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This paper confirms the suitability of an accelerated kiln schedule for presurfaced upland red and white oaks. With an estimated 25 percent reduction in drying time, a 12 percent increase in kiln capacity, and the capability of virtually eliminating costly air drying inventories, this research brings into sight savings of $15 per MBM or more when drying oak from the green condition. Major emphasis is put on the essential findings and their contribution toward commercial application. Further information on potential timesavings is given in a new U.S. Forest Service Research Note FPL-0214 (see page S of this issue).

New Kiln Schedule for Presurfaced Oak Lumber

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Abstract

An accelerated kiln schedule, previously developed for presurfaced northern red oak, was tested for 1-inch white and cherrybark oak. Internal checking was prevented in both species. Surface checking was prevented in the white oak but was excessive in the cherrybark oak, except when the first part of the schedule was considerably modified. Presurfacing, accelerated schedule, and higher air velocities were concluded to hold promise for substantial reductions in cost of drying red and white oak. Suggestions are given for seasoning cherrybark oak.

OAKS MAKE UP ONE-THIRD of the hardwood timber in the United States and about one-half of the current production. But all oaks dry at a slow rate and tend to develop defects as drying is accelerated. Accordingly, very conservative drying procedures have been the rule and drying costs have been very high. One research goal of the Forest Products Laboratory is a 30 percent reduction of these costs.

In searching for means to accomplish this goal, scientific and practical evidence indicated that presurfacing before kiln-drying was one of the most pomising possibilities. Presurfacing greatly reduces the tendency for surface checking and thereby permits a significant acceleration of the kiln schedule without degrade. This acceleration should make kiln-drying from the green condition an attractive alternative to air-drying or forced air-drying plus kiln-drying (1).

The research covered by this paper was directed primarily at experimentally testing the applicability of the recently devised schedule for presurfaced northern red oak (4) to green material from two other prominent oaks. The experiment sought to determine whether the

The authors are, respectively, Technologist and Technician, USDA Forest Service, Forest Products Laboratory, Madison, Wis. Acknowledgment is made of the assistance of the Anderson-Tully Company, Vicksburg, Miss.; the Southern Hardwoods Laboratory, Stoneville, Miss.; and the Wisconsin Department of Natural Resources. This paper was presented at Session 6 - Wood Drying - of the 24th Annual Meeting of the Forest Products Research Society, June 30, 1970, in Miami Beach, Fla. It was received for publication in October 1971.

new schedule caused significantly more drying defects than the regular schedule, using similarly presurfaced material. No rough lumber was included.

This paper does not answer the question of whether oak surfaced green to 1.00 inch can provide flat, dry cuttings for final product thicknesses of 3/4 to 25/32 inch. Neither does it show how much drying time can be saved by presurfacing and the new schedule. Such considerations are being studied in pilot tests, three of which are mentioned later.

Information was also obtained on applying the schedule to presurfaced and predried material. The kiln schedule acceleration described involved both increased temperature and higher than customary air velocities. Kiln conditions were changed in accordance with the average moisture content of all specimens, which is a further step toward 'automatic programming and control (9).

Presurfacing and Accelerated Schedule

A foundation for this work was laid by McMillen and Youngs (5) in research on drying strains and across-the grain mechanical properties of oak. Adaptation of these findings to improve kiln schedules did not appear feasible, however, until Rietz and Jenson (8) and others demonstrated that "presurfacing" made oak lumber much less susceptible to surface checking.

Presurfacing, as used in this report, means removing all the saw-tooth marks. Gaby (3) showed that this generally required surfacing to a 1/16-inch depth, but he and others who experimented with presurfacing used kiln schedules too severe for commercial practice.

