SAW-DRY-RIP PROCESSING: TAKING THE CROOK OUT OF THE STUD GAME

Timothy Larson, Robert W. Erickson and Harlan D. Petersen[1]
University of Minnesota
St. Paul, Minnesota

Introduction

A resource analysis for paper birch (Betula paperifera) in Minnesota states that currently there are 266.5 thousand cords of paper birch available for utilization. The projection is that by 1985 the available volume of birch will be 202.4 thousand cords (5).

"Paper birch in Minnesota ranks second in terms of net growing stock volume. Since there is no significant industrial use of the species in the state, it ranks first in terms of potential wood industry expansion opportunities" (6). Consequently, potential uses of paper birch need to be investigated.

Paper birch is a small diameter hardwood with a propensity to warp when processed by conventional methods. The warp problems are attributable to the high percentage of pieces with juvenile wood plus the presence of growth stresses in the small diameter log. Juvenile wood is formed in the region surrounding the pith and has greater longitudinal shrinkage than adult wood (7). This greater longitudinal shrinkage contributes to warp problems during processing.

Figure 1 shows the distribution of growth stresses in the tree. Tension (-) forces dominate the area near the bark while the inner portion is under compressive (+) forces. The existence of these opposing forces in a conventionally sawn stud, e.g., can cause it to warp immediately upon sawing. In some cases the superposition of shrinkage upon the existing growth stress pattern can cause this warp to be aggravated during drying. The net result is low quality lumber and in the case of stud manufacture a high percentage of rejects due to warp.

Wood scientists at the United States Forest Products Laboratory (USFPL) in Madison, Wisconsin, have developed a process called Saw-Dry-Rip (SDR) that is focused on producing structural lumber from small diameter, low to medium density hardwood species. They see this processing technique as an opportunity to better utilize small diameter hardwoods, increase hardwood management opportunities, reduce transportation costs

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and produce high quality lumber from previously underutilized species such as paper birch (1).

The SDR process consists of live sawing logs through and through on the same plane into 7/4 flitches. The flitches are rough edged to make a compact kiln load and then dried to an average moisture content (M.C.) of about 10 to 12 percent. The dry flitches are then ripped and surfaced into structural lumber. Figure 2 is a flow chart for the SDR process.

The principle behind SDR is the restraining effect of the wide flitches on warp during drying. As the flitch dries the growth stresses are largely relieved due to slippage of the wood cells relative to one another while the piece holds its shape. Also, the usual end-of-drying stresses are opposite to any remaining growth stresses (2). With correct processing, the pieces ripped from the dry flitch can be essentially free of crook, bow and twist.

The USFPL has investigated the use of SDR on a number of species with excellent results. In particular, their application of SDR with a high temperature drying schedule to yellow poplar resulted in a rejection rate of only 0.5% of the studs produced using a criteria of stud grade or better. In contrast, 22.2% of the studs failed to make stud grade or better using conventional sawing and drying methods (3). It is evident that SDR, especially along with high temperature drying, has the ability to reduce warp in processing small diameter hardwoods.

Experimental Objective

To evaluate the SDR process in the production of 8' studs from paper birch under several different drying methods.

Experimental Materials and Procedures

Harvesting and Allocation of Logs

The trees were harvested in northeastern Minnesota in the fall of 1981 from the Superior National Forest on a timber sale purchased by Hedstrom Lumber Co. of Grand Marais, MN. Selected trees were 8 to 12 inches in diameter at breast height (dbh). Each tree felled was given a number and as each 100" log was bucked from the tree it was given the tree number plus its log number. The logs were numbered 1 through n starting with the butt log. Usually there were 4 to 5 logs per tree. Trees with excessive lean, rot or extremely poor form were excluded from the study. Also, logs with a sweep of 3" or more per 8' length were discarded. Finally, logs bucked for the study had to have a minimum small end diameter inside the bark (dib) of 4.5".

After bucking, the logs were immediately end coated, and tree plus log numbers were recorded on each end of the log after the end coating had adequately cured. The logs were then transported to Hedstrom's log yard in Grand Marais where they were stored in a log deck over the winter.

In November 1981 the 216 logs were segregated into 12 piles, with each pile representing one of two replications of six treatments. The initial step was to measure the small end dib of all logs. They were then sorted into 1" diameter classes starting with the 5" class (4.5" - 5.4") through the 10" class (9.5" - 10.4"). Beginning with the 5" dib class a number was drawn from a hat containing the numbers 1 through 6 in order to determine the treatment allocation for that log. A flip of a coin then determined the replication within the treatment. Butt logs were segregated and allocated separately because their location in the tree has been found in some species to produce studs with greater average crook than logs from other positions in the tree. Even distribution of butt logs to treatments and replications negated the possibility of biasing the results due to this factor.

Sawing and Planing

All logs were live sawn through and through on one plane to produce 7/4 flitches. The flitches were double end trimmed to 97" and then rough edged. Flitches were numbered in the sequence they were sawn from each log, and the tree and log numbers were also transferred to the flitch face from the log end.

The flitches were block piled, wrapped in plastic and transported to Kaufert Laboratory on the St. Paul Campus in a matter of a few days where they were then stored in the coldroom (≈ 33°F) to await processing.

