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KILN-DRYING HARDWOOD DIMENSION PARTS.(U)
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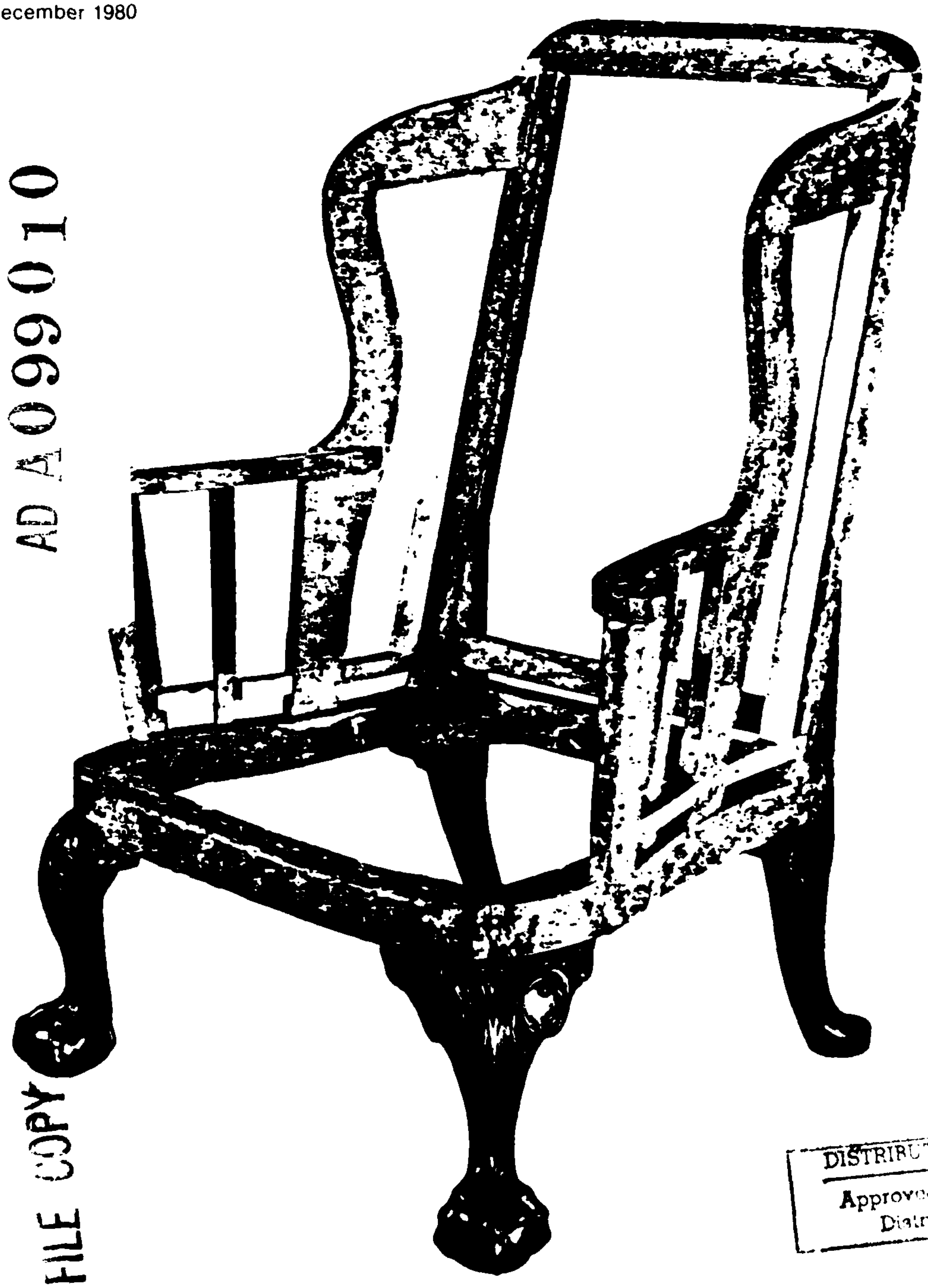

Abstract

Furniture manufacturers are utilizing increasing amounts of low-grade lumber. Low-grade boards contain significant proportions of wood that cannot be used in final products. Hardwood lumber is usually dried as entire boards; thus significant energy and kiln capacity is wasted in drying the unusable portions of these low-grade boards. In this report advantages and disadvantages of drying only usable cuttings are analyzed, and results given of an investigation on the effect of kiln schedule and of end coating on cutting quality. Crook in long cuttings and cup in wide cuttings were found to be significant problems that must be overcome before the energy-saving drying technique could be successful.