About 3 years ago, research was started at the Forest Products Laboratory to develop an accelerated kiln schedule that would dry presurfaced 1-inch northern red oak in considerably less time than required for rough 4/4 stock using the recommended schedule, T4-D2 (6). It was reasoned that both the thinner cross section of the presurfaced material and an accelerated schedule would reduce drying time. The increased amount of lumber in the kiln because of thickness reduction and the shorter drying time would combine to increase annual kiln capacity markedly The uniformity of thickness would greatly reduce warp.

Forest Service Research Paper FPL 122 (4) describes the research and includes the analysis of previous strain and mechanical data, new strain analyses, and the new schedule. Salient features of the accelerated schedule are an initial temperature higher than 110°F and subsequent early use of 120° and 130°F. Although the relative humidity of the kiln air was the same as in the recommended schedule, the EMC at the wood surface was considerably lower than customary because air velocity through the load was increased to 375 to 400 feet per minute.

The accelerated schedule reduced the drying time of northern red oak to 14-1/4 days (4). Compared with a minimum assumed time of 20 days for rough oak under conventional schedule and air velocity conditions. this represented a 29 percent savings in drying time.

Research Approach

Oak Material

For drying schedules, oak is considered in one of three groups - red oak, white oak, and southern lowland oak.

Red and white oak are generally from northern or southern upland sites, and the major difference between them in regard to seasoning is the generally lower green moisture content of the white oaks. In kiln schedules, this is handled by changing kiln conditions at lower moisture levels for the white oak. Although white oaks are slightly more refractory than red oaks, the wet-bulb depressions or EMC's during the early steps of the schedules are the same.

For this study, we selected the most prominent upland white oak, *Quercus alba* L., and the most prominent southern red oak, cherrybark (*Q. falcata* var. *pagodaefolia* Ell.), grown on a bottomland site.

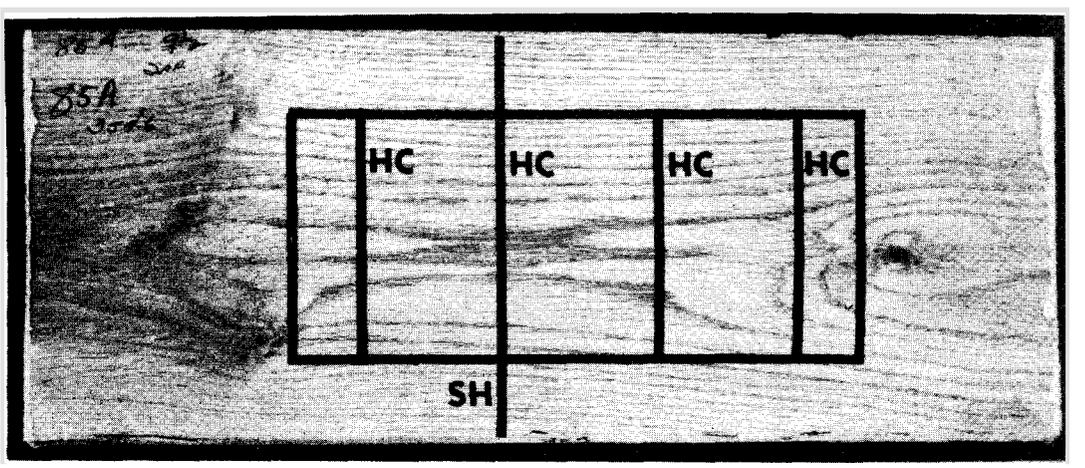

Figure 1. - White oak specimen at end of drying by accelerated schedule showing area of check measurement and lines for honeycomb observation (HC) and shrinkage measurement (SH).

Method

The experimental method was essentially the same as used for northern red oak (4) except that the faces of the green presurfaced specimens were exposed to room air during marking and overnight storage. Fifteen boards were randomly selected from each of two batches of 100 boards of No. 2 Common and Better grade at a separate commercial sawmill for each species. Each board was divided into four end-matched specimens. These were randomly distributed to the drying groups and stored at 36°F. until needed. On the day before starting a drying run, the 1-1/8-inch or thicker rough material was presurfaced to 1.00 inch, cut to 22-1/2-inch length, end coated, and marked for defect observation. For each species, duplicate kiln runs using the new schedule were compared with matched runs using one of the recommended schedules (6). Another set of runs simulated kiln-drying after forced air-drying. For the cherrybark oak only, a fourth set of kiln runs was made that applied the new schedule in the latter half of the drying, after very mild conditions were used in the first half.

