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Drying Small Quantities of Green Hardwoods

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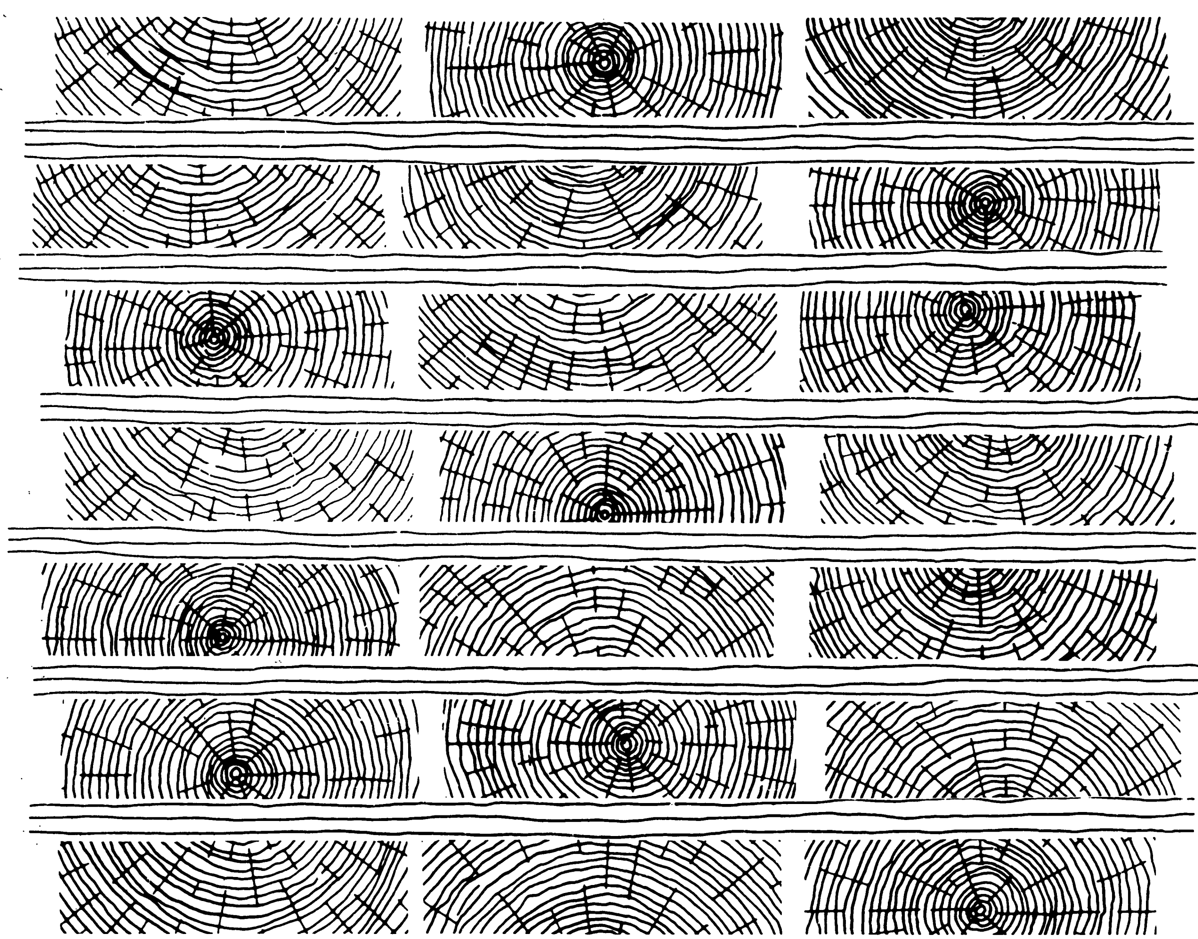

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DRYING SMALL QUANTITIES OF GREEN HARDWOODS AT HOME

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Woodworking hobbyists desiring to dry green lumber or freshly cut cross sections of tree stems may find little information to guide them in their undertaking. Hobbyists can readily obtain practical information on the machining and finishing of wood, but little comparable information is available about drying green wood to the low moisture contents required for most woodworking projects.

In our search of publications available to the hobbyist we found only a few items dealing with drying green wood. For example, Rasmussen (1965) provides some useful general directions that the experienced woodworker may apply. Bois and Wengert (1977) prepared a checklist for hobbyists planning to cut logs into lumber and dry the boards produced. Neither of these items advises the woodworker about the effects of species, thicknesses, and drying conditions on the length of time to dry all quantities of short lumber (less than 8 feet long) to the desired moisture content or the amount of defects that will develop during drying.

This study was undertaken to evaluate methods that the hobbyist might use to dry green lumber. We wanted to find a low-cost method that required little or no equipment and could be carried out in locations common to most yards and houses. The evaluation was based on actual drying trials under conditions likely to be encountered by the hobbyist so the results obtained in this study should be comparable to the results a hobbyist would obtain practicing the same methods.

METHODS

We determined the effect of species, thickness, and drying location on the time to dry green boards and cross-sectional disks to the 6 to 10 percent moisture contents required for many woodworking projects. Species considered difficult to dry, moderately difficult to dry, and easy to dry were represented in that order by white oak (*Quercus alba* L.), black cherry (*Prunus serotina* Ehrh.), and silver maple (*Acer saccharinum* L.). Five-foot-long bolts were obtained locally from trees 12 to 18 inches d.b.h. Full-section disks, 1 inch and 2 inches thick along the grain, were cut from the ends of the bolts so that the drying characteristics of full cross sections could be studied also. The bolts were cut on a portable bolter saw to boards 4/4 and 8/4 thick and edged on a table saw to 6 inches wide. One hundred twenty boards for each species were produced; 60 boards were cut to 4/4 thickness and 60 to 8/4 thickness.