All the machining of flitches and conventionally sawn studs was done at Lake Elmo Hardwood Company, Lake Elmo, Minnesota, which is only 20 miles from Kaufert Laboratory. Green flitches for the production of conventionally sawn studs were premarked at Kaufert Lab by use of a plastic sheet template overlay for maximum yield of 2 by 2's, 2 by 3's and 2 by 4's. The dried SDR flitches were also premarked for maximum yield of 2 by 2's, 2 by 3's and 2 by 4's. We used different templates for premarking the green and dry flitches since the green flitches needed a shrinkage allowance built in for the conventionally sawn studs to be produced from them. All rough dry studs, both SDR and conventionally sawn, were surfaced to a thickness of 1-7/16" and standard finished widths of 1-1/2, 2-1/2 and 3-1/2". The less than standard thickness was the result of high thickness shrinkage. In future sawings it will be necessary to use a slightly greater green target size.

It was not always possible to immediately take the dried material to Lake Elmo for machining. The maximum amount of time that material was held at Kaufert Laboratory before machining was approximately 2 to 3 weeks. During this storage the material was block piled.

Drying

Prior to initiating this research we conducted exploratory high temperature and dehumidification drying of paper birch 7/4 flitches. In so doing we discovered that the darkwood[2] of paper

[2]Darkwood refers to tissue that is darker in color than normal heartwood, occurs in irregular patterns near the heart of the tree, has higher MC than non-darkwood tissue (whitewood) and appears to have its origin associated with branch stubs and possibly other tree intrusions.

birch, as it is referred to throughout this paper, is comparatively high in initial MC, impermeable and subject to severe degrade. Post drying of the darkwood with associated warp were expressions of the non-uniform final MC. As a result of this non-uniformity we decided it was appropriate to begin the equalizing treatment when the driest kiln sample board reached an average MC of 8% and continue it until the wettest sample board had an average MC of 12%. This was possible, of course, only for the drying done in the steam heated kiln and was not an option for our dehumidification kiln or the air drying.

Following is a list of the treatment abbreviations used in the remainder of the paper. The first letter represents the type of sawing and the second letter represents the type of drying.

1. SH_{WBC} SDR with high temperature drying and the subscript is to designate wet bulb controlled
2. SH_{WBU} SDR with high temperature drying and the subscript is to designate wet bulb uncontrolled
3. SD SDR with dehumidification drying
4. SC SDR with conventional drying
5. SA SDR with air drying
6. CH Conventional sawing with high temperature drying
7. CC Conventional sawing with conventional temperature drying

All drying was done at Kaufert Lab except for the air drying which took place at Hedstrom's air drying yard in Grand Marais. A top load restraint of 60 lbs/ft^2 was used for all treatments except SA.

Every charge kiln dried contained six sample boards that were selected as being representative of the material. Four of the six sample boards contained varying amounts of darkwood while the other two were totally "whitewood". Whitewood refers to all wood other than the darkwood and consequently a given whitewood flitch could have been all sapwood or a combination of sapwood and normal heartwood. Each of the two air drying units contained 4 sample boards. Once again sample board selection was representative of the material in the two units. Table 1 shows drying conditions by treatment.

The recommended USFPL procedures (8) for cutting MC sections and estimating ovendry weights were followed and a heavy application of black plastic roof cement was used for end coating. The sample boards were weighed at intervals considered adequate for the subsequent construction of drying rate curves and in keeping with practical limitations. In addition to being periodically weighed they were also measured in both width and thickness to provide shrinkage data. At the end of drying, average and shell sections were prepared. For sample boards that contained darkwood, a cross section was cut for subdivision and individual determination of darkwood and whitewood MC's. A stress section was also cut from each sample board.

Moisture Content of Dried Flitches and Studs

A resistance type electric moisture meter was used to take MC readings on about one-third of the flitches and conventionally sawn studs at the end of drying. Readings were taken at three locations along the length of the piece; about 18" from each end and at mid-length. When a band of darkwood was present two readings were taken at each location; one within the darkwood and another immediately adjacent in the whitewood.

Immediately after machining and at the time of the first warp measurements, MC was again determined on one-third of the studs. The treatments were then stickered 4' O.C. in individual units, using 3/4" thick stickers. After approximately one month of such storage the warp was again measured, and the MC determined on the same studs that were checked just prior to stickered storage.

Collection of Warp Data

Crook is defined as the maximum deviation of the narrow edge from a straight line end to end. Bow is the maximum deviation flatwise from a straight line end to end. Twist is a deviation flatwise, or flatwise and edgewise, in the form of a curl or spiral so that the four corners of any face are not in the same plane.

All three forms of warp were measured to the nearest 1/32". The first measurement was accomplished within two or three days of final machining of the studs. The second measurement of warp came after the approximate one month of stickered storage in Kaufert Lab that was previously mentioned.

A metal wedge made with 1" of rise for its 6" of run was used to measure all 3 forms of warp. Lines were projected from the 6" edge of the wedge to its hypotenuse and scribed on one triangular face of the wedge. In measuring crook, e.g., the stud was placed on a perfectly flat table with the convex narrow edge of the stud resting on the table. The wedge was then inserted as far as possible at the point of maximum crook, which was normally at mid-length. The crook was then read to the nearest 1/32" off the triangular face of the wedge. For example, insertion of the wedge to line 12 would indicate 12/32" of crook. Measurements of bow and twist were made in an analogous manner. In the case of twist, three of the four corners of the stud were made to contact the table top and the wedge was inserted under the raised corner.

Results and Discussion

The data collection has just been completed and due to time constraints this report is somewhat limited. A more comprehensive report with additional statistical analysis will be submitted to the Canadian Journal of Forestry in the fall of 1983.