Periodically during each run, the specimens were weighed and significant surface checking was measured. The specimen in Figure 1 shows a 75-square-inch zone for check measurement laid out on the flattest grain portion of the surface. It also shows four lines for crosscutting at the end of drying to measure internal checking (honeycombing) and a line on which green and dry widths were measured for shrinkage. These locations also were used for measuring minimum thickness and maximum cupping per 6 inches of width.

Table 1. - INITIAL CONDITIONS AND DRYING TIMES FOR PRESURFACED WHITE AND CHERRYBARK OAK.

Procedure	Initial Temperature (°F.)	Initial EMC (%)	Drying Time (Days)
	White Oak		
Kiln, T4-C2	110	17.5	16.2
Kiln, new	1 I5	17.5	15.8
Forced air + kiln	85	13.5	13.3
	Cherrybark Oak		
Kiln, T4-D2	110	17.5	22.5
Kiln, new	115	17.5	19.8
Kiln, mild	96	21.3	21.8
Forced air + kiln	90	15.9	20.5

Table 2. - DRYING CONDITIONS USED FOR PRESURFACED 1-INCH WHITE OAK.

Accelerated kiln schedule[1]			Combination forced air-plus kiln-drying[2]		
Average moisture content (%)	Dry-bulb temperature (°F.)	EMC (%)	Average moisture content (%)	Dry-bulb temperature (°F.)	EMC (%)
Above 42	115	17.5	Above 40	85	13.5
42	115	16.2	40	90	10.2
37	120	13.4			
30	130	10.0	33	95	8.2
26	130	4.4	28	105	5.4
21	140	2.6	24	130	3.0
16	180	3.3	20	180	3.3

[1]Air velocity through load 375-400 feet per minute.

[2]Air velocity through load 575-600 feet per minute to 24 percent moisture content, 400 feet per minute thereafter.

Table 3. - DRYING CONDITIONS USED FOR PRESURFACED 1-INCH CHERRYBARK OAK.

Accelerated kiln schedule[1]			Mild kiln schedule[2]			Combination forced air-plus kiln-drying[3]		
Average moisture content (%)	Dry-bulb temperature (°F.)	EMC (%)	Average moisture content (%)	Dry-bulb temperature (°F.)	EMC (%)	Average moisture content (%)	Dry-bulb temperature (°F.)	EMC (%)
			[4]Green	....	25±			
			(5)	96	21.3			
			(5)	97	19.0			
			(5)	98	17.5			
			(5)	99-1 03	16.1			
Above 50	115	17.5	(5)	105	14.0	Above 50	90	15.9
50	115	16.2	(6)	110	12.0	50	95	11.6
41	120	13.4	41	120	10.0	42	100	9.2
35	130	10.0	35	130	8.0	35	110	6.3
30	130	4.4	30	130	4.4			
25	140	2.6	24	140	2.6	25	130	3.0
18	180	3.3	18	180	3.3	20	180	3.3

[1]Air velocity through load 375-400 feet per minute.

[2]Conditions above 41 percent MC suggested by Willis Dykes, Anderson-Tully Co. Air velocity through load 200-225 feet per minute.

[3]Air velocity through load 375-400 feet per minute.

[4]Kiln gradually raised to kiln temperature, using steam spray only, in 3 hours.

[5]Kiln operated on a time basis, 2 days on each of the first three steps, 3 days on the fourth, and 1 day on the fifth.

[6]Time 2± days until 41 percent MC reached.