After sawing, 6 inch-long pieces along the grain were trimmed from each end of every board and half-inch-long moisture content specimens were cut from the inner portion of this end trim. These moisture specimens were wrapped in plastic immediately after cutting, weighed, and ovendried to determined moisture content of each board. The boards were segregated by species and thickness into 24 bundles of 5 boards each. These were wrapped immediately in plastic and stored in coolers and 35° F until needed.

The following six locations were selected for the drying tests: heated room with fan, heated room, unheated shed, outdoors under roof, unheated attic with fan, and walk-in freezer.

Attics, sheds, and outdoor spaces were selected because they are often underutilized and would be readily available. Heated indoor space was included because the low moisture content targets and slow drying outdoors in winter would necessitate heated locations, at least for final drying.

Two stacks of 30 boards each were constructed at each site (fig. 1). In building the 12 stacks, boards of each species and thickness were removed from the plastic wrap, weighed to the nearest 0.01 pound, measured for width and thickness at four different points along their length, end coated with paraffin to reduce end checks, and stacked between 3/4-inch stickers to promote air flow across the surface of the boards. The stacks are arranged in alternate rows of 4/4 and 8/4 lumber with the species arranged randomly in each row. Cement blocks were placed on top of the pile to help keep the boards flat (fig. 1). In the heated room and the unheated attic a 20-inch-diameter fan was placed 3 feet from the face of the stack.

When wood is worked indoors, the lumber should be dried to less than 10 percent moisture content. The relative humidity of outside air is often too high to dry wood quickly much below 20 percent moisture content; consequently, the material in the shed, under the roof, and in the attic were dried outdoors to 20 percent moisture and then moved into a heated room and restacked. Drying continued indoors until the weights of selected sample boards indicated a moisture content below 10 percent.

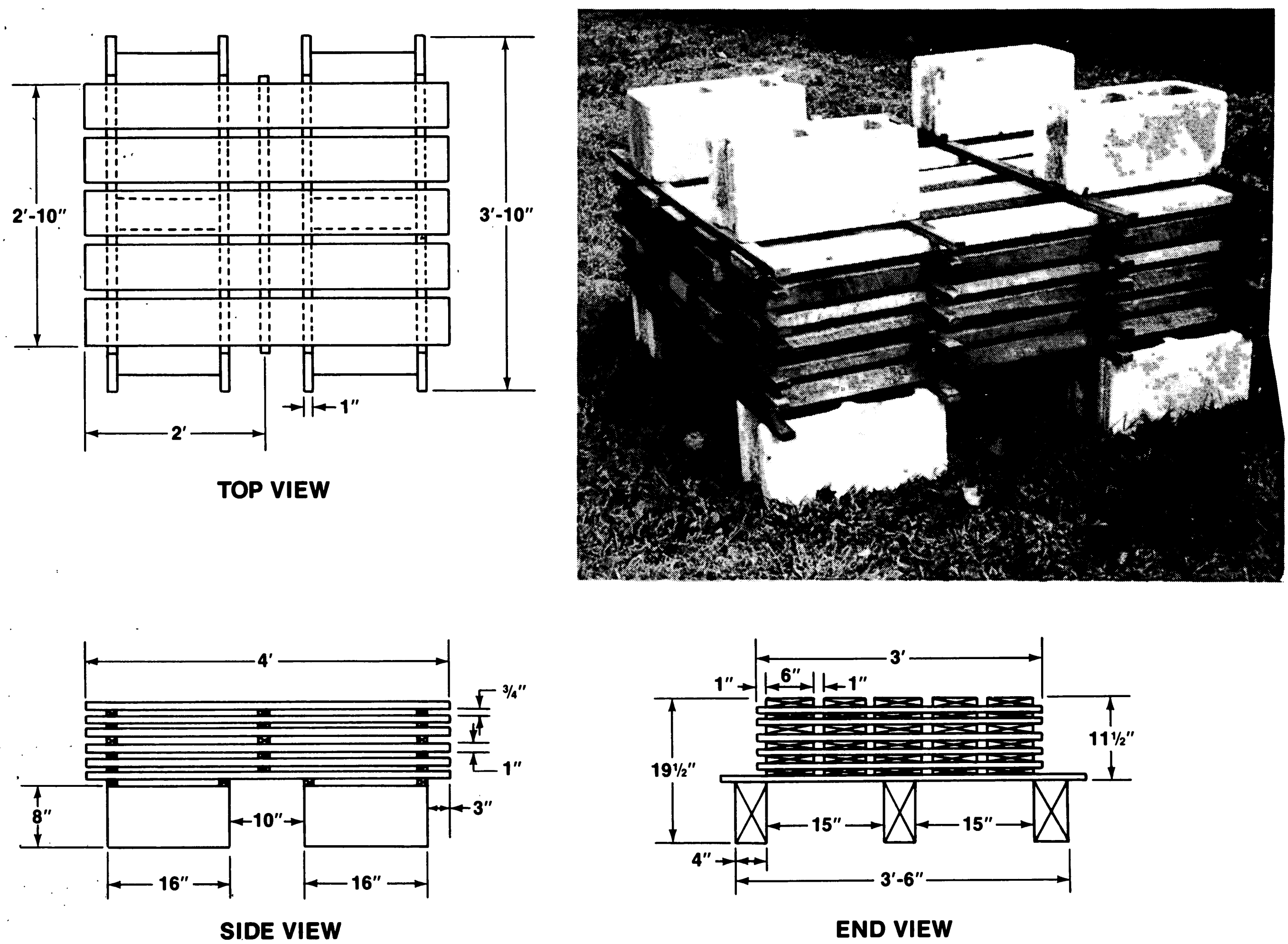

Figure 1.—*Typical lumber stack and arrangment when drying lumber.*

Disks were dried in a heated room with a fan and in the freezer. In the heated room, the disks were placed on stickers that spanned the space between the cement blocks on top of the stack. In the freezer, the disks were placed on stickers that had been arranged on shelves that lined the freezer wall. Prior to drying, the disks were weighed to the nearest 0.01 pound and their moisture contents measured with a penetrating, resistance-type moisture meter that gave the data required to calculate the ovendry weights of the disks.