Moisture content data for the sample boards by treatments is summarized in Table 2. Average MC at the end of drying ranges from 6.0% for SH_{WBU} to 22.3% for SA. The high value for SA is attributable to high relative humidity and uptake of both vapor and liquid water during the last couple months of outdoor storage.

Note that the darkwood for all treatments kiln dried has a higher MC than the whitewood. In addition, the range in final average MC for many of the treatments is quite large. These features illustrate the difficulty of removing moisture from the darkwood and the effect this has on drying time and final uniformity of MC.

The replications for the SH treatment produced an interesting comparison. Figure 3 contains the drying curves for the sample with the most darkwood from each of the two runs. Run 1 is identified as SH_{WBU}. It is the run in which the wet bulb reservoir went dry and kiln vents were wide open for hours 5 through 18. The problem was then corrected and the kiln was operated at 240°F dry bulb temperature (dbt) and 190°F wet bulb temperature (wbt) until equalizing commenced at about 38 hrs. of kiln residence. The severe drying conditions during the period in which the vents were open resulted in dropping the average MC of the sample boards to about 10% in 18 hours kiln residence. Further drying at 240°F dbt and 190°F wbt produced an average MC of about 5% at 38 hours. The subsequent equalizing raised the MC slightly and after about 65 hours total kiln residence the darkwood and whitewood had almost identical MC's and the flitches were stress free.

In run 2, which typifies all of the high temperature runs in which the wet bulb was controlled, the results were quite different. There was no dramatic reduction in average MC and at 22 hours it was still 30%. At that point, one of the whitewood sample boards was at 7 to 8 percent MC so equalizing was commenced. Equalizing at 200°F dbt and 180°F wbt was continued for 6 days. After 167 hours of kiln residence the average MC was still 10% with a difference of 6% for the whitewood and darkwood. Also, these flitches contained severe MC gradients and drying stresses. We did additional drying runs to verify these comparative results and a report has been submitted to the Forest Products Journal for publication.

Honeycomb occurred in all treatments but was most severe in conventional and high temperature drying and the least in air drying. There was no apparent difference in honeycomb for SH_{WBU} and SH_{WBC}. In all treatments the honeycomb was restricted to the darkwood. It also had a propensity to collapse and surface check in the early stages of drying.

Tables 3 and 4 present warp data on the 2 by 4 studs. Since crook is the most restrictive warp type for meeting stud grade, it will be emphasized in the following discussion.

Table 3 gives the warp data that was collected within a few days of final machining. Table 4 gives warp data on the same 2 by 4's after about one month of stickered storage in Kaufert Lab. In each table the treatments have been arranged in the order of lowest to highest crook value. Note that in both tables the SDR treatments, with the exception of SA, have considerably lower crook than treatments with conventional sawing. The poor performance of SA is due to the high MC of the flitches at the time of machining, with the average MC still at 16.1% and the range 11 to 23 percent.

Table 5 shows a statistical comparison of average crook by treatments for all studs, i.e., for 2 by 2's, 2 by 3's and 2 by

4's. For both the first and second measurements the SDR treatments, with the exception of SA, are significantly different from conventional sawing. The second measurement produced no changes in the significant difference groupings of treatments even though average crook had increased for all treatments.

Bar graphs have been employed in Figure 4 to compare the absolute crook in 2 by 4's for the first and second measurements and by treatment. All treatments show an increase in crook during the one month storage but the increase is consistently least for the SDR treatments that were kiln dried. SA shows the largest increase of the SDR treatments and this is no doubt due to the comparatively high average MC of the air dried flitches at the time they were machined into studs.

The increase in crook between the first and second measurements may not be independent of the SDR process. Table 3 shows that the MC picture at the end of drying for CH and CC is at least equal to that for SC and SD. Yet the increase in crook during storage for CH and CC is about double that for SC and SD. This suggests that drying in the flitch form removes longitudinal stresses which in the case of the drying of conventionally sawn studs are not removed and consequently cause them to undergo more crook increase during subsequent MC changes.

The average absolute crook for each of the kiln dried SDR treatments falls between 3/32 and 4/32 of an inch for the first measurement. For the conventionally sawn studs and the SA treatment, the first measurement values are between 5/32 and 6/32 of an inch. The average increase in crook for the kiln dried SDR treatments during storage was about 1/32 of an inch whereas for the conventionally sawn studs it was between 2/32 and 3/32 of an inch. In summary, the average absolute crook of the conventionally sawn studs for both the first and second measurements is almost twice that of the average for the three kiln dried SDR treatments.

It is interesting to note from Figure 4 that SC and SD, both of which were dried at comparatively low kiln temperatures, have absolute crook values essentially equal to that for the best high temperature SDR treatment, SH_{WBU}. This suggests that the ability of SDR to significantly reduce crook in the production of 2 by 4's from paper birch is independent of kiln drying temperature. In light of this, possibly the SA treatment would have produced warp results equivalent to those for the best of SDR treatments if the air drying had produced comparably low MC's in the flitches.

A comparison of the results for treatments SC and CC probably best illustrates the SDR effect. Table 3 shows that these two treatments are quite similar in final average MC and Table 2 shows the similarity of total drying time. Figure 4 allows an easy comparison of their absolute crook values. In view of their similarities in MC and drying time, the reduction in crook for SC seems directly and totally attributable to the SDR process.

