, green density, or heat capacity would have on drying time and the final MC distribution and concluded that presorting would be only marginally effective for this species group. They determined that post sorting the same set of boards would reduce the final MC variation, raise the average final MC, as well as reduce overall drying time. Because this was a lab study on small pieces, no grade or cost information could be obtained.

Procedure

Approximately 1.4 million board feet of nominal 2"x8" predominately white fir (*Abies concolor*) lumber were dried in 12 charges at the Bennett Lumber Company[2]. 96% of the pieces were 14' or 16' in length and the remainder were 18' and 20' feet in length.

Stacking

The lumber was stacked with a 2-foot sticker spacing and loaded onto the kiln carts using consistently good practices (Milota et al. 1991) so as to not influence the grade and recovery of the lumber. The 14' and 16' pieces were mixed in mixed packages as were the 18' and 20' pieces.

Schedules

The drying schedules for the primary and secondary dryers are shown in Figure 2. The schedule used in the primary dryer is typical for a western softwood mill aggressively drying white fir in a modern kiln. Primary drying time was varied from 52 to 74 hours by removing time or steps from the end of the schedule so charges came from the kiln different average moisture contents. The air velocity was 700 feet per minute. Each charge was allowed to cool for at least 15 hours prior to unstacking and planing. Charges were run in both older and newer kilns at both the high and low redry rates.

Sorting

The lumber was unstacked and passed in cross flow across a 4-head Wagner 683 in-line moisture meter. The average moisture content of each piece was recorded to the nearest 1% moisture content between 6% and 26%, less than 6%, or greater than 26%. These were treated as 5% and 30%, respectively. The meter was connected to a tipple which allowed approximately 5% of the lumber in the primary production to exceed the 19% limit. The tipple was activated at moisture meter readings above 20 to 21.8%, depending on the redry rate. As the redry rate was increased, the

[2]The authors wish to thank Earl Britt and the Bennett Lumber Company, Princeton, ID. Without their participation, excellent cooperation, and helpful suggestions, this study would not have been completed.

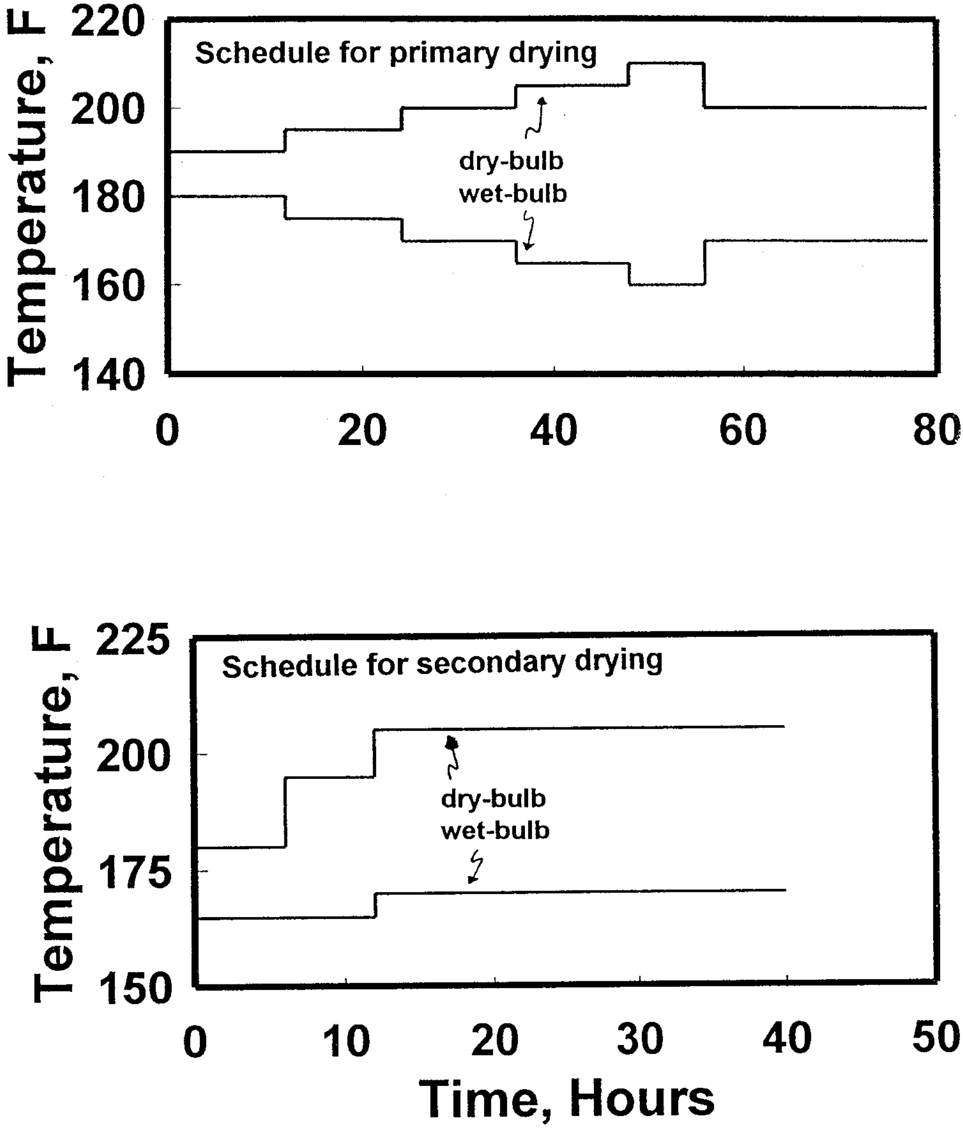

FIGURE 2. Drying schedules used for primary drying (top) and secondary drying (bottom).

tipple activation MC must be reduced because a greater proportion of the MC distribution falls between 19% and the activation MC as the average MC increases (Milota et al.1993). Anywhere from 5.3 to 28.2 percent of the pieces in any given charge were dropped out to be redried. This was dead-piled by hand and returned to the stacker.