At each drying location, temperature and humidity conditions of the ambient air were measured and repeat measurements were made once a week until the end of the drying period. At each site, weights of six selected boards (one board for each species and thickness) were monitored weekly for moisture content. At the end of the drying period, weights, dimensions, and warp (crook, bow, cup, and twist) were measured. Also three 1-inch-long stress sections and three moisture sections were cut from the ends and center of each of the sample boards for estimating case hardening and determining differences in shell and core moisture contents by standard tests (Rasmussen 1961).

The cross-sectional disks of each species were divided into two groups of six disks each, one disk of each species and thickness. We kept one group in a heated room for 8 months, and the second group first in a freezer for 13 months and then in a heated room for final drying. We weighed the disks periodically so we could calculate their moisture contents as drying progressed. At the end of the drying period, we measured the number, length, and maximum width of splits that developed.

The experiments were designed for statistical analysis using the analysis of variance technique for testing the effects of the three main variables—species, thickness, and location—and their interactions on the drying times and drying defects. The responses tested were total number of days to dry to 10 percent moisture content and crook, bow, cup, and twist in inches. Where significant differences were found, Duncan's Multiple Range Test was used to array the variables in their order of importance in causing significant differences in the response under test. Two separate stacks were built at each location to replicate the experiment for purposes of estimating the error variance.

RESULTS AND DISCUSSION

Drying Rate—Lumber

The two indoor locations produced the most rapid drying rate for all species and thicknesses of lumber (table 1). Except for 8/4 white oak, all material in heated indoor locations dried below 10 percent moisture content in 90 days. As expected, the easiest to dry species of the three, silver maple, dried fastest followed closely by the moderately difficult-to-dry species, black cherry. White oak, known to be difficult to dry, was notably slower in initial drying, but the 4/4 white oak dried to less than 10 percent moisture content within 90 days. The 8/4 white oak took from 120 to more than 150 days at indoor locations to reach 10 percent moisture content.

The unheated attic with fan produced about the same drying rate as the heated indoor locations. Only small differences existed between the drying curves obtained in the heated rooms and attic, especially when these are compared to the curves obtained in the unheated locations and the freezer.

In the unheated locations, silver maple, black cherry, and 4/4 white oak took approximately 60 days to dry from the green condition to 20 percent moisture content. Indoor locations took only 30 days to produce the same moisture content drops. But once these materials were moved into heated space after 75 days at the unheated locations, they dried to 10 percent moisture content in an additional 15 days so that the total time to dry was about 90 days, essentially the same for material kept indoors. White oak of 8/4 thickness would take more than 120 days to dry to 10 percent moisture content using this two-stage drying sequence involving an unheated location followed by a heated location.

The average drying times by runs for the three species, two thicknesses, and six locations give a numerical comparison between the three main variables—species, thickness and location (table 1). A comparison of the data for the heated room and the heated room with a fan indicates that the use of a fan in a heated space only slightly increases the initial drying rate.

Table 1.—*Time required to dry green 4/4 and 8/4 white oak, black cherry, and silver maple lumber to 10 percent moisture content*[1] *at six different locations*

Location	Run	Lumber						Range
		4/4 Thick			8/4 thick			
		White oak	Black cherry	Silver maple	White oak	Black cherry	Silver maple	
	Number	*Days*						
Heated room with fan	1	62	42	32	107	90	62	32-112
	2	62	43	44	112	66	51	
Heated room	1	55	72	30	105	83	50	24-105
	2	56	42	24	79	62	55	
Unheated shed	1	100	81	80	126	107	97	80-241
	2	239	235	236	233	241	236	
Outdoors under roof	1	60	73	55	61	98	64	55-246
	2	246	240	241	232	241	246	
Unheated attic with fan	1	65	56	54	88	67	61	54-104
	2	69	58	59	104	87	62	
Freezer	1	192	182	170	217	199	180	166-228
	2	180	166	168	223	228	228	

[1]Drying times are to 15 percent moisture content for 8/4 white oak.

Wood placed in a freezer for approximately 150 days lost little moisture, especially after an initial moisture drop in the first 10 days. Upon removal from the freezer and stacking between stickers in a heated room, the material dried to 10 percent moisture content at about the same rate as green material placed directly in a heated room and no significant differences in drying defects were observed. Although Walters (1975) reported reduced drying defects in prefrozen wood, the results in this study demonstrated that prefreezing had little effect on subsequent drying characteristics.

Despite the obvious differences in drying rates between locations analysis of variance of the drying time data indicated that only species and thickness had a significant effect on drying time. Locations did not have a significant effect despite the slow drying that occurred in the freezer. The causes of this unexpected outcome were the low value for drying time in the freezer obtained by moving the material to a heated room after only 150 days and the large mean square for the error term created by differences between runs No. 1 and No. 2 at the outdoor locations. The runs were treated as replicates for purposes of estimating the error variance when, in executing the experiment, the runs actually were begun 1 week apart because of the time required to build each stack. We expected the time differential between runs to be inconsequential, but a sudden onset of cold weather occurred immediately after the first-run material reached 20 percent moisture content but before the second-run material did so. As a result, the second-run material was retained at the outdoor locations for an additional 105 days before being moved into heated space. This difference between runs in drying time produced the overestimate of the error variance that reduced the power of the treatment tests.