Figure 5 compares rejection rates for 2 by 4's by treatment and time of measurement. The best treatment was high temperature SDR with the wet bulb uncontrolled. It had zero rejection for the first measurement and a 4 percent rejection[1] after storage. The conventionally sawn studs had a rejection rate of about 20 percent for the first measurement and this increased by two or three percent following storage. In general the rejection rates for SDR treatments, again with the exception of SA, are far superior to the conventionally processed studs.

The increases in rejection rates for the second measurement show the necessity for uniform drying to a sufficiently low MC. The forest products industry needs to recognize this fact in protecting its market against metal studs and for increasing consumer acceptance and satisfaction with wood studs.

Figure 6 gives the percent rejection rate for all studs by treatment and time of measurement. Once again the kiln dried SDR treatments are far superior to the conventionally sawn studs. Since the picture that emerges in Figure 6 is quite similar to that of Figure 5, it demonstrates that SDR processing is effective not only on 2 by 4's but 2 by 2's and 2 by 3's as well.

The data summarized in Figure 5 and 6 is probably the most important to an operation involved in stud production. The failure to make stud grade due to warp limitations can amount to significant dollar losses. This data shows the ability of SDR to dramatically improve the recovery of stud grade material. This should be important not only in the potential application of SDR to producing birch studs for structural purposes but also for non-structural uses such as furniture, doweling, etc.

Table 6 summarizes the shrinkage data of sample boards by treatment. There is a strong indication of shrinkage increasing with drying temperature. The high temperature treatments show thickness shrinkage of about 10% or greater. The conventional temperature and dehumidification drying have average thickness shrinkage closer to 7%. However, the final average MC's are slightly higher. It would appear that for high temperature drying there should be a thickness shrinkage allowance of perhaps 12%. With a green target thickness of 1-3/4" we did encounter a number of kiln dried flitches that did not dress out to 1-1/2" and consequently it was necessary to surface to 1-7/16"

Conclusions

1. The major problem in the drying of paper birch is the presence of darkwood that is high in MC, impermeable and has the propensity to check, honeycomb and collapse even at mild drying conditions. All of the degrade that was observed in this research occurred in the darkwood. As a general rule, the higher the drying temperature the more severe the degrade. Under all drying methods employed, with the possible exception of air drying, the degrade of the darkwood was such as to prevent its use for furniture.

2. The SDR process significantly reduced crook and the percent rejection rate of studs for all treatments that were kiln dried. SDR with air drying produced warp results not significantly different from those obtained with conventionally sawn studs.

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[1] In absolute numbers this constituted one 2 by 4 stud out of the 25 in this run.

This is believed due to insufficient drying. If lower MC had been achieved in the air dried flitches, the SDR effect on warp probably would have expressed itself.

3. It is necessary to dry to a low and uniform MC in order to produce studs that are dimensionally stable. All of the treatments increased in absolute crook and percent rejection rate during approximately one month of stickered storage. The increases were least for SDR treatments.

4. The SDR effect was independent of kiln drying temperature. This was demonstrated by the fact that the absolute crook for SDR in combination with either conventional temperature or dehumidification drying was equal to or slightly less than that obtained with SDR in combination with high temperature drying.

5. Obtaining the full benefits of SDR on warp required the attainment of low and uniform flitch MC. This was most quickly and efficiently achieved in this study by drying at a dbt of 240°F with the kiln vents open for most of the first day of kiln residence. Equalizing at 200°F dbt and 180°F wbt was started when the wettest kiln sample was at about 10% average MC. Total kiln residence for the 7/4 flitches was less than 70 hours and both the darkwood and whitewood were at essentially 6% MC at the end of the run. The flitches were also free of casehardening. Conventional temperature and dehumidification drying produced the next best uniformities of MC but at the expense of extended drying times.

6. In the high temperature drying of paper birch flitches the shrinkage could be as high as 12%. Consideration should be given to this factor in establishing green target sizes.

Literature Citations

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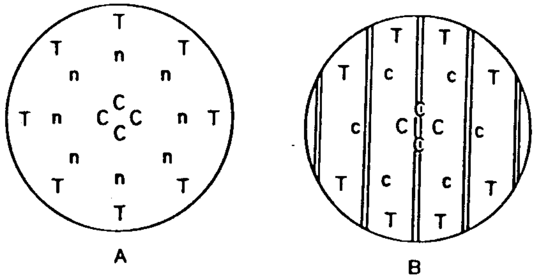

Figure 1: A) Distribution of longitudinal growth stresses. T = tension, n = neutral, and C = compression.
B) Growth stresses are balanced on the wide face of flitch in live-sawing.

Source: Maeglin, R. R. and R. Sidney Boone, "Manufacture of quality yellow-poplar studs using saw-dry-rip (S-D-R) concept". Fores Prod. J. 33(3), p. 11, 1983.