The wood in the primary production stream continued through the planer where each piece was resawn and planed to two nominal 2x4s. It then was graded, trimmed, and tallied. The grades were #1 and better, standard and better, utility, economy, rip and other. These were hand-marked on the boards, then read and tallied by a Lucidyne Technologies grade mark reader. As set up, the equipment did not allow grade, trim loss, and MC to be assigned to a specific board.

Handling wood to be redried

The wood to be redried was returned to the green chain, restacked on stickers, taken to a single-track dry kiln, and redried using the schedule in Figure 2. The wood was redried so that no more than 5% of the pieces were over 19% moisture content. In practice, it would be desirable to shorten the drying time and postsort the redried wood; however, for study purposes the volume from the second sort would have been difficult to track through its next cycle. The redried material was then allowed to cool, unstacked, passed over the moisture meter, resawn, planed, graded, trimmed, and tallied in the same manner as the primary production. The time to accomplish these tasks was recorded so that labor and equipment costs could be included in the analysis.

Analysis

Linear equations were used to express all production parameters as functions of the redry rate. These parameters included the overall MC, primary drying time, secondary drying time, grade recovery, and the labor and time to operate the equipment necessary to handle the wood to be redried.

Results and Discussion

Drying time

As the percentage of wet pieces from the primary dryer increases from 5 to 28%, the time in the primary dryer and overall drying time (Figure 3) decrease. The actual relationships would not be linear for 0 to 100% redry; however, given the relatively narrow range of redry rates in the data, we were unable to justify fitting curvilinear equations to the data. The most practical implication of this is that the primary drying time is probably underpredicted for 0% redry causing work based on these equations to err on the conservative side. The linear, least squares best fits are represented by

$$\textbf{\textit{Overall Drying Time}} \ \text{-}\ 79.6 - 0.551\ x\ \textbf{\textit{Redry}}\ ;\ r^2\ \text{-}\ 0.69 \qquad (1)$$

$$\textbf{\textit{Primary Drying Time}} \ \text{-}\ 79.9 - 0.956\ x\ \textbf{\textit{Redry}}\ ;\ r^2\ \text{-}\ 0.89 \qquad (2)$$

where redry is expressed as a percentage and the times are in hours.

Subtracting Equation 2 from equation 1 and adjusting for the redry rate predicts that the time in the secondary dryer approaches zero as the redry rate approaches zero. Intuitively this seems correct; however, it arises from having no charges dried to a low redry rate, such as 1%. The average moisture content of the wood to be redried ranged from 23.6% at a 5% redry rate to 25.6% MC at a 30% redry rate. From this one would expect an average MC above 23% for wood to be redried when the redry rate is very low - less than 1%. Based on observations during the tests, the drying rate for this wood is about 0.26% per hour which means that it would require approximately 30.7 hours to take the average MC from 23% to 15%. For this reason in modeling the process, Equations 2 and 3 were used within the range of the experimental data (5.3% to 28.2% redry rate) and 35 hours was used for the secondary drying time at redry rates below 5.3%.

If the mill were to go from a 0% redry rate (5% wet pieces in the primary production) to 20%, the overall kiln track hours would be reduced by 14.1% resulting in a similar increase in drying capacity if kiln space was limited and the steam supply was adequate.

Final MC

As the percent of wet pieces from the primary dryer increases, the overall average MC (%, dry basis) of the mill's production increases. The linear, least squares best fit is represented by

$$\textbf{\textit{Overall Average MC}} \ \text{-}\ 9.1 + 0.194\ x\ \textbf{\textit{Redry}}\ ;\ r^2\ \text{-}\ 0.81 \qquad (3)$$

At a 0% redry rate (5% wet pieces in the primary production) overall average MC would be about 9% (Figure 3). By redrying 20% of the pieces, the overall average MC would increase to about 13%. The higher MC wood will result in less shrinkage allowing the sawyer to decrease the target size, will feed through the planer easier, and be easier to work with at the job site.

Just as important as the average MC is reduction in board-to-board MC variability. This is apparent when the moisture content distribution of the