Although the statistical tests were impaired by the problems with the second-run material at the outdoor locations, our observations document the very slow drying rate that occurs in winter at northern latitudes (figs. 2-4). This drop in dryng rate is not unexpected because a similar set of drying curves was reported by Koch (1972) for shortleaf pine dried in an unheated shed in northern Indiana, and Rietz (1972) estimated that in the northern United States the summer drying rate for wood is six times faster than the winter rate.

Drying Rate—Cross-Sectional Disks

The disks in the heated room with fan dried somewhat faster than the lumber but, in practice, the boards and the disks should be handled the same (fig. 5). The 4/4 white oak disks, just as the 4/4 lumber, dried to 10 percent moisture content in 90 days but the 8/4 disks of white oak took more than 3 months to reach that target.

The disks held in the freezer for 13 months dropped only 10 percent in moisture content but quickly dried

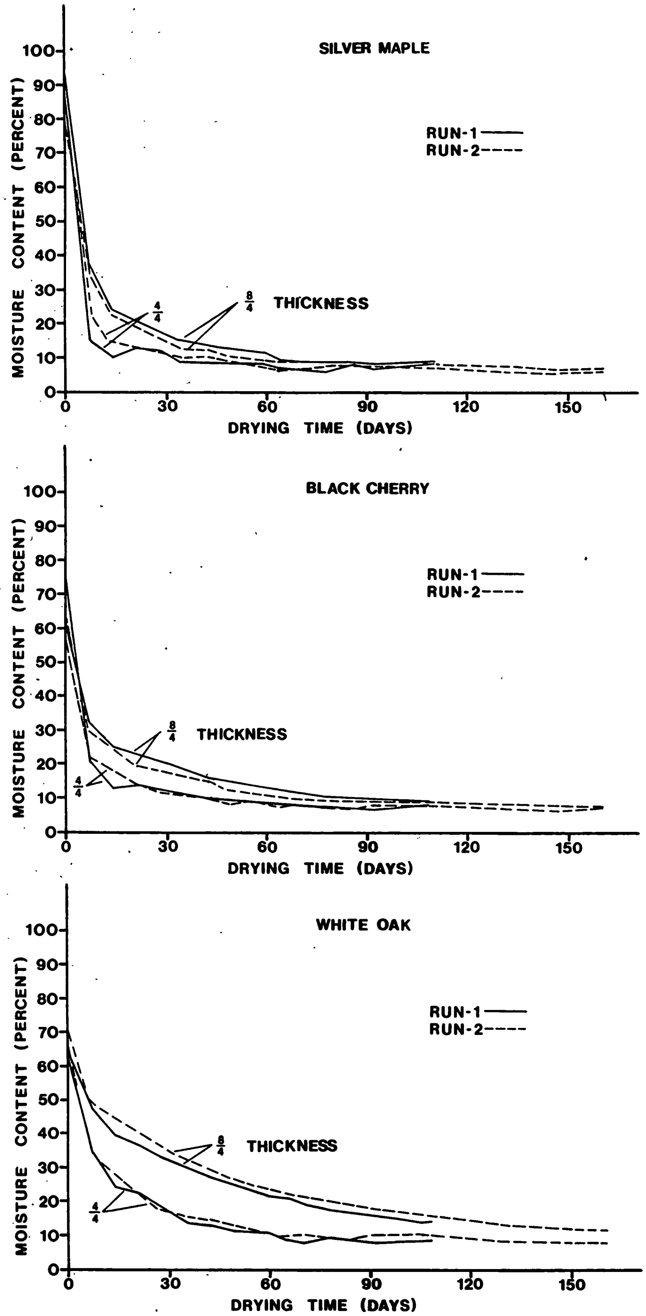

Figure 2.—*Drying curves for three species of 4/4 and 8/4 lumber in a heated room with a fan.*

to less than 10 percent moisture content when moved to a heated room (fig. 5). In this sequence of drying, the disks dried to about the same rate as the boards of the same species and thickness.

Drying Defects—Lumber

Except for a location-species interaction, there were no significant differences in the average ways of the boards between locations but there were significant differences between species and thickness in the levels of warp observed (tables 2 and 3). White oak exhibited the most bow and crook, silver maple develope, the greatest amount of twist, and black cherry and the most cup. Twist was affected also by a location-species interaction and a species-thickess interaction that was associated with the differential response of silver maple. Differences in crook and cup were significant only between species, and the Duncan's Multiple Range Test showed black cherry to have significantly less crook but more cup than the other two species.

End checking and surface checking were not severe in most instances. Surface checking appeared confined mostly to the pith and knots. Both defects occurred whenever the pith was included in the board. When the pith was near the surface, checking usually developed into splits, especially in the 8/4 lumber. White oak accounted for most of the end checking in clear wood. Surface checking in clear wood was slight, showed no consistent pattern with drying location, and was greatest in 8/4 white oak.

Case hardening was evident in all of the lumber tested. White oak, being the most refractory species of the three and having the highest shrinkage, developed the most severe case hardening at all locations. Black cherry developed moderate case hardening and silver maple only slight case hardening. Visual inspection of the qualitative data indicated no differences between thicknesses and drying location.