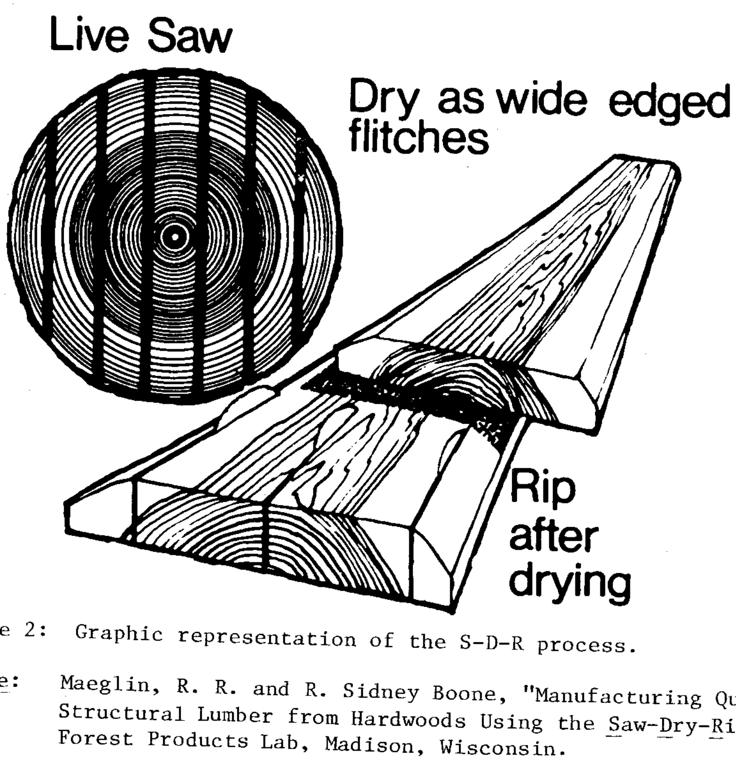

Figure 2: Graphic representation of the S-D-R process.

Source: Maeglin, R. R. and R. Sidney Boone, "Manufacturing Quality Structural Lumber from Hardwoods Using the Saw-Dry-Rip Process" Forest Products Lab, Madison, Wisconsin.

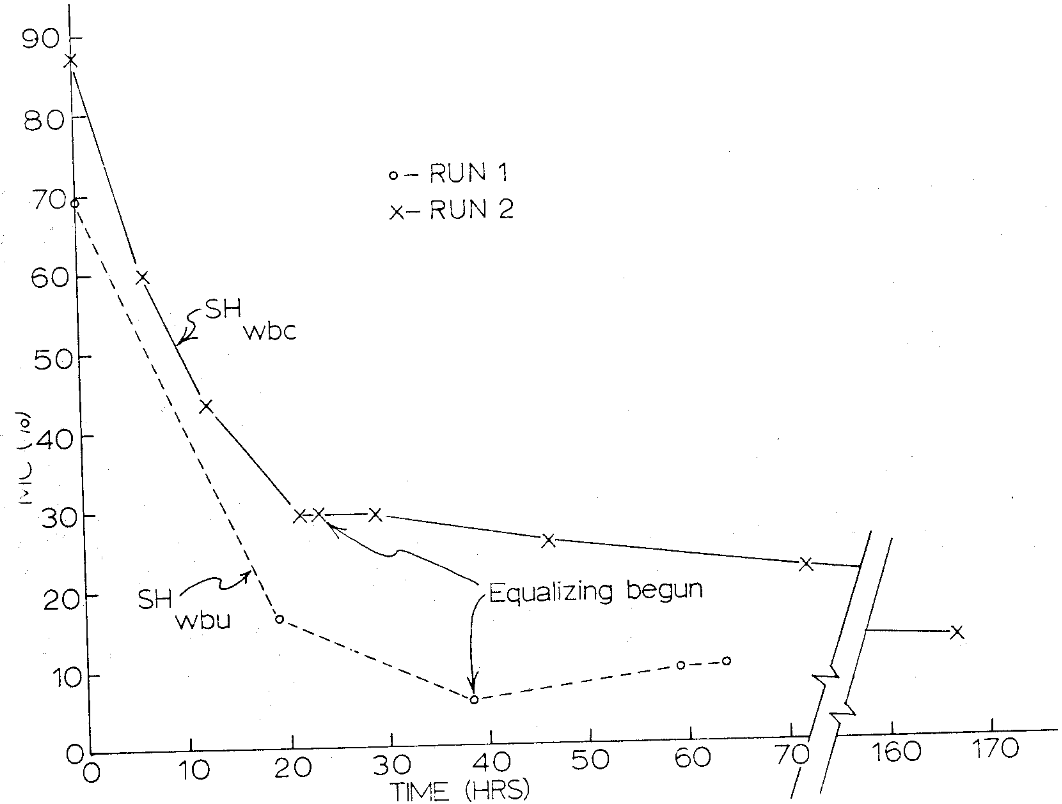

Figure 3: Drying curves for runs 1 and 2. See Table 1 for the drying conditions employed on these two runs.