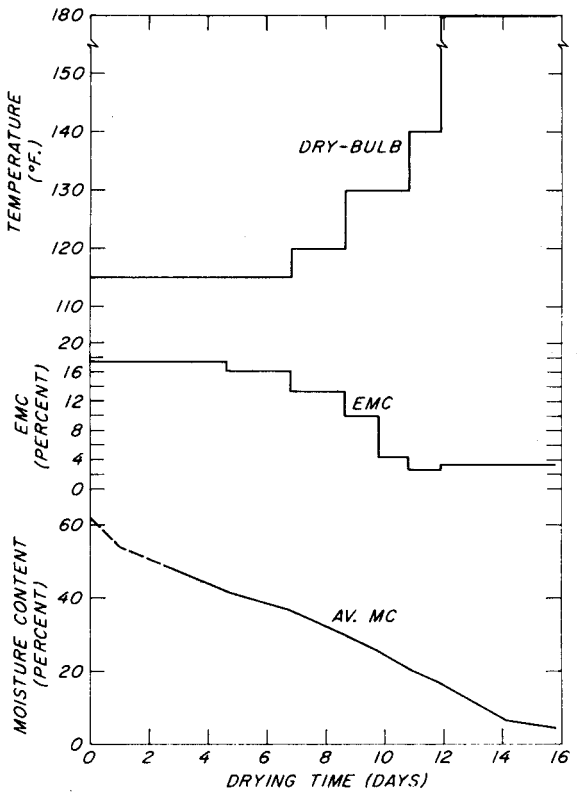

Figure 2. - Drying conditions and average moisture content curve for accelerated schedule, 1-Inch white oak.

Kiln-Drying Results

A summary of initial conditions and drying times is given in Table 1. The kiln schedules T4-C2 and T4-D2, used for comparison purposes, are described in the Dry Kiln Operator's Manual (6). Details of the other drying procedures are given in Tables 2 and 3.

Green White Oak

The accelerated kiln schedule was entirely satisfactory for the presurfaced white oak. Kiln conditions and the drying curve obtained from the average moisture content of all specimens are shown in Figure 2. Changes in kiln EMC and temperature were made at lower moisture content values than for northern red oak (4), partly because green moisture content of white oak is typically lower and partly to achieve about the same time on each schedule step as used for red oak. The fact that essentially all surface checking developed in the first 6 days of drying and that 180°F. at 20 percent moisture content was satisfactory in the forced air- plus kiln-drying runs indicated that the total drying time for the white oak could have been shortened about 1 day by making all schedule changes somewhat earlier. This would have resulted in the drying time for presurfaced oak under the new schedule being about 22 percent less than the 19 days estimated by the authors to be the minimum for rough 4/4 white oak of this species and quality under conventional kiln schedule and air velocities.

The reduction in thickness itself probably would account for about one-half of the total reduction in drying time. The other half of the time saving comes from the acceleration of the schedule and the higher air velocity.

The results of the seasoning behavior observations[1] on the white oak kiln runs are given in Table 4. For comparison, the most significant results on northern red oak (4) were:

	Surface checks per 100 square inches (In.)	Internal checking per 10 width inches (In.)
Old schedule	1.62	0.31
Accelerated schedule	1.11	.30

Surface checking under the new schedule was not significantly different from that under the recommended white oak schedule, T4-C2, and neither were internal checking, average depth of deepest check, width shrinkage, minimum thickness, nor cup. The very few surface checks present were tightly closed at the end of drying. The absence of internal checking is shown in Figure 3.

[1]Assistance in statistical analysis by Frank Freese, U.S. Forest Products Laboratory.

Table 4. - RESULTS OF KILN-DRYING AND FORCED AIR- PLUS KILN-DRYING PRESURFACED WHITE OAK.