Volumetric shrinkage showed no significant differences between thickness or drying location, but species showed significant differences by analysis of variance. White oak decreased 10.5 percent in volume upon drying to 8 percent moisture content, but black cherry and silver maple shrunk only 8.7 percent upon drying to 8 percent moisture content. These results agree with the volumetric shrinkage published in Wood Handbook (U.S. Department of Agriculture 1972) for green-to-oven drying of these species.

Drying Defects—Cross-Sectional Disks

It is commonly known that tree-stem cross-sections develop radial splits during drying. They split because the shrinkage in circumference is disproportionately greater in wood than the shrinkage in

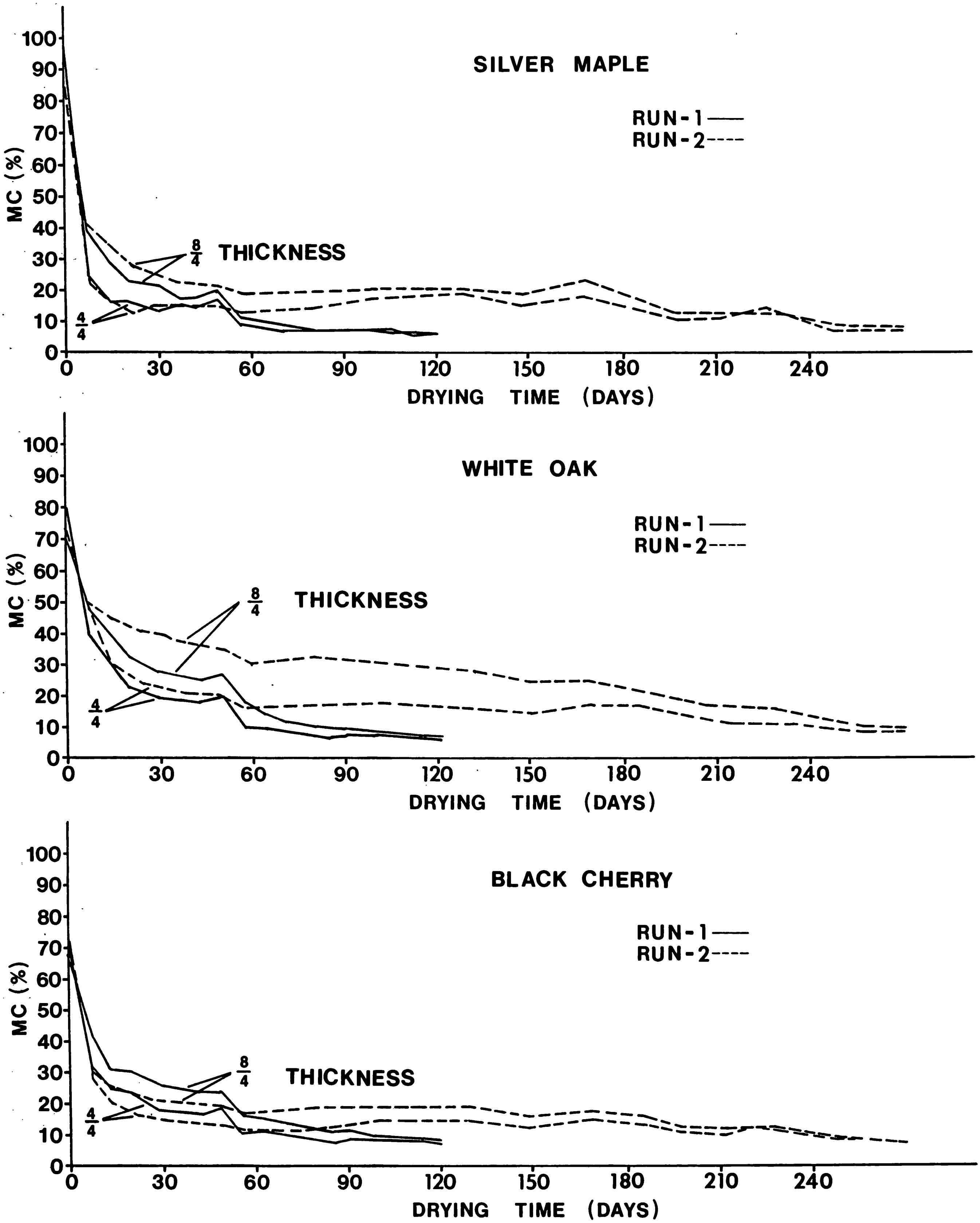

Figure 3.—*Drying curves for three species of 4/4 and 8/4 lumber kept outdoors under a roof.*