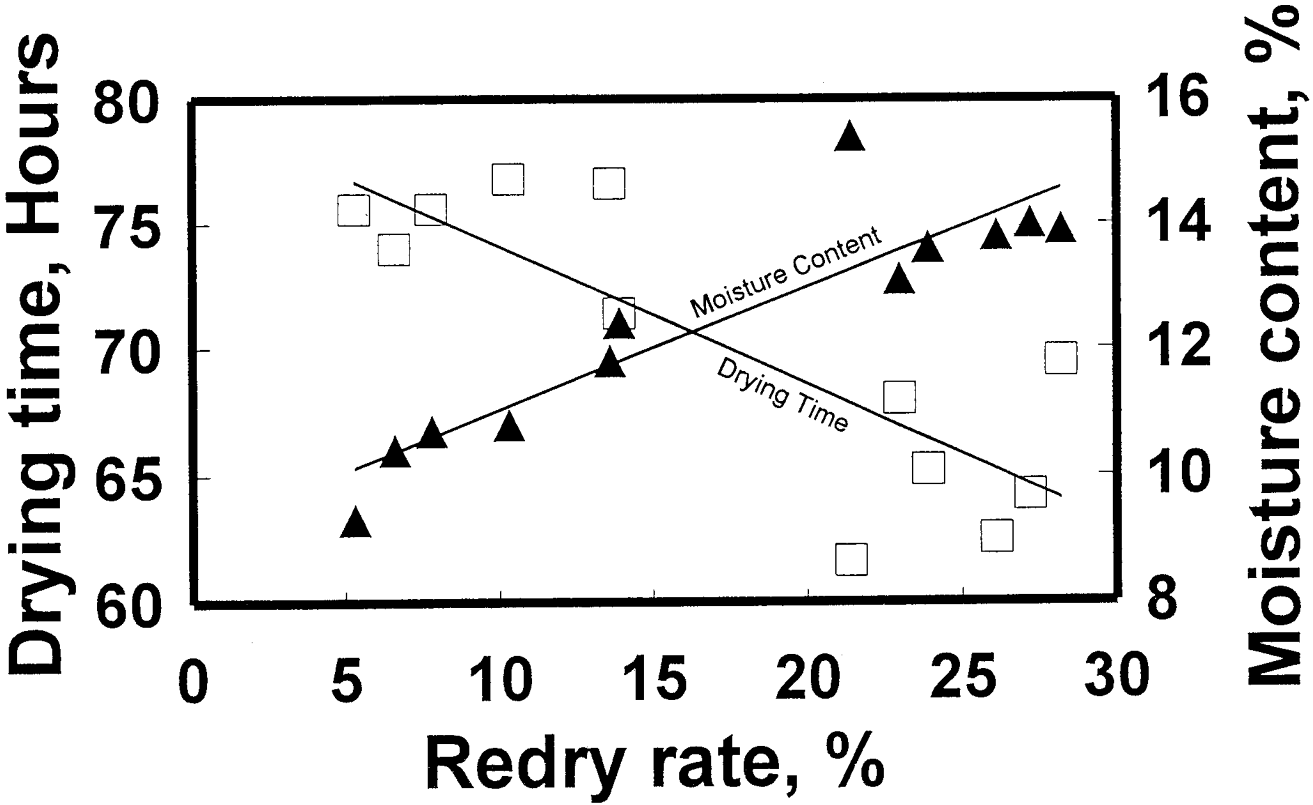

FIGURE 3. Overall drying time (squares) and MC (triangles). Primary production and secondary production are combined so each point in the overall value for one of the 12 charges.

pieces from the primary dryer (at a 5.3% redry rate) is compared to the overall moisture content distribution for a 21.4% redry rate (Figure 4). Not only is the mean moisture content higher, but the width of the distribution is considerably narrowed. We expect that a charge dried with 0% redry (5% wet pieces) would have a distribution similar to that shown in Figure 4, but shifted to the left. This distribution illustrates the main challenge facing a mill drying any species containing pieces that dry very slowly.

Additionally, using a redry system takes some of the pressure off the kiln operator to always dry to exactly the correct moisture content since few wet pieces reach the customer and those that do are near 19% MC (assuming that the redried wood is postsorted). This should result in fewer claims for MC and moisture-related problems such as stain.

Grade

The effect of redry rate on grade (Figure 5) is much less clear than on MC and drying time. In general, there was an increase in select and a corresponding decrease in the other grades as the redry rate increased. It was not clear that the redry rate had any effect on grade above 20% so we averaged these results to obtain the horizontal segments in Figure 5. Below 20%, a linear relationship for each grade was obtained by least squares regression forced to meet the horizontal segment at 20% redry. These are the sloped segments in Figure 5. The equations for grade recovery are summarized in Table 1.

Like drying time, we expect that the true relationships for grade recovery are not linear all the way to zero percent redry. It's likely that recovery is worse than predicted at low MCs so our estimations may be conservative. At zero percent redry (5% wets in product) the mill could expect 79.6% standard and better, whereas at 20 percent redry this is 83.3%. Within this, however, the amount of select increases by 46%, from 15.5% to 22.6%.

Operating times

The times (in minutes per mbf of total production) required to operate various pieces of equipment are given in Table 2. These include the planer (dry end), stacker, and forklifts. Linear regressions were used in cases where an r^2 is given, otherwise the measured values were averaged.

Primary planing time decreases as the redry increases because there is less wood going through the planer and the planer can be run faster at a higher MC. This primary planing time could have been further improved in