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**Forest
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Kiln-Drying Hardwood Dimension Parts[1]

By
WILLIAM T. SIMPSON, Forest Products Technologist
Forest Products Laboratory
[redacted]
JAMES G. SCHROEDER, Principal Wood Scientist
Southeastern Forest Experiment Station

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Introduction

Hardwoods used for furniture, millwork, flooring, and similar piece items are usually dried as entire boards. However, because increasingly greater numbers of small, low-grade logs are being used, much of the lumber processed contains a large percentage of volume not usable in an end product. To dry this wood in entire boards, only to discard the nonusable wood later, is a waste of energy and dry kiln capacity. Although it would be possible to cut out the defective material before drying, some significant obstacles would have to be overcome before this could be feasible.

In this report some of the advantages and disadvantages of drying only usable hardwood cuttings are discussed, and results are given of an investigation to determine effects of kiln schedule and end coating on quality in drying oak for interior frame parts of upholstered furniture.

Advantages and Disadvantages of Drying Cuttings

Advantages of drying only usable cuttings instead of entire boards are the following:

1. Reduced energy consumption.
2. Increased kiln capacity.
3. Potential for reduced transportation costs.

Disadvantages:

1. Greater number of pieces to handle.
2. Increased potential for end checking.
3. Increased warp.
4. Increased wet residue to handle.

The major advantages of drying usable cuttings, reduced drying energy and increased kiln capacity, are summarized for northern red oak in table 1 (*4*).[3] If 100 percent clear 4/4 oak were kiln-dried from 50 to 7 percent moisture content, approximately 4.51 million British thermal units (Btu) per usable 1,000 board feet (Mfbm) would be required, and 1 board foot of kiln capacity would be required for each usable board foot of lumber. No. 2 Common (C) lumber can have significant waste (33 to 50 pct); energy consumption per usable Mfbm averages 7.73 million Btu; and required kiln capacity averages 1.714 board feet of holding capacity per usable board foot. If the unusable parts of No. 2C boards were cut out before drying, an average of $8.05 per Mfbm could be saved in energy costs (assuming a cost of $2.50 per million Btu).

The overall feasibility of drying only usable cuttings will depend on the degree to which the disadvantages

[1] The authors acknowledge the help and cooperation of James Rettenmaier, Plant Manager, Marmont Furniture Company, Marion, N.C., and Walton Smith, Franklin, N.C., in carrying out this investigation.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] Italicized numbers in parentheses refer to Literature Cited at end of paper.

Table 1.—Potential savings in energy and dryer capacity by drying 1-inch northern red oak cuttings instead of entire boards

Grade	Clear surface required	Energy required per usable 1,000 board feet in drying from 50 to 7 percent[1]	Required dryer capacity per usable 1,000 board feet	Savings in energy costs (at $2.50 per million Btu) by drying *only cuttings*
	Pct	Million Btu/ 1,000 fbm	1,000 fbm	Dol/1,000 fbm
All clear	100	4.51	1.000	0
Firsts	91-2/3-100	4.71	1.044	.50
Seconds	83-1/3-91-2/3	5.15	1.142	1.60
Selects	91-2/3-100	4.71	1.044	.50
No. 1C	66-2/3-83-1/3	6.01	1.333	3.75
No. 2C	50-66-2/3	7.73	1.714	8.05
No. 3a	33-1/3-50	10.83	2.401	15.80
No. 3b[2]	25-33-1/3	15.46	3.428	27.38

[1] Simpson and Tschernitz *(4)*.
[2] Requires sound cuttings, not clear.

can be overcome. Most handling equipment is designed for full-size lumber and does not process small pieces efficiently. Furthermore, cutting full-length boards into several shorter pieces generates more ends in which checking can occur. For example, a 5-inch-long end check reduces yield more in a 3-foot-long cutting than in an 8-foot-long board. Warp is another potentially serious problem. If individual pieces are cut close to final dimension before drying, little machining allowance is left to eliminate warp that can occur in drying. Handling additional green residue may or may not be a problem; but if it is burned for fuel, the energy saved by drying only parts is offset by the reduced heating value of the residue.