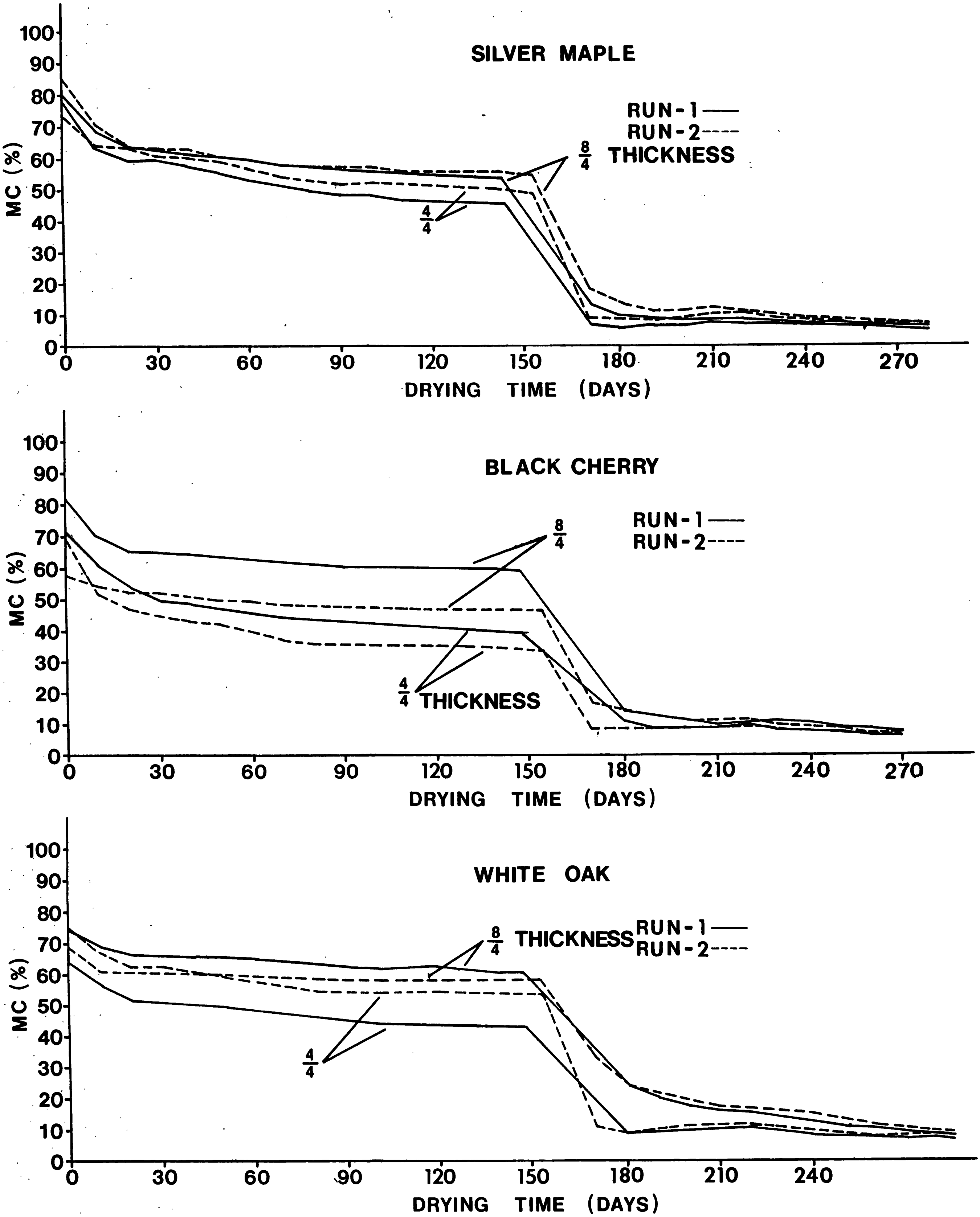

Figure 4.—*Drying curves for three species of 4/4 and 8/4 lumber kept in a freezer.*