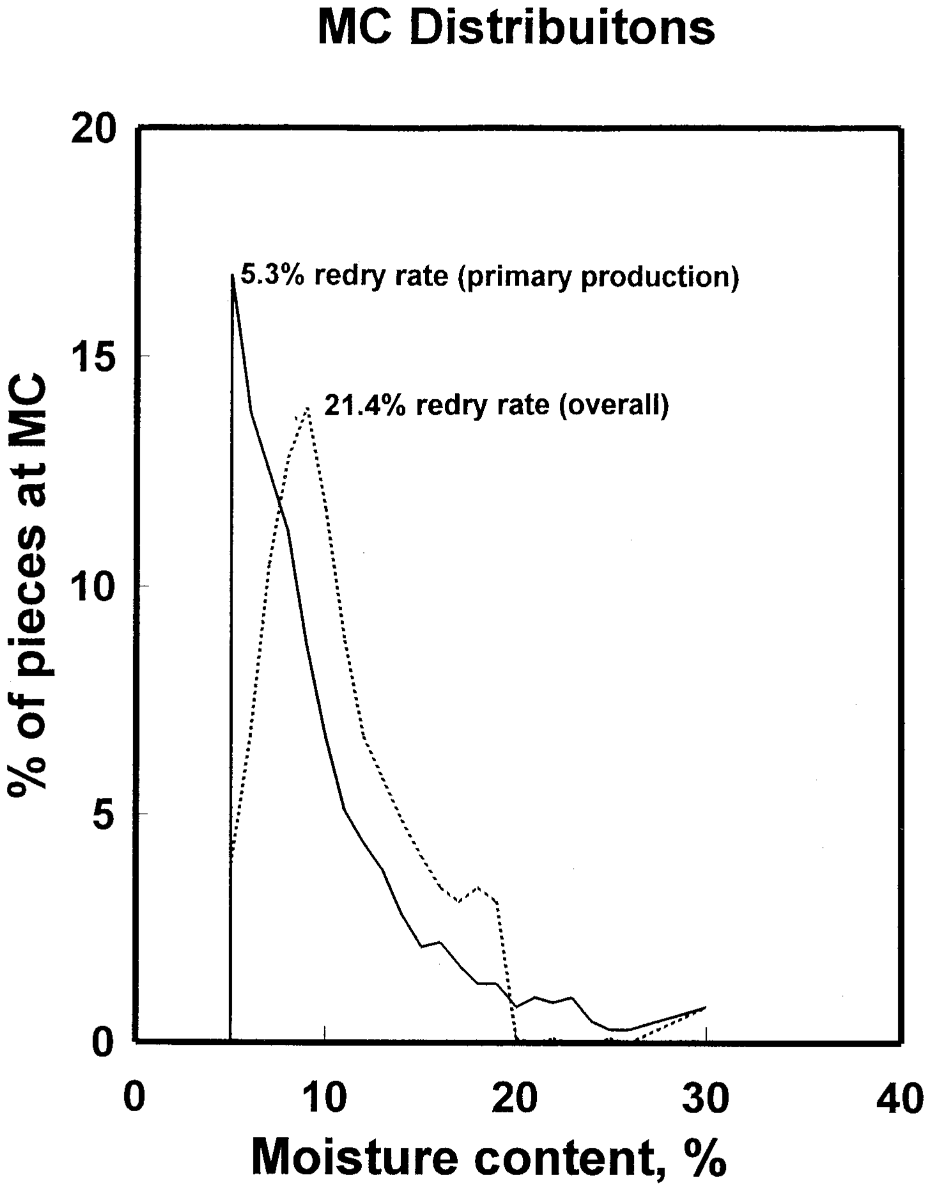

FIGURE 4. MC distributions for the primary production from a charge with a 5.3% redry rate and the overall production with a 21.4% redry rate. The 5.3% redry rate most closely resembles the distribution that would be obtained without using redry. At 0% redry the distribution would shift slightly to the left.

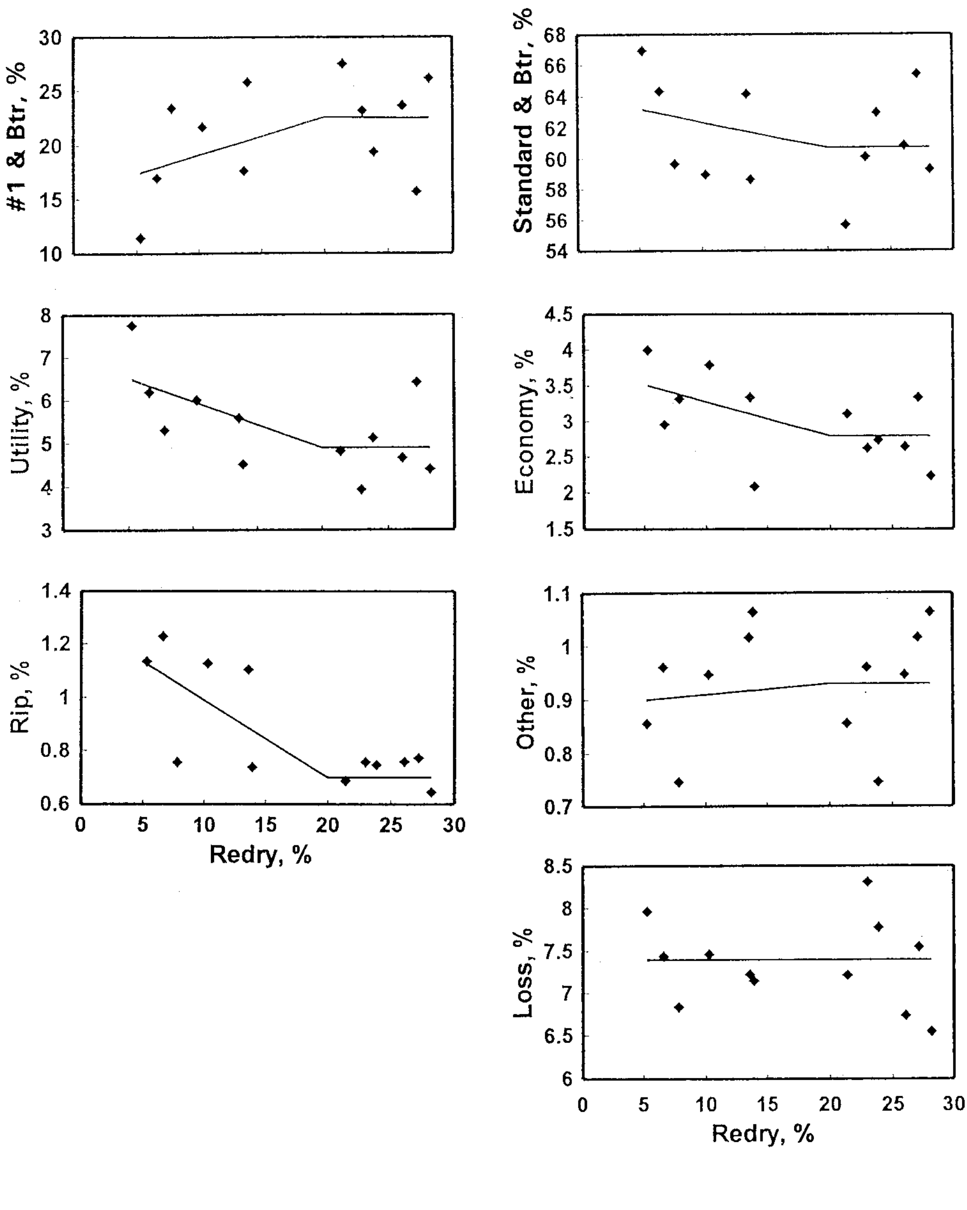

FIGURE 5. Percent of production falling into each grade as a function of the redry rate. Sloped segments are a least squares fit for points at less than 20% redry. The fit was forced to match the horizontal segment at 20% redry. Horizontal segments are the average for points at redry rates greater than 20% redry. Equations for lines and regression coefficients are given in Table 1.