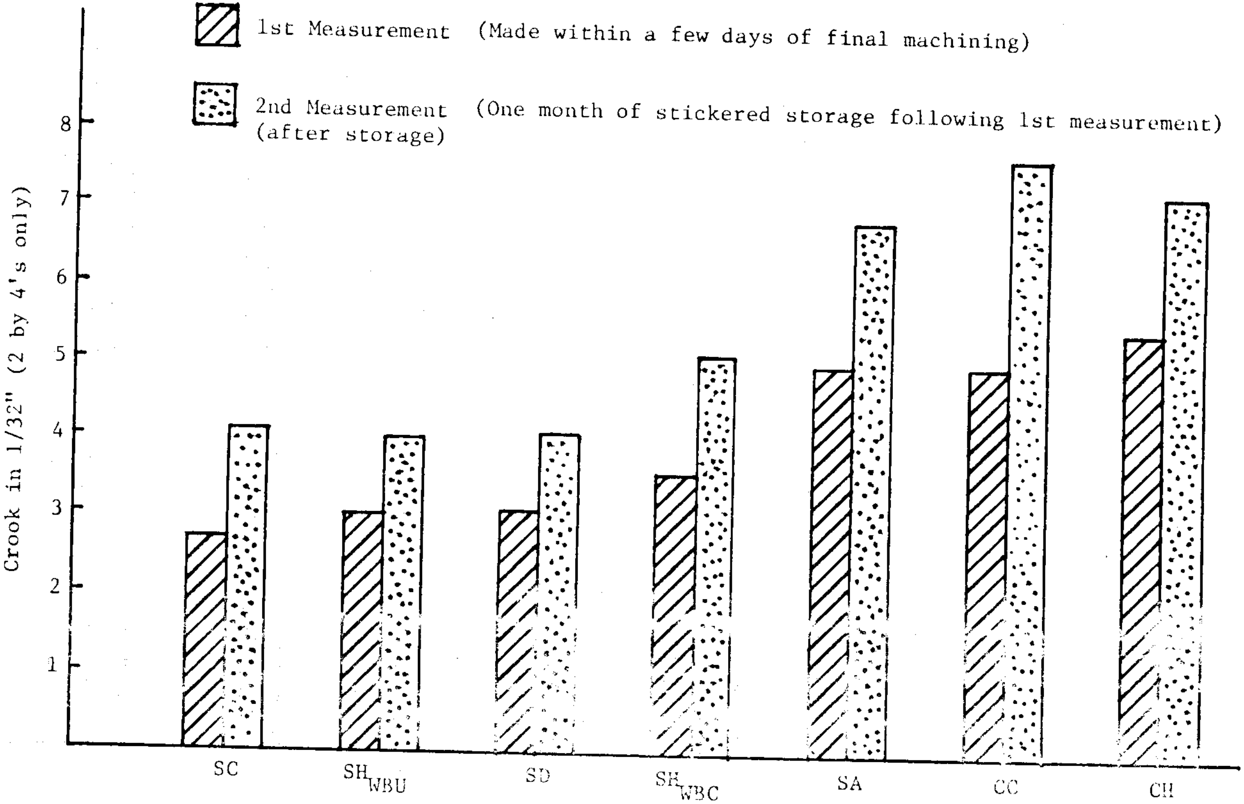

Figure 4: Comparison of absolute crook for 2 by 4's by treatment and time of measurement.

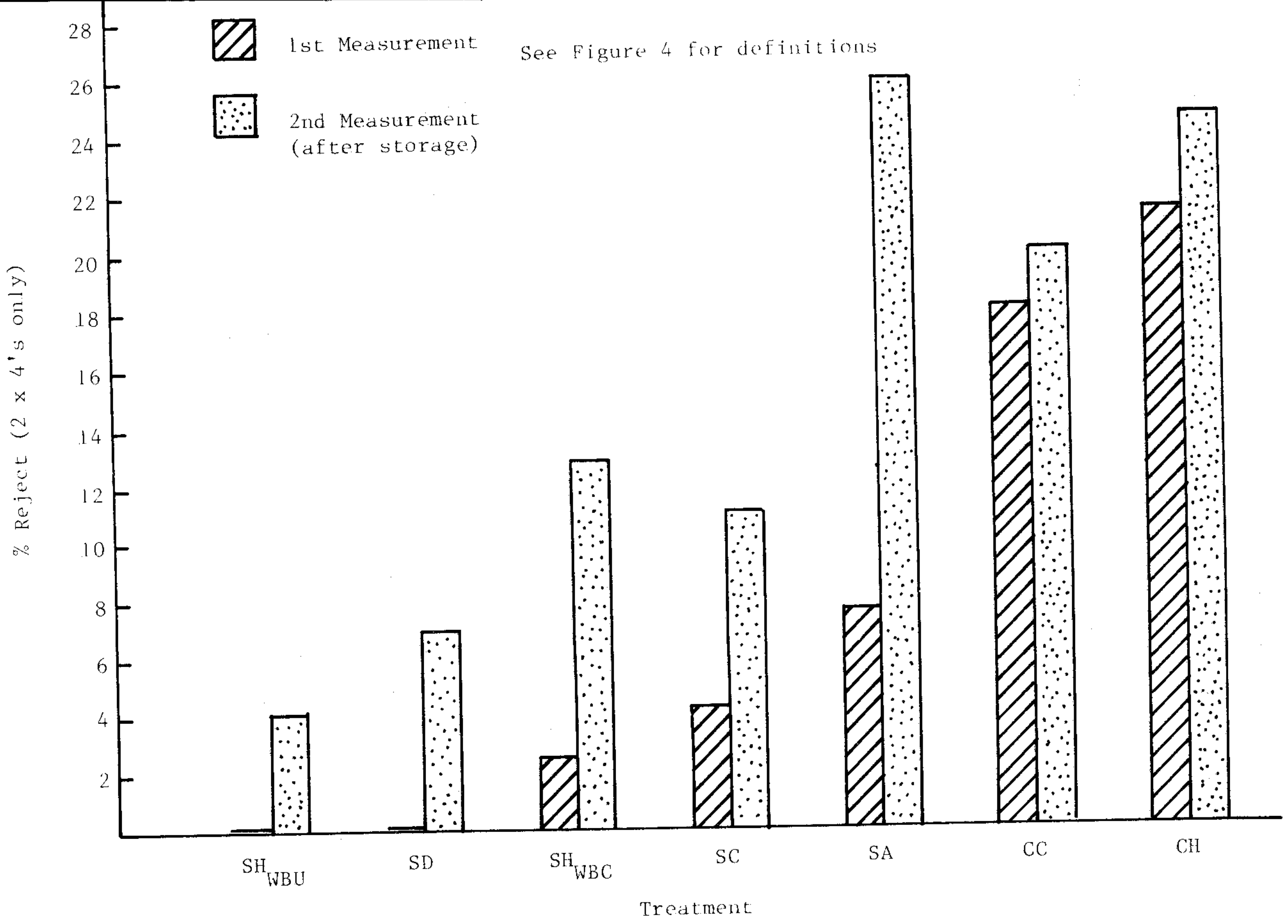

Figure 5: Percent rejection rate for 2 by 4's by treatment and time of measurement.