Procedure	Length[1] of surface checks per 100 sq. in. (In.)	Length[1] of internal checks per 10 width in. (In.)	Average depth of deepest check[2] (In.)	Average width shrinkage[1] (%)	Average minimum thickness[1] (In.)	Average cup[1] (In.)
			Kiln-Drying			
T4-C2	1.33	0.08	0.13	8.26	0.92	0.08
Accelerated schedule	1.84	.03	.14	8.50	.91	.09
			Forced Air- Plus Kiln-Drying			
Combination	2.86	.09	.22	7.42	.90	.09

[1]Differences not significant at 0.05 level.

[2]Measurable specimens only, no significant difference.

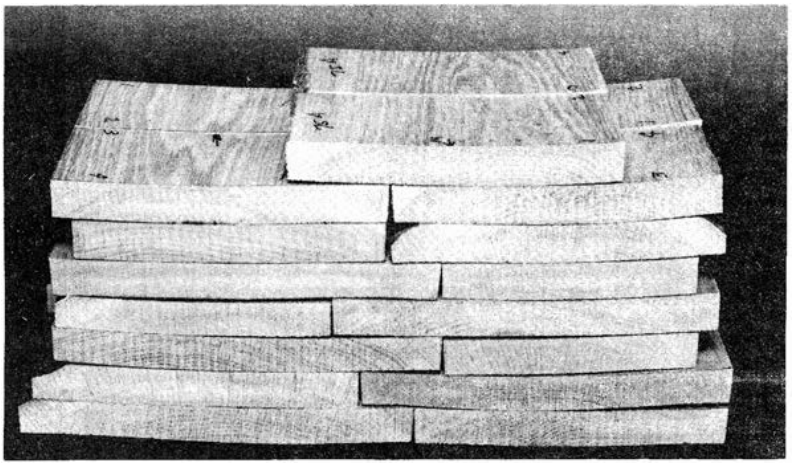

Figure 3. - Cross sections of white oak at end of drying by accelerated schedule.

The fact that apparently large percentage differences between surface checking values in Table 4 are not statistically significant indicates a considerably larger number of specimens and replicas would be needed to determine significance of differences between drying procedures with essentially equivalent effects. The actual amounts of checking are small. These differences contrast quite strongly with the **330** percent difference in surface checking and the **430** percent difference in internal checking between the results with the excessively accelerated schedule and those with the other schedules in the northern red oak experiment **(4).**

Green Cherrybark Oak

Although the accelerated schedule resulted in 2.7 days (12 percent) less drying time in this experiment than the upland red oak schedule, T4-D2, both the new schedule and the recommended schedule caused too much surface checking in this species (see Table 5). The next step was to use a very mild set of conditions[2] down to the 41 percent average moisture content level, then to use the new schedule the rest of the way. This proved successful. The entire schedule and drying curve are shown in Figure 4. Drying time from 41 percent to 5 percent moisture content was 11 days.

Surface checking and internal checking results by this modified new schedule were about the same as attained with white oak and considered satisfactory. Average depth of deepest check was slightly greater than the comparable value for white oak dried by the new schedule, but the check depth was less than that for northern red oak. Average shrinkage and cup were slightly greater and average minimum thickness slightly smaller than the corresponding values for white oak and northern red oak, but the values of these properties among the different drying procedures used for the cherrybark oak were not significantly different from each other, except for shrinkage. Figure 5 shows cross sections of cherrybark oak specimens dried by mild initial conditions and new-schedule conditions after **41** percent moisture content was attained.

Predried Oak

The suitability of the final stages of the new schedule for finishing the drying of predried white oak is indicated in Figure 6 and Table 4. A dry-bulb temperature of 130°F. and an EMC of 3.0 percent were used when the average moisture content of all specimens was