TABLE 1. Grade recovery (% of total production) as a function of redry percentage. The constants in the linear equations represent the predicted percent in that grade at 0% redry.

Grade	Above 20%	Below 20% redry	r^2
#1 & Btr	22.6	15.56 + 0.352 x Redry	0.22
Std & Btr	60.7	64.04 - 0.167 x Redry	0.13
Utility	4.9	7.04 - 0.107 x Redry	0.40
Economy	2.8	3.76 - 0.048 x Redry	0.21
Rip	0.7	1.28 - 0.029 x Redry	0.12
Other	1.0	0.89 + 0.002 x Redry	0.04
Loss	7.4	7.43 - 0.0003 x Redry	0.00

regular production with a more consistent redry rate. Planing the secondary production (redried wood) took slightly longer per mbf through the planer than the primary production and was only weakly dependent on the redry rate.

Labor

Solid piling the wet pieces required a part time person at low redry rates, however, after a certain point the person needs to be present full time, even if there are breaks in the actual work being done. The number of persons used for this job was therefore calculated as

$$\begin{array}{ll} 0.1 \times Redry & \text{for } Redry < 10\% \\ 1.0 & \text{for } 10\% < Redry < 20\% \\ 0.1 \times Redry - 1 & \text{for } 20\% < Redry \end{array} \tag{4}$$

The length of time for which these persons were needed was the same as the time for primary and secondary planing times given in Table 2.

Restacking onto stickers required a 4-person crew at the stacker. This crew worked during the time to restack given in Table 2.

The labor to transport the lumber by forklift was the same as the hours of forklift operation given in Table 2.

TABLE 2. Times for equipment operation. A unit was approximately 3.57 mbf.

Operation	Time expressed as min/(mbf of total production)	r^2
Plane primary production	2.172 - 0.0114 x Redry	0.29
Forklift - Dry chain to stacker	0.0056 x Redry	-
Restacking	0.0139 x Redry	-
Forklift - Stacker to kiln	0.0069 x Redry	-
Forklift - Kiln to breakdown	0.0056 x Redry	-
Plane secondary production	[2.237 + 0.001 x Redry] x (Redry/100)	0.00

Loading and unloading the kiln with redry required 1 person to work for 45 minutes per charge (for single-track redry kiln). The labor to operation the kiln is included with the cost of kiln operation.

Cost Analysis

Given the grade, operating times, and cost data above, it becomes possible to calculate the costs and benefits that accrue by dropping out and redrying wet pieces. Of the many possible scenarios, three are covered in this paper.

> The mill has the equipment in place and wants to determine if the added expense and inconvenience of handling the wet pieces are worth the benefits. In this case, we assume that the mill does not want to increase their overall production.
>
> The mill must install the necessary equipment to begin to redry, but there is no desire to increase overall production.
>
> The existing kilns are operating at capacity and the drying represents an obstacle to increasing production. In this case, a choice must be made between installing a new kiln and installing the necessary equipment to begin to redry.

Scenario 1: To redry or not to redry

In this first case, we assume that all the equipment is in place and the mill needs to make a decision about the redry rate at which to operate. At the top of this spreadsheet (Figure 6) are the operating conditions at the mill. We have assumed a redry rate of 20% and an annual production rate of 50,000 mbf for discussion purposes. The kiln size is important because it determines the number of charges to be dried in a given year at a given production rate. We have only considered the things that change and made no effort to predict costs that are not affected by the redry operation. Subtotals represent the sum of the costs in a category and the relative subtotals represent the change in cost from the case in which the redry rate is zero (5% wets in the product).

Lumber prices during the month of January of 1995 were used. The percent produced in each grade was determined from the equations in Table 1. As the redry rate increases from 0 to 20%, the value of the lumber produced increases from an average of $440.50/mbf to $449.90/mbf, a change of $9.40/mbf. The majority of this comes from lumber moving into the #1 and better grade (select) from lower grades. Of all the expense/revenue categories that were measured, this is the most significant.

As a point of curiosity, we often hear that 1% of the lumber value is lost for each 1% MC that the lumber is dried below the target MC. Often times people say $2.50 - 3.00/mbf per percent overdried [Bassett (1973) said $1-3]. The average MC of the overall product changed by 3.9% MC between the 0 and 20% redry rate. This is $2.41 per mbf per percent that we were able to raise the average MC. Again, we expect that this is not linear and that greater damage occurs at lower MCs and less at higher MCs. However, it illustrates that the kiln operator can cause serious losses to the company by overdrying. Redry aside, for a 120 mbf charge overdried by 2% MC, the cost in degrade is almost $600 in addition to 6 to 10 hours of operating cost for the kiln and lost production time.

The average operating costs for a kiln were estimated based on the data in Table 3. Steam costs per hour are lower for redrying because the drying rate will be lower on a per hour basis.

The operating times for the kilns were taken from Equations 1 and 2, except that 35 hours was used as a minimum redry time at redry rates below 5.3%. The cycles per year are based on total production and kiln size for the primary dryer and the redry rate, total production, and kiln size for the secondary dryer. The dryer operating cost is reduced by $4.56/mbf, largely due to an annual track-hour reduction of 9,433 hours.