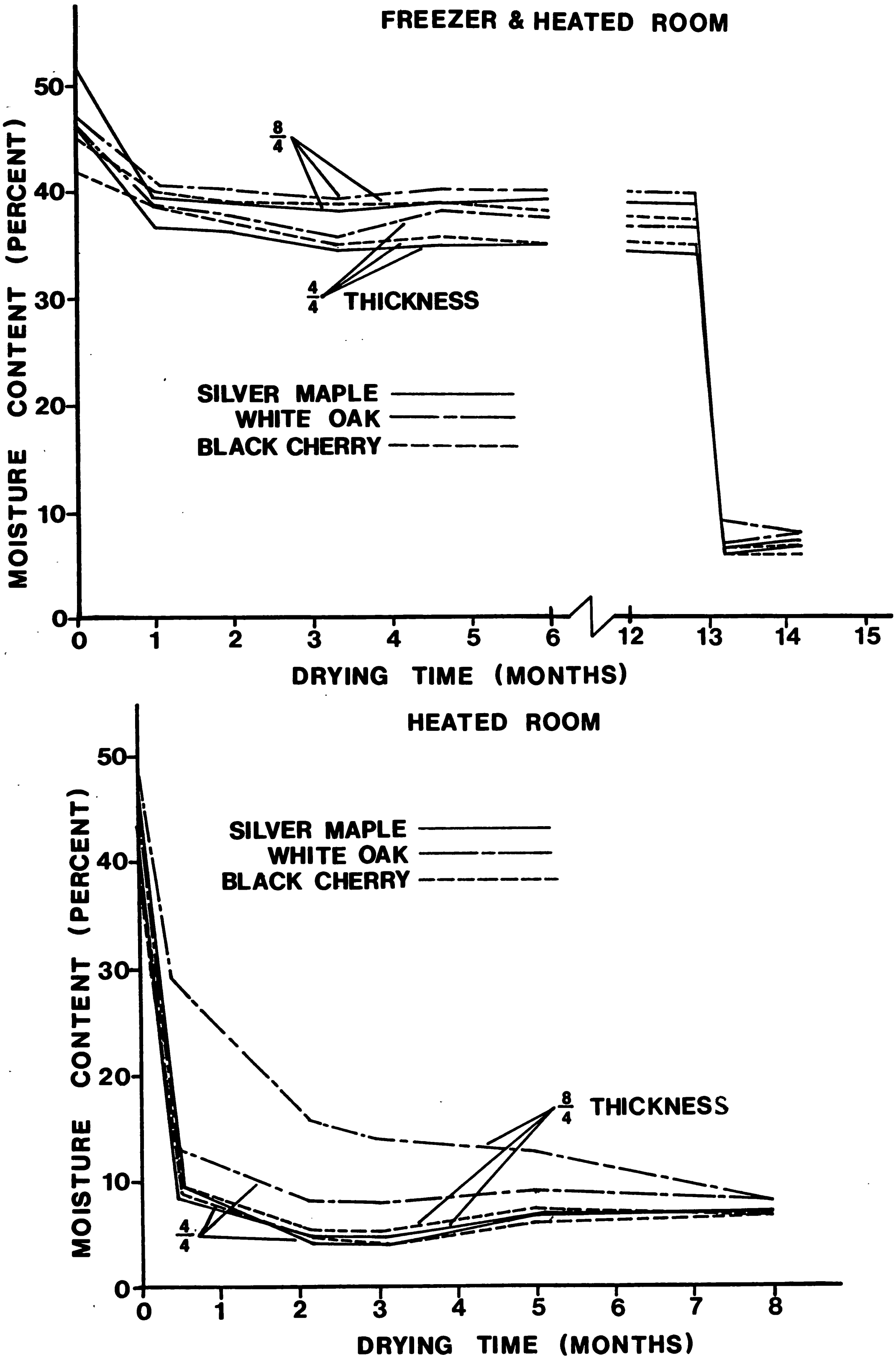

Figure 5.—*Drying curves for three species of 4/4 and 8/4 wooden disks. (A) The disks were kept in a freezer for 13½ months and then moved to a heated room. (B) The disks were kept in a heated room.*

Table 2.—*Warpage of 4/4 and 8/4 white oak, silver maple, and black cherry lumber by drying locations*[1]

Location	Species	4/4 thickness Twist	Bow	Crook	Cup	8/4 thickness Twist	Bow	Crook	Cup
		Inches							
Heated room with fan	White oak	0.24	0.60	0.66	0.20	0.13	0.46	0.56	0.07
	Silver maple	.47	.41	.51	.14	1.06	.54	.50	.12
	Black cherry	.29	.60	.45	.39	.29	.32	.34	.18
Heated room	White oak	.27	.38	.48	.13	.30	.63	.51	.12
	Silver maple	.47	.55	.53	.09	.69	.51	.57	.08
	Black cherry	.49	.43	.60	.23	.45	.39	.37	.18
Unheated shed	White oak	.32	.39	.59	.06	.24	.44	.53	.12
	Silver maple	.53	.34	.62	.13	.99	.41	.51	.11
	Black cherry	.32	.41	.44	.19	.45	.60	.45	.18
Outdoors under roof	White oak	.27	.49	.80	.06	.40	.66	.64	.03
	Silver maple	.53	.23	.49	.16	.93	.27	.49	.08
	Black cherry	.31	.37	.41	.19	.45	.48	.45	.18
Unheated attic with fan	White oak	.19	.78	.49	.10	.29	.58	.54	.08
	Silver maple	.81	.31	.58	.20	1.05	.44	.59	.05
	Black cherry	.37	.51	.46	.15	.29	.52	.47	.17
Freezer	White oak	.32	.57	.75	.04	.31	.64	.52	.18
	Silver maple	.54	.34	.50	.08	.85	.42	.43	.05
	Black cherry	.35	.38	.40	.08	.67	.32	.49	.14

[1]Average of 10 boards (5 boards per replication).

Table 3.—*Statistically significant difference for warp defects*

Analysis of variance: Warp defect	F value	P(F)	Source of variance	Warp defect	Duncan's Multiple Range Test $\alpha = 0.05$	Mean value
					Species	
Twist	146.16	0.0001	[1]S	Twist	White oak	0.27 [2]A
	3.84	0.0155	L*S		Silver maple	.74 B
	8.99	0.0241	T		Black cherry	.39 C
	6.16	0.0144	S*T			
					Thickness	
				Twist	4/4	.39 A
					8/4	.55 B
					Species	
Bow	1.768	0.0003	S	Bow	White oak	.55 A
	3.63	0.0190	L*S		Silver maple	.40 B
					Black cherry	.44 B
Crook	8.80	0.0044	S	Crook	White oak	.59 A
					Silver maple	.53 A
					Black cherry	.44 B
Cup	18.14	0.0002	S	Cup	White oak	.10 A
					Silver maple	.11 A
					Black cherry	.19 B

[1]S is the species, L is location, and T is thickness.
[2]Mean values followed by the same letter are not statistically significant from each other.

radius causing tensile failure perpendicular to the tangential direction. In our study white oak disks showed the smallest splits because these disks contained two piths—which reduces the length of the tangential grain to the radial grain (fig. 6, table 4). No difference was observed in the amount of splitting produced by drying in a heated room compared to drying in a freezer followed by drying to final moisture content in a heated room.

CONCLUSIONS AND RECOMMENDATIONS

The results obtained in this study demonstrate that the woodworker can dry 4/4 and 8/4 thick lumber from the green condition to 10 percent moisture content or less in 3 months. Lumber should be stacked between stickers to provide good air flow between tiers and the stack should be protected from precipitation. Because lumber dries faster at higher temperatures, the stack should be dried in warm air either by outside exposure only during the warm months of the year or by building the stack indoors in heated space during cooler months. An attic with good air flow will permit equally rapid drying if the attic temperatures are equivalent to summer air temperatures or indoor air temperatures in the heating season. Operating a fan in a heated room to accelerate drying produces little benefit.