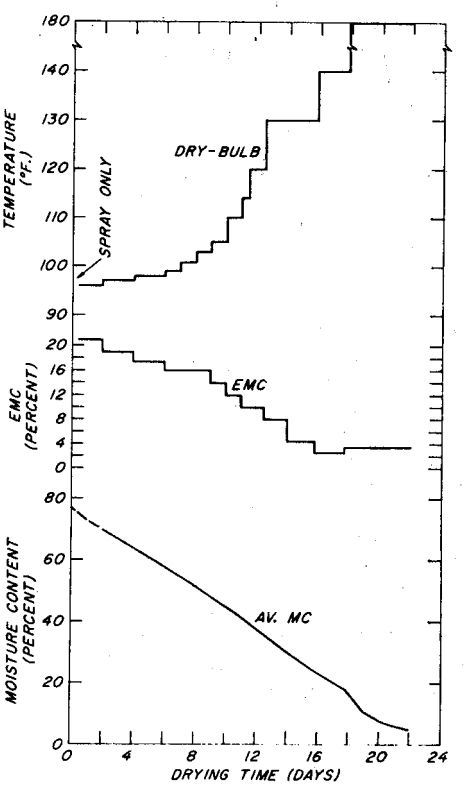

Figure 4. - Drying conditions and average moisture content curve for 1-inch cherrybark oak kiln-dried by the mild schedule.

[2]Based on suggestions from Willis Dykes, Anderson-Tully Co.

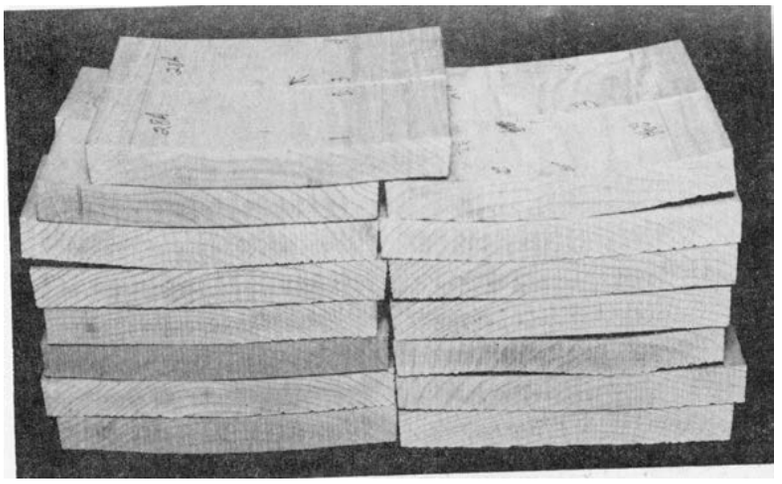

Figure 5. - Cross sections of cherrybark at end of drying by the mild schedule.

24 percent. One day later, the average moisture content was 20 percent, and the dry-bulb temperature was raised to 180°F. Drying time from 24 to 5 percent moisture content was only 4.5 days. Internal checking, width shrinkage, thickness shrinkage, and cupping were not significantly greater than for the two kiln-drying procedures. Length of surface checking and depth of deepest check also were not Significantly greater than for kiln-drying.

For cherrybark oak, the use of 130° and 180°F. at 25 and 20 percent moisture content, respectively, did not cause significantly more internal checking, shrinking, or cupping than the mild kiln schedule (Table 5). The predrying conditions themselves, however, were not considered satisfactory. Surface checking was 5.97 inches per 100 square inches.

Progress Toward Commercial Application

The results of this and the previous study (4) indicate that the new U.S. Forest Products Laboratory kiln schedule for presurfaced green, 1-inch oak lumber is applicable to a variety of upland red and white oaks. The estimated timesaving for presurfaced white oak, compared with rough white oak under conventional schedule and air velocity, is 22 percent. Considering the estimated timesaving with northern red oak of 29 percent, a general saving for upland red and white oak of 25 percent seems justified.