— PRODUCTION CONDITIONS —		— KILN DATA —			— OTHER —
			Primary	Secondary	40 OPE rate,
20	Redry Rate, %	Cpcty, mbf	120	60	
50000	Overall Production, mbf/year	Min. to load	90	45	
		Tracks	2	1	

PRODUCT INFORMATION

Grade	Value, $/mbf	Quantity, % of Prod.	Value $/year	Value $/mbf
Select	$510.00	22.6	$5,763,000	
Standard	$501.00	60.7	$15,205,350	
Utility	$315.00	4.9	$771,750	
Economy	$150.00	2.8	$210,000	
Rip	$300.00	0.7	$105,000	
Other	$150.00	1.0	$75,000	
Loss	$100.00	7.3	$365,000	
Subtotal			$22,495,100	$449.90
Relative Subtotal			$470,230	$9.40

OPERATING EXPENSES

Dryers

	Time hr	Rate $/hr	Cycles #/year	Track hr	Loading hr	Cost $/year	
Primary Drying	60.8	$40.96	416.7	50650	625.0	($1,037,312)	
Secondary Drying	39.0	$15.09	166.7	6500	125.0	($98,085)	
Subtotal	68.6		583.3	57150	750.0	($1,135,397)	
Relative Subtotal				9433		$228,230	$4.56

Forklifts

	Time hr	Rate $/hr		
Move to Stacker	92.5	$12.78	($1,182)	
Move to Kiln	115.0	$12.78	($1,470)	
Move to Planer	93.3	$12.78	($1,193)	
Subtotal	300.8		($3,845)	($0.08)

Labor

	Time hrs	Rate $/hr	# empl.	OPE $/hr		
Solid pile wets	1987.8	$10.75	1	$4.30	($29,917)	
Move to stacker	92.5	$10.95	1	$4.38	($1,418)	
Stacking	231.7	$10.95	4	$4.38	($14,206)	
Move to kiln	115.0	$10.95	1	$4.38	($1,763)	
Load kiln	450.0	$10.95	1	$4.38	($6,899)	
Move to planer	93.3	$10.95	1	$4.38	($1,431)	
Planer (dry end)	174.5	$10.95	7	$4.38	($18,726)	
Subtotal	2970.3				($74,359)	($1.49)

Stacker

	Time hr	Rate $/hr		
	231.7	9.9	($2,294)	($0.05)

Planer

	Time hr	Rate $/hr		
Plane primary	1623.3	100	($162,333)	
Plane redry	364.5	100	($36,450)	
Subtotal	1987.833		($198,783)	
Relative subtotal	174.5		($17,450)	($0.35)
Relative total			$600,513	$12.01

FIGURE 6. Spreadsheet for a redry rate of 20%. Subtotals are the sum of the costs in that category. Relative subtotals are compared to 0% redry. In value columns, numbers in parenthesis represent a cost, numbers without parenthesis represent a benefit.

TABLE 3. Cost of kiln operation. Data were estimated based on operation at the mill before and during the study period.

	Cost, $/hour			
	Primary drying		Secondary drying	
	Single-track	Double-track	Single-track	Double-track
Electricity	$0.84	$0.84	$0.84	$0.84
Labor and Maintenance	6.75	10.12	6.75	10.12
Steam	15.00	30.00	7.50	15.00
Total	22.59	40.96	15.09	25.96
Cost per mbf at 20% redry (approximate)	$28.23	$25.60	$5.00	$4.30

The cost to move the wood using forklifts was based on the times in Table 2 and an hourly cost based on a single-shift rental rate of $2250/month for a forklift. This includes the fuel.

Labor costs were based on an hourly rate plus 40% other payroll expenses (OPE). All labor is included in this section except the labor to operate the kiln which is included in the kiln operating expenses. The labor to solid pile wets includes the personnel required for the same number of hours as the overall planing time. We used the overall planing time rather than primary planing time to be sure all calculations are conservative, but more importantly because the redry should be postsorted to minimize drying time. The labor required at the planer accounts for the extra operating time required at the dry end to accommodate the redry. Adding a person to solid pile the wet pieces is the largest labor expense, requiring 1988 hours of labor per year. The increase in operating time at the planer is small; however, a large labor expense results because of the 7-person crew.

The annual costs to operate the stacker and the dry end were estimated to be 6% of the equipment cost, $6.90 per hour for the stacker and $90 per hour for the dry end. For the stacker and dry end $3 and $10 per hour were added to this to cover other operating costs, such as electricity. This leads to a cost of $2294 to operate the stacker for 231.7 hours and a cost of $17,450 to operate the dry end and extra 174.5 hours per year. These are exclusive of labor.

With the costs described above the spreadsheet in Figure 6 was set to various redry rates between 0 and 30 percent to obtain the plot in Figure 7.