Table 2.—Processing costs for producing oak dimension parts in dollars per usable 1,000 board foot[1]

Item	Processing costs[2]		
	Dry as parts, *no end* coat	Dry as parts, end coat	Dry as whole boards
Labor	$106.52	$124.00	$105.80
Kiln drying	5.09	5.59	18.79
Machine costs	108.51	108.63	108.41
Utilities	7.12	7.69	19.82
End coat	—	1.60	--
Total	$227.24	$247.51	$252.82

[1] Rice *(3)*.
[2] 1964 costs.

Past Research in Drying Cuttings

Rice *(3)* compared yields and processing costs of hardwood dimension parts manufactured from 4/4 air-dried No. 2C red oak lumber processed in three different ways:

1. Air-dried lumber cut into parts; the parts kiln-dried.
2. Air-dried lumber cut into parts; the parts end coated, then kiln-dried.
3. Kiln-dried lumber cut into dimension parts.

His results showed no significant difference among the three methods in yield of usable parts. Total processing costs per unit of usable volume were also analyzed, and are shown in table 2. Labor costs were higher if the parts were end coated, but otherwise both labor and machine costs were almost the same for all three methods. The cost of handling many small parts (compared with handling whole boards) was apparently offset by the ease of handling small pieces and the fact that only usable parts were stacked. Costs of kiln drying and utilities accounted for much of the difference in costs between the three methods: kiln drying increased from $5 to $19, and utilities increased from $7 to $20 per usable Mfbm if whole boards were dried. The net result was that processing costs were lower if parts were cut before drying.

Ward *(6)* investigated kiln-drying beech dimension stock. He found significant losses caused by warp, with twist and bow being the most common form. End checking was controlled by end sealing.

Delaney *(1)* reported commercial success in drying beech dimension ranging from 6/4 to 10/4 squares, to 4/4 to 6/4 flats from 3 to 6-1/2 inches wide. The dimension was air-dried before kiln drying; although the overall operation was considered successful, surface and end checking during air drying can result in losses as high as 10 percent.

Experimental Procedure

The main objectives of this investigation were to determine if furniture cuttings could be dried successfully and if kiln schedule and end coating could have a significant effect on end and surface checking, honeycomb, and warp. The work was conducted in cooperation with the Marimont Furniture Company, Marion, N.C. The Company supplied the experimental material and carried out

Table 3.—Dimensions of interior parts of sofa

Part	Length	Width
	In.	In.
Back post block	14	1-1/8
Back upright	14-7/16	1-1/8
Back support	16-1/2	2
Stump	21	3-1/2
Back support brace	22-1/2	1-1/8
Bottom side rail	26-7/16	3-1/8
Center side rail	28-7/16	2
Arm RSF	29-1/2	2-3/4
Arm LSF	29-1/2	2-3/4
Back post RSF	31	5-1/4
Back post LSF	31	5-1/4
Bottom front rail	80	3-1/8
Center back rail	80	2
Bottom back rail	82-3/16	3-1/8
Top back rail	82-3/16	2-3/4

the final inspection of the cuttings for quality. Marimont manufactures upholstered furniture; the material dried in this investigation was from material used for the frames of one of their standard sofas. They utilize 5/4-inch mixed hardwood lumber from small-diameter, 7-foot-long bolts sawed on a bolter mill *(5)*.

Approximately 4,400 board feet of 5/4-inch mixed hardwood lumber was sawed on a bolter saw, and the green lumber shipped to the Forest Products Laboratory for study. Sofa parts were made from the lumber using a cutting bill; quality specifications were furnished by the Company. The dimensions of the parts are shown in table 3. Lengths range from 14 to 82 inches and dry widths from 1-1/8 to 5-1/4 inches; 6 typical parts are shown in figure 1. The cuttings were divided into 6 groups; each group contained all of the cuttings for about 25 sofas—about 375 board feet per group. The six groups were kiln-dried from the green condition by three schedules: two groups were kiln-dried by a mild schedule; two groups, by a conventional; and two groups, by an accelerated schedule. Cuttings of one of each of the two groups were end coated; the others were not.