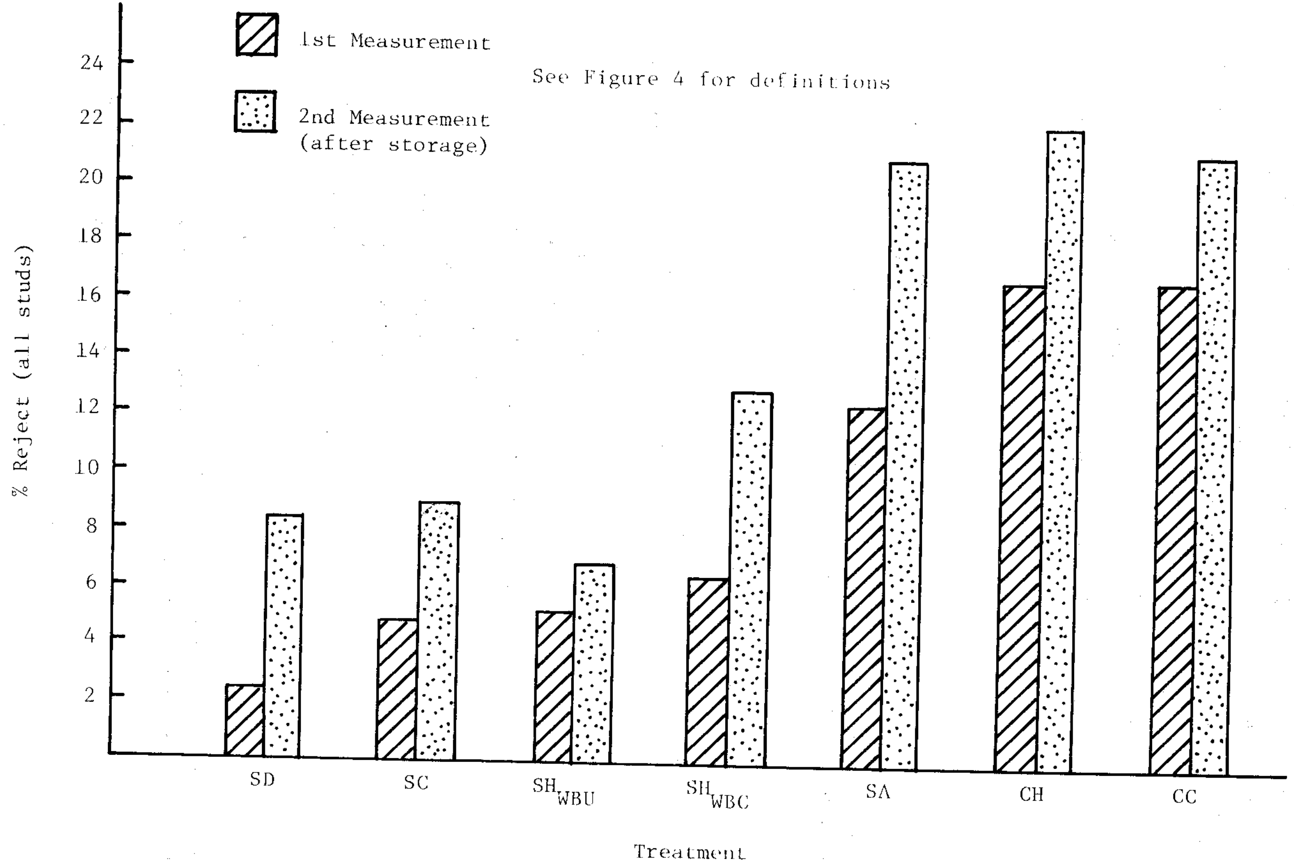

Figure 6: Percent rejection rate for all studs by treatment and time of measurement.

Table 1: Summary of the drying conditions by treatment

1) SH_{WBU} - Drying conditions
dbt = 240°F
wbt = 185°F
Note: The wet bulb reservoir went dry and the kiln vents were wide open for the hours of drying 5 through 18.

- Equalizing
dbt = 200°F
wbt = 180°F

2) SH_{WBC} - Drying conditions
dbt = 240°F
wbt = 185°F

- Equalizing
dbt = 200°F
wbt = 180°F

3) SC - Schedule recommended by FPL:T8C3

- Equalizing
dbt = 180°F
wbt = 160°F

4) SD - Drying conditions
dbt = 110°F
wbt = 99°F $\xrightarrow{}$ (3 days) 88°F $\xrightarrow{}$ (14 days) 82°F
compressor operating continuously

- Equalizing
none

5) SA - Drying conditions were those in effect at Hedstroms' air drying yard in northeastern Minnesota

6) CH - Drying conditions
dbt - 240°F
wbt = 190°F

- Equalizing
dbt = 200°F
wbt = 180°F

7) CC - Schedule recommended by FPL:T8C3

- Equalizing
dbt - 180°F
wbt = 160°F

NOTE: With the exception of treatment 1, equalizing began when the driest sample board reached 7 to 8% MC and continued until the wettest sample board had a MC of about 12%. In treatment 1 the equalizing commenced when the wettest kiln sample was about 10% MC and continued until all the sample boards reached approximately 6% MC.