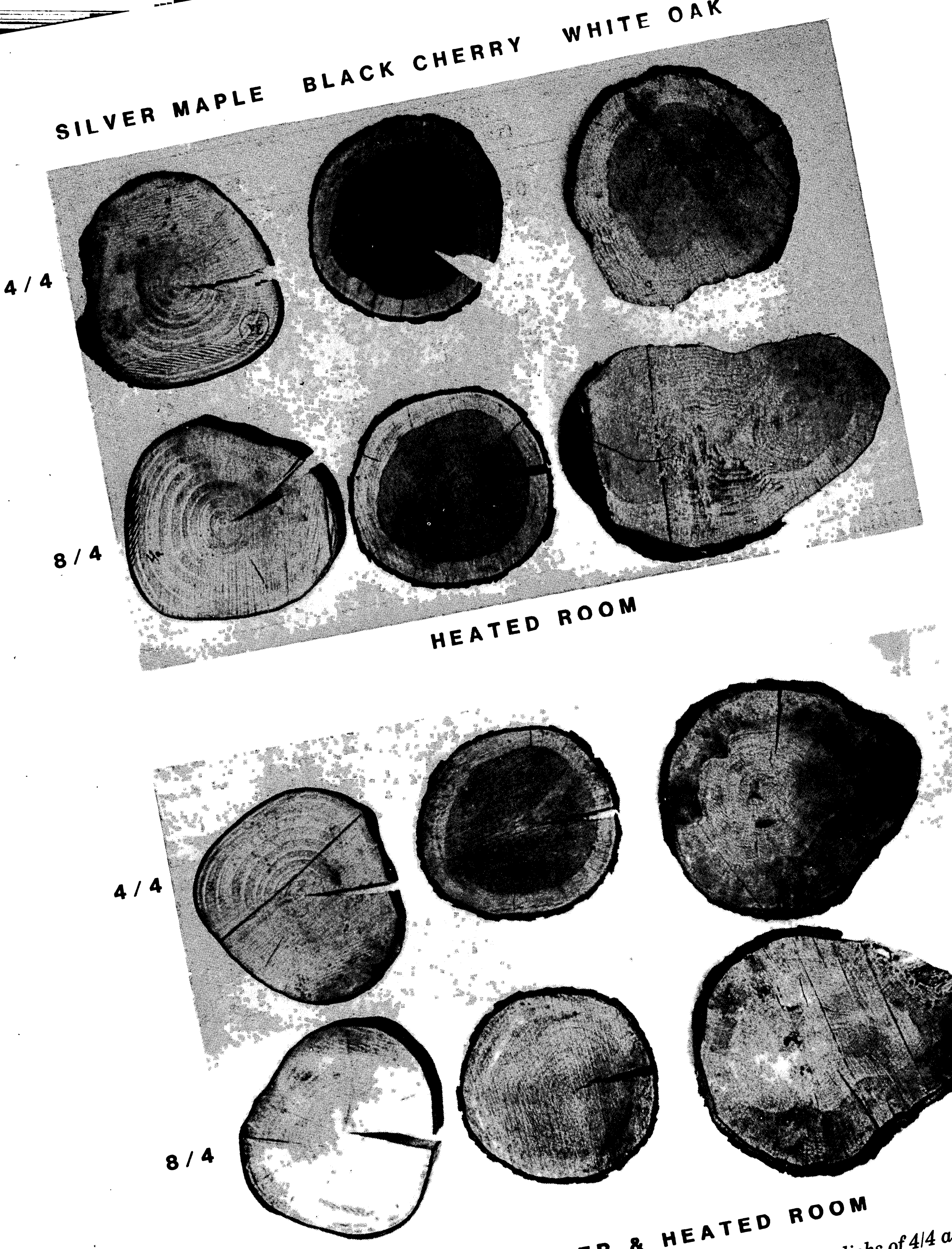

Figure 6.—*Comparison of the splits that developed in cross-sectional disks of 4/4 a*
oak, silver maple, and black cherry kept in a heated room and those kept firs
and then moved to a heated room.

Table 4.—*Comparison of dimensions of splits between the cross-sectional disks kept in a heated room and those kept first in a freezer and then in a heated room.*

Species	4/4 thickness split dimension		8/4 thickness split dimension	
	Radially	Tangentially	Radially	Tangentially
		Inches		
HEATED ROOM EXPOSURE ONLY				
Silver maple	3.4	0.6	3.5	0.6
Black cherry	3.3	.4	2.9	.3
White oak	2.8	.1	2.8	.1
FREEZING FOLLOWED BY HEATED ROOM EXPOSURE				
Silver maple	3.2	.4	3.3	.6
Black cherry	3.2	.3	3.1	.4
White oak	2.4	.1	2.8	.1

Drying is extremely slow in a freezer or at exterior temperatures near the freezing point. The woodworker who desires to dry lumber on a schedule can disregard the time that the material spends in temperatures at or near the freezing point in calculating the time required to dry to a target moisture content. Freezing before drying in a heated room does not reduce defects in the dry lumber.

When stacks are built level with sufficient top weights to keep the boards flat between stickers, drying defects will be slight. Only difficult-to-dry species will develop severe case hardening. For these species the woodworker may find it worthwhile to cut all pieces as close to final dimensions as practical so as to avoid the crook, bow, or cup that results upon resawing to width or thickness. Green lumber should be cut at least 10 percent oversize in width and thickness to allow for remachining and shrinkage during drying.

We were unsuccessful in our attempts to dry the cross-sectional disks without splitting. Splitting developed because the circumferential shrinkage of wood stems is much greater than the diameter shrinkage. Special chemical treatments such as that described by Mitchell (1963) using polyethylene glycol would enable the stem sections to be dried without splitting.

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Freshly sawn boards and stem cross-sectional disks, 4/4 and 8/4 thick, of three hardwood species were dried at six indoor and outdoor household locations in southern Illinois. It took silver maple and black cherry 90 days and white oak from 90 to 150 days to dry to less than 10 percent moisture content at the indoor locations.

KEY WORDS: Lumber, warpage, defects, checking, *Prunus serotina, Acer saccharinum, Quercus alba.*

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