The kiln schedules are shown in table 4. The mild schedule was accomplished with a 3-horsepower dehumidifier dryer in a 1,500-board-foot experimental dry kiln (fig. 2). Initial dry bulb was 90° F with a 4° F depression; final temperature was 115° F with a 30° F depression. Stress relief was accomplished with conventional steam coils in the kiln. The conventional schedule was the 5/4 oak schedule recommended in the

Table 4.—Experimental kiln schedules for furniture cuttings of 5/4 oak

Schedule	Moisture content	Dry bulb	Wet bulb	Relative humidity
	Pct	°F	°F	Pct
Mild (dehumidifier)	Above 50	90	86	85
	50-40	95	89	80
	40-30	100	91	70
	30-20	105	88	50
	20- 7	115	85	20
Conventional (T4-D2)	Above 50	110	106	87
	50-40	110	105	84
	40-35	110	102	75
	35-30	110	96	60
	30-25	120	90	31
	25-20	130	80	10
	20-15	140	90	14
	15- 7	180	130	26
Accelerated	Above 55	115	111	88
	55-50	117	112	85
	50-45	119	113	82
	45-40	122	114	77
	40-35	127	115	68
	35-30	132	112	52
	30-25	136	98	25
	25-20	140	90	14
	20- 7	230	—	—

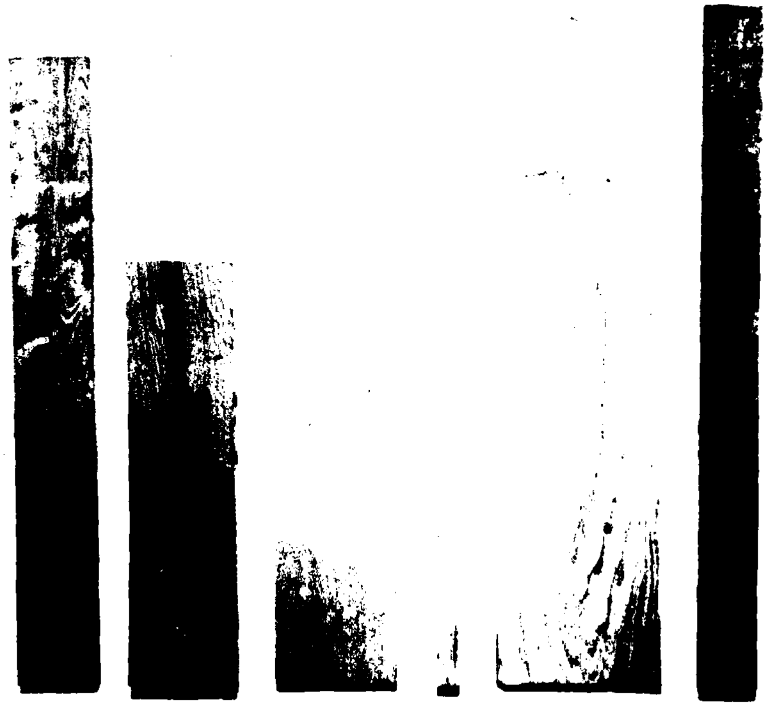

Figure 1.—Six typical interior wood parts for sofa; lengths shown range from 20 to 31 inches; widths from 1-1/8 to 5-1/4 inches.

(M 147 450-2A)

Dry Kiln Operator's Manual *(2)*; drying was also done in a 1,500-board-foot experimental kiln. The accelerated schedule starts at 115° F; subsequent temperature increases are at moisture contents higher than those called for in the conventional schedule, and the final temperature (below 20 pct moisture content) is 230° F. A 1,000-board-foot high temperature kiln was used for this run.

The cuttings were stacked for kiln drying so that all sizes were represented in each kiln run (fig. 3). An asphalt-base end coating was then applied. Air velocities for the 3 kiln schedules were 450 feet per minute for the mild and conventional schedules and 800 feet per minute for the accelerated schedule. Kiln samples were prepared to represent the range of cutting sizes; eight samples were included in each kiln run.

Results and Discussion

Drying Time

Because of the wide variety of sizes in each kiln run, drying rates were compared for the largest and the smallest samples in each charge (3-1/4 by 82-3/16 in. and 1-1/4 by 14 in., respectively). The resulting drying curves for the six combinations of kiln schedule and end treatment are shown in figures 4 to 6. Moisture content has been reduced to a fractional basis to make comparisons easier than if all of the different initial moisture contents were considered. The basis is defined as

$$E = \frac{M - M_f}{M_i - M_f}$$

where

E = fraction of drying unaccomplished

M = moisture content

M_i = initial moisture content

M_f = final moisture content

With the mild (dehumidifier) schedule (fig. 4*A*,*B*) the difference in drying rate between the two sizes is not very large. Total drying time from green to nominal 7 percent was 39 days. The average final moisture content was 7.3 percent with a difference of

Figure 2.—Dehumidifier dryer in experimental dry kiln.

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