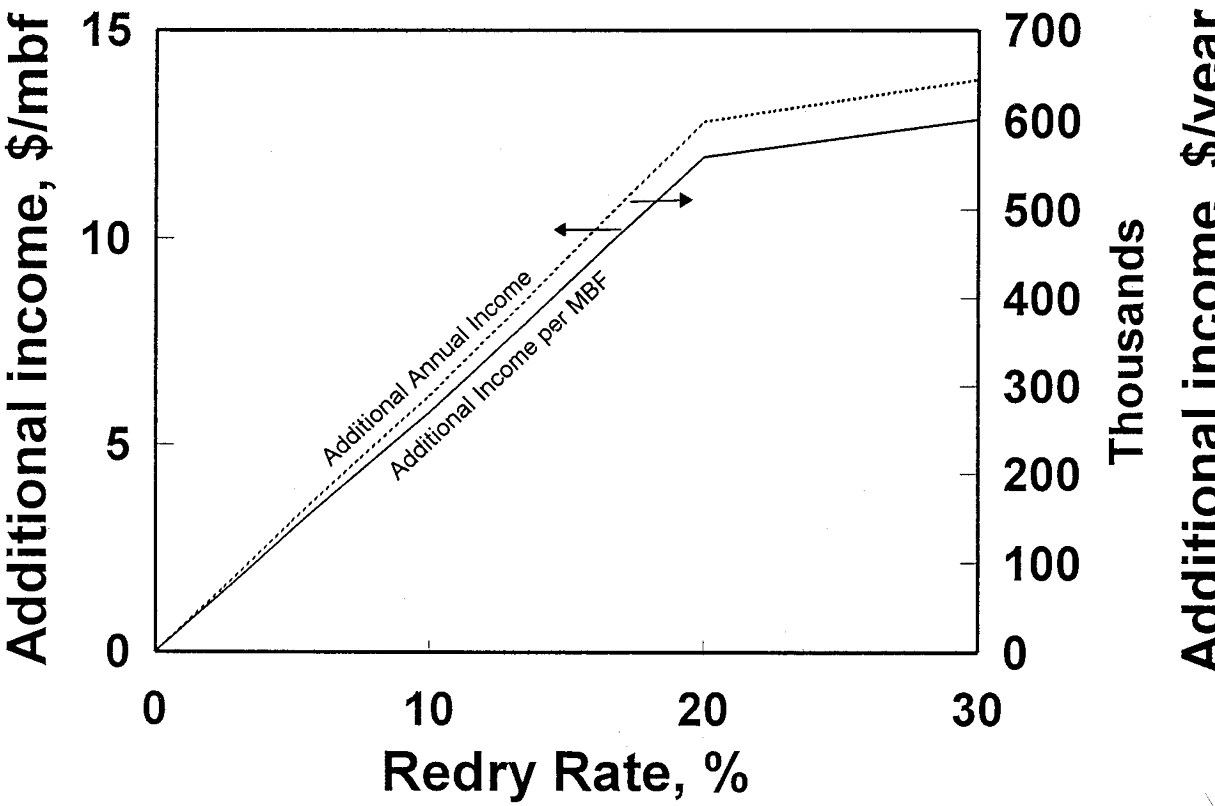

FIGURE 7. Additional income per unit of production (left axis) and for a 50,000 mbf per year mill (right axis) versus the redry rate.

A nearly linear relationship exists for additional profit up to a 20% redry rate, then a second linear relationship above a 20% redry rate. This is a result of the linear relationships used to fit the data. In practice, this should be a curve which reaches a maximum at some redry percentage, probably near 30%, however the redry rates used in this study were not high enough (28% maximum) to determine the point at which profitability will decline.

For a mill with the required equipment in place, we can with certainty conclude that hem-fir should be dried with a redry rate greater than 15 to 20% and with less certainty set 25 to 35% as the redry rate at which maximum benefits would be obtained. This is why a 20% redry rate has been used in examples and discussions and will be used in the following sections.

Scenario 2: Installing equipment to redry

The additional equipment required to implement postsorting and redrying includes the items in Table 4. A moisture meter is included in the cost; however, in practice it is possible to not install a moisture meter after the planer rather than having two. The tipple is needed to drop out the wet pieces. An unscrambler must follow the tipple so the lugs going to the planer remain full; otherwise, the planer idle time would increase as the redry rate increases.

The redried boards are dropped out to the conveyor which carries them to an unscrambler and small stacker. For this scenario, it is assumed that the stacker is capable of placing stickers between the courses of wood. A stacker without this capability would be approximately half the cost, but would require two extra moves with the forklift and time on the main stacker at the green end.

The initial investment must include the installation costs which are assumed to be 50% of the purchase price for a total investment of $270,000. The spreadsheet in Figure 6 was modified to account for the small stacker at the dry end and the reduced handling of the wet pieces. The modified spreadsheet is shown in Figure 8 for a 20% redry rate. The change in annual profit is $617,000 compared to the 0% redry case. The payback period on the equipment is slightly over six months at an annual interest rate of 9%.

Scenario 3: Choosing between a new kiln and redry

If the desired increase in production is greater than 10 to 15%, investment in a new kiln becomes necessary because postsorting will not increase kiln throughput enough to meet the need. We consider here, however, the case in which production through the kilns needs to be increased up to 10 to 15% and there is a choice between investing in a new kiln and the equipment to postsort and redry. This assumes that the boiler capacity is adequate to handle the increased demand and that the mill is large (presently operating more than five kilns) so all drying capacity is utilized.

TABLE 4. Capital costs for the equipment needed to implement redry.

Item	Cost
Moisture meter	$15,000
Tipple	15,000
Unscrambler 1	35,000
Conveyor	20,000
Unscrambler 2	35,000
Small stacker	60,000
Total	$180,000

The cost for a new kiln is approximately $225,000, and probably $325,000 to $350,000 installed. Therefore, the investment in a new kiln is on the same order of magnitude as the equipment to postsort and redry ($270,000 installed). Since the two investments are similar, a comparison of the operating costs should be made.

Any assumptions of an increase in grade recovery simply from installing a new kiln must be limited to the wood from that one kiln. A new kiln with higher and perhaps more uniform airflow than the old kilns combined with some form of zone control should reduce the MC distribution and improve grade recovery. The average recovery in the #1 and better grade was 23.4% for the three charges for which primary drying was done in the new kiln and 20.2 percent for the nine charges from the older kilns. Data based on only three charges may or may nor be indicative of a trend but do suggest better performance from newer kilns. The average overall MCs were 12.5% and 12.4% for the new and old kilns. respectively.

Similarly, any reduction in overall drying time attributed to a new kiln would only apply to wood from that kiln. In this study, the average overall drying time for the nine charges dried in older kilns was 70.5 hours versus 67.8 for the three charges dried in newer kilns. Again, data based on only three charges may or may not be indicative of a trend.

For the sake of argument, let's assume that the benefits (grade increase and reduced drying time) to be gained by adding a new kiln are equal to those obtained by redrying - - but only apply to 20% of the production. The savings was $617,000 annually by implementing post sorting and redry on an investment of $270,000. For a new kiln the savings would be $124,000 (20% of $617,000) annually on an investment of $325,000.

Thus the payback period on the kiln is a little over 3 years at an annual interest rate of 9% versus 6 months for the payback period on the sorting equipment. For individual situations, of course, other factors may enter into this decision, such as the age and condition of the older kilns and the long-term plans for their replacement.