Table 2: Summary of sample board MC data by treatment at the end of drying

MOISTURE CONTENT DATA OVENDRY
BASIS BY TREATMENT

Treatment	Avg. Initial MC (%)	Final Avg. MC (%) Overall	Final Avg. MC (%) White-wood	Final Avg. MC (%) Dark-wood	Range of Final MC's (%)	Drying Time (hrs.)
SH_{WBU}	65.4	6.0	5.8	6.0	5.6 - 6.2	64.75
SH_{WBC}	78.8	10.0	8.3	14.4	7.1 - 12.1	167.0
SC	76.8	9.9	8.9	13.7	7.8 - 12.6	359.5
	69.9	8.3	8.6	10.6	6.7 - 9.9	434
SD	50.2	8.9	8.4	11.0	6.2 - 11.1	394.5
	68.4	12.3	11.2	16.7	8.7 - 16.0	523.5
SA	71.8	19.4	22.7	22.0	12.5 - 22.4	*
	74.4	22.3	22.2	21.3	19.8 - 25.6	*
CH	69.8	7.3	6.4	8.4	6.0 - 11.7	68.0
	64.4	6.2	6.2	6.6	5.2 - 7.0	68.5
CC	82.2	8.4	8.4	10.0	6.8 - 9.7	381.5
	74.3	8.1	7.7	9.4	7.0 - 10.2	378.5

* In air drying yard at Hedstroms' in Grand Marais, MN from May to December, 1981 and then covered outdoor storage on stickers at Kaufert Lab until January, 1982.

Table 3: Summary of warp and MC data obtained for the 2 by 4 studs within a few days of final machining and their return to Kaufert Laboratory.

Treatment	Nos. of 2 x 4's	Ave. Crook (1/32")	Ave. Bow (1/32")	Ave. Twist 1/32"	Ave.[1/] MC (%)	Range[1/] of MC Values (%)
SC	72	2.7	5.1	2.1	9.9	7.5 - 17
SH_{WBU}	24	3.0	6.9	3.2	[2/]	7 - 7
SD	57	3.1	5.5	1.6	8.9	7 - 11.5
SH_{WBC}	39	3.6	5.8	1.0	[2/]	7 - 8
SA	66	4.9	5.9	2.6	16.1	11 - 23
CC	50	4.9	5.9	4.7	9.6	8 - 11
CH	61	5.5	4.7	3.6	9.3	7 - 13

1/ These are MC values that were determined with the resistance meter in the manner described in Experimental Materials and Procedures.

2/ Meter readings were taken but the majority were less than 7% and did not register.

Table 4: Summary of warp and MC data obtained for the 2 by 4 studs after approximately one month of stickered storage in Kaufert Laboratory after the 1st measurement.

Treatment	Nos. of 2 x 4's	Ave. Crook (1/32")	Ave. Bow (1/32")	Ave. Twist 1/32"	Ave. MC (%) [1/]	Range [1/] of MC Values (%)
SH_{WBU}	24	4.00	7.4	1.9	[2/]	↓ 7
SD	57	4.0	5.4	2.4	7.3	7 - 8
SC	72	4.2	5.5	2.6	8.3	7 - 10.5
SH_{WBC}	39	5.1	5.7	0.8	[2/]	↓ 7 - 7.5
SA	66	6.8	5.2	3.7	8.00	7 - 10
CH	61	7.2	6.0	3.8	8.1	7 - 13
CC	50	7.6	4.7	5.4	8.1	7 - 10

1/ These MC values were obtained by resistance meter on the same studs for which MC data is given in Table 3.

2/ Meter readings were taken but the majority were less than 7% and did not register.

Table 5: Bonferroni test for significant differences in average crook; includes all studs, i.e., 2 by 2's, 2 by 3's, and 2 by 4's.

1st Measurement

Treatment	SD	SC	SH	SA	CH	CC
$\bar{x}$	3.40	3.64	3.64	6.35	6.77	7.02

2nd Measurement

Treatment	SD	SC	SH	SA	CH	CC
$\bar{x}$	4.04	4.16	4.53	6.90	7.22	7.61

$\bar{x}$ = avg. crook in 32nds of an inch

Note: All treatments under a single line are not significantly different from each other. Treatments grouped under one line are significantly different from those grouped under the other line. ($\alpha = 0.01$)

Table 6: Summary of shrinkage values for the treatments

	Average shrinkage of the sample boards (%)[1]		
Treatment	Width	Thickness	Final Avg. MC (%)
SH_{WBU}	4.68	9.88	6.0
SH_{WBC}	3.27	9.46	10.0
SC	5.65	7.62	9.1
SA	3.44	3.79	21.9
CH	4.85	13.68	6.8
CC	7.04	7.34	8.3
SD	4.71	6.86	10.6

[1] For the SH treatment the replications are listed individually due to the different drying environments that resulted for each replication. The values for the other treatments are the averages obtained from the two replications.