To achieve such savings commercially would involve the use of all three factors of improvement over present practice: Presurfacing, accelerated schedule, and higher air velocity. The air velocity factor is important not only because it results in a lower effective EMC at the surface of the boards but because it keeps the conditions throughout the kiln load closer to the entering-air conditions. Even with air velocities in the neighborhood of 400 feet per minute, commercial kilns probably will not be able to achieve the short drying time of this experiment. However, a 25 percent savings over commonly mentioned commercial times for rough green 4/4 oak of 25 to 31 days would amount to 7 days. At $2 per day per 1,000 board feet, the savings would be about $14. This is about 10 percent of the air-dry lumber value.

To verify that the projected savings in drying time and reduction in seasoning costs can be obtained in commercial use, considerable pilot testing is needed. Such a program should aim to complete the development and demonstrate the benefits. It is suggested that it

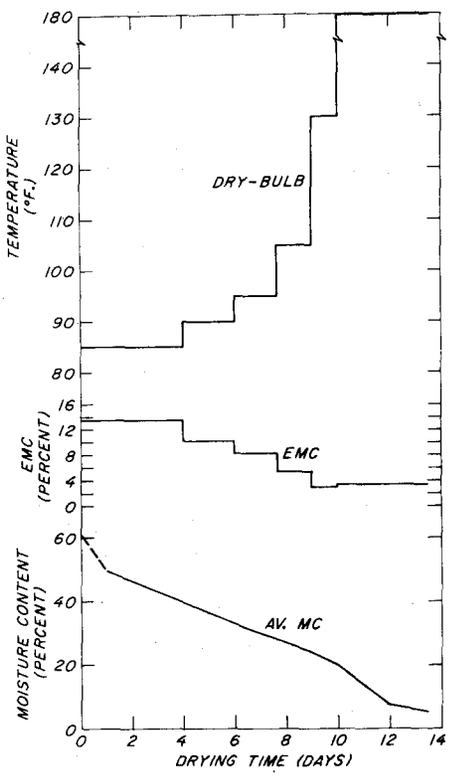

Figure 6. - Drying conditions and average moisture content curve for I-inch white oak dried by forced air- plus kiln-drying.

Table 5. - RESULTS OF KILN-DRYING AND FORCED AIR- PLUS KILN-DRYING PRESURFACED CHERRYBARK OAK.

Procedure	Length[1] of surfacechecks per 100 sq. in. (In.)	Length[2] of internal checks per 10 width in. (In.)	Average depth of deepest check[3] (In.)	Average width shrinkage[4] (%)	Average minimum thickness[2] (In.)	Average cup[2] (In.)
			Kiln-Drying			
14-02	8.42	0.04	0.24	11.78	0.88	0.18
Accelerated schedule	1 1.23	.07	.24	12.36	.86	.14
Mild schedule	1.46	.01	.22	11.34	.86	.15
			Forced Air- Plus Kiln-Drying			
Combination	5.97	.14	.26	10.45	.a7	.15

[1]Statistical analysis not meaningful; one kiln behaved abnormally in first two procedures.

[2]Differences not significant at 0.05 level.

[3]Measurable specimens only, no significant difference.

[4]Difference between accelerated kiln procedure and the combination is significant at 0.05 level.

be in five phases, investigating effects of: 1) presurfacing, 2) the new schedule, 3) application to commercial mixtures of species, 4) forced air- plus kiln-drying, and 5) the autokiln (9).

One aspect of the program has been carried out at the Department of Forestry, University of Massachusetts, at Amherst, involving the comparison of an approach to the new schedule on presurfaced northern red oak with the recommended schedule on rough 4/4 oak (7). In this test, bandsawn 1-1/8-inch oak was carefully planed down to 1.03 inches before drying. It was successfully used for normal large hardwood dimension cuttings.

Another test was carried out at the Forest Products Marketing Laboratory, Princeton, W. Va., using mixtures of Appalachian red and white oaks (2). This material also was presurfaced to 1.03 inches, kiln-dried by the new schedule, and used in an industrial product. A test of presurfacing and new schedule in the autokiln is in progress at the Forest Products Laboratory, Mad ison, Wis. Studies on other phases by other qualified agencies and interested companies would help bring about any necessary adjustments.