Conclusions

The product quality, drying times, and final MC variability will all be improved by implementing postsorting and redry in hem-fir and probably other species or species groups that exhibit a large number of wet pieces in the mix coming out of the kiln. Examples of where this might be applied would be the Fir-larch and SPF species groups as well as sugar pine. It might also be useful in situations where salvage logs (fire- or beetle-killed timber) are mixed in the sawmill with fresh logs and sorting by some other means cannot be implemented. It is probably preferable, however, to segregate the logs in this case.

Postsorting and redry will reduce the overall drying time and allow more wood to be dried at a given facility. A 14.1% reduction in drying time was obtained at the mill for a 20% redry rate compared to a 13.8% reduction predicted by Milota et al. (1993) using small samples in a laboratory.

Postsorting and redry will reduce the overdrying which occurs when trying to meet the dimension lumber requirement of 95% of the pieces under 19% MC. A redry rate of 20% resulted in an increase of 4% in the average product MC for hem-fir. This is almost identical to that predicted by Milota et al. (1993).

When all major costs and benefits are considered, it's likely that postsorting and redry can increase the profitability of a hem-fir mill by more than $10 per mbf. Not considered in this study are intangible benefits such as less pressure on the kiln operator to always pull the charge at the right time or customer satisfaction with less overdried lumber and fewer wet pieces. A few measurable things, such as an increase in shipping weight of the product, are not considered. We also did not consider that the wet pieces could be sold as green or airdried rather than redried at certain locations during certain times of the year.

References

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	Relative to 0% redry	
	$/year	$/mbf
PRODUCT INFORMATION		
Grade	$469,330	$9.36
OPERATING EXPENSES		
Dryers	228,230	4.56
Forklifts	(2,663)	(0.05)
Labor	(58,735)	(1.17)
Stacker (green end)	(0)	(0.00)
Planer	(19,195)	(0.38)
TOTALS	616,967	12.32

FIGURE 8. Summary of spreadsheet from Figure 6 adjusted to account for the addition of a small sticker stacker at the dry end. The redry rate is 20%.

Casehardening, A Misunderstood Word

Casehardening refers to stress in the wood at the end of drying before conditioning - tension in the core and compression in the shell. The Dry Kiln Operator's Manual (USDA. 1991. Ag. Handbook #188. Available from Gov. Printing Office) describes a prong test to indicate if lumber is casehardened. Examples are shown below.

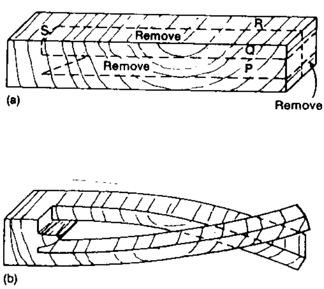

Figure 6-5—(a) Method of cutting stress sections for severe casehardening tests. (b) Prongs are offset so that they can cross and indicate severity of casehardening. (ML88 5584)

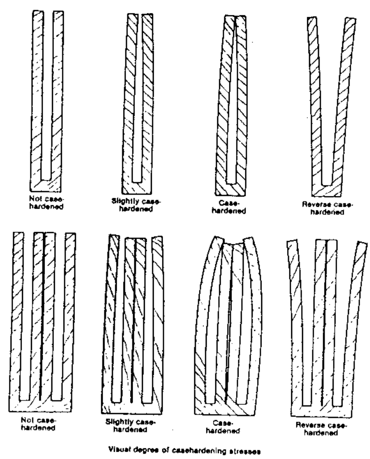

Figure 6-4—Method of cutting stress sections for casehardening tests. Lumber that is less than 1-1/2 in thick is cut into three prongs, and the middle prong is removed; lumber that is 1-1/2 in thick or thicker is cut into six prongs, and the second and fifth prongs are removed. (ML88 5585)

Casehardening is minimized by slow drying. It is relieved at the end of drying by conditioning - steaming the lumber at an equilibrium MC 3% higher than the target MC to put water back into the wood. Lumber that has not been conditioned may warp when resawn or machined.

Here's the confusion - In other industries, casehardening refers to the formation of an outer sealing layer which inhibits the loss of internal moisture (Mujumdar, A.S. 1987. Handbook of Industrial Drying, Marcel Decker, Inc. NY). This is clearly different from the definition used in the lumber industry.

Equilibrium Moisture Content

The equilibrium moisture content (EMC) is the moisture content to which a piece of wood will finally reach if left at a certain temperature and relative humidity long enough. The EMC is consistant enough among species, that there is only one table, part of which is reproduced below (Dry Kiln Operator's Manual, USDA, 1991). As defined, the EMC describes the condition of the air, not the wood. If the EMC in the kiln is 10%, then a board at a 15% MC will lose water while a board at a 5% MC will gain water until both boards reach approximately 10% MC.

The EMC is affected by how the wood is handled. Kiln drying at high temperatures will cause the wood to have a slightly lower in-service MC than air-dried wood. Other factors, such at preservative treatment, presence of heartwood, decay, and reaction wood, also affect the MC to which a piece of wood will equilibrate at a given EMC.

Wet-bulb depr	Values in %	Temperature, F						
		80	100	120	140	160	180	200
5	RH	79	83	85	87	88	89	90
	EMC	15.5	16.1	16.2	15.8	15.2	14.5	14.0
10	RH	61	70	72	75	77	79	80
	EMC	10.9	12.4	12.1	11.9	11.5	11.1	10.8
15	RH	44	54	60	64	67	70	72
	EMC	8.1	9.2	9.7	9.6	9.4	9.0	8.8
20	RH	29	41	49	54	58	62	64
	EMC	5.8	7.4	7.9	8.0	7.9	7.6	7.2
30	RH	3	21	31	38	43	47	51
	EMC	0.3	4.2	5.4	5.8	5.8	5.7	5.4
40	RH	-	4	17	25	31	35	39
	EMC	-	0.7	3.3	4.1	4.3	4.4	4.3