For those who wish to make cautious commercial trials on upland red or white oak of the findings to date, it must be recognized that large kilns cannot be operated on a time basis using the charts shown in Figures 2, 4, and 6. Until kiln automation is achieved, kiln samples are required. The exact method of operation involves special considerations that are outlined in part III of FPL 122. For white oak, the suggested moisture content values for kiln changes in the first half of the schedule (III, FPL 122) are 42, 37, and 33 percent, respectively. For the second half, the values are the same as for red oak. When there is a mixture of red and white oak in the kiln, it is possible to operate the kiln on the basis of the moisture content of the samples of the predominating species, because the times from the green condition to the first and second wet-bulb depression changes are about the same for both kinds of oaks. If the amount of red and white oak is about even, use an equal number of samples from both kinds of oak. Average the moisture content values given above and the red oak values from FPL 122 to determine the change points. If either the red or the

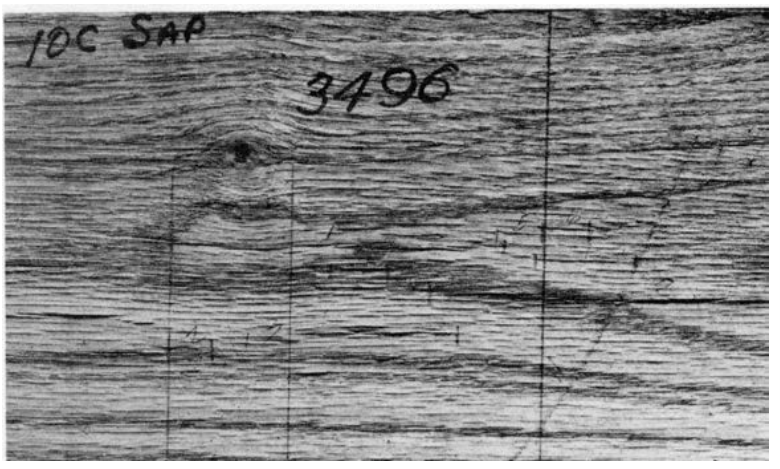

Figure 7. - Closeup photograph of cherrybark oak specimen during early stage of drying by the accelerated FPL schedule. Note open surface checking and protuberance of wood rays above wood surface.

white oak is not strictly green, the kiln should be operated on the basis of the samples and schedule for the species closest to the green moisture content (6).

Suggestions for Cherrybark Oak

Cherrybark oak is more prone to extensive surface checking than most northern red oaks. The type of surface checking that occurs is shown in Figure 7. This photograph was taken during the early stages of drying, when the surface checks were quite open. At this stage of drying the wood rays protruded from the surface considerably. This phenomenon has been reported for other oaks, but it has not been observed in this intensity by the authors before.

For the present, the prospect of kiln-drying presurfaced cherrybark oak from the green condition does not appear to be promising. The ultra-mild initial conditions could, because of temperature drop across the load, result in saturation in the middle- and leaving-air portions of the loads. Further experimentation to improve the first part of the mild schedule might improve this prospect somewhat. Currently, the best procedure appears to be air-drying under shed or pile roofs, followed by kiln-drying. Depending on weather, a 25 percent moisture content can be reached in 60 to 120 days. Then a dry-bulb temperature of 130°F. could be used to start the kiln-drying, continuing with 180°F. at 20 percent moisture content, as in the forced-air combination of this study. When necessary, air-drying could be stopped at a higher moisture level up to 41 percent and then the latter portions of the new schedule applied. The schedule would be entered at the appropriate moisture level. Caution is advised if the lumber is at or below 30 percent moisture content but recently has undergone surface moisture regain because of rain or prolonged high humidity. In this event, a 10 percent EMC should be used the first 12 to 24 hours before the appropriate EMC for the moisture level is used. Very little or no steam spray should be used in kiln warm-up (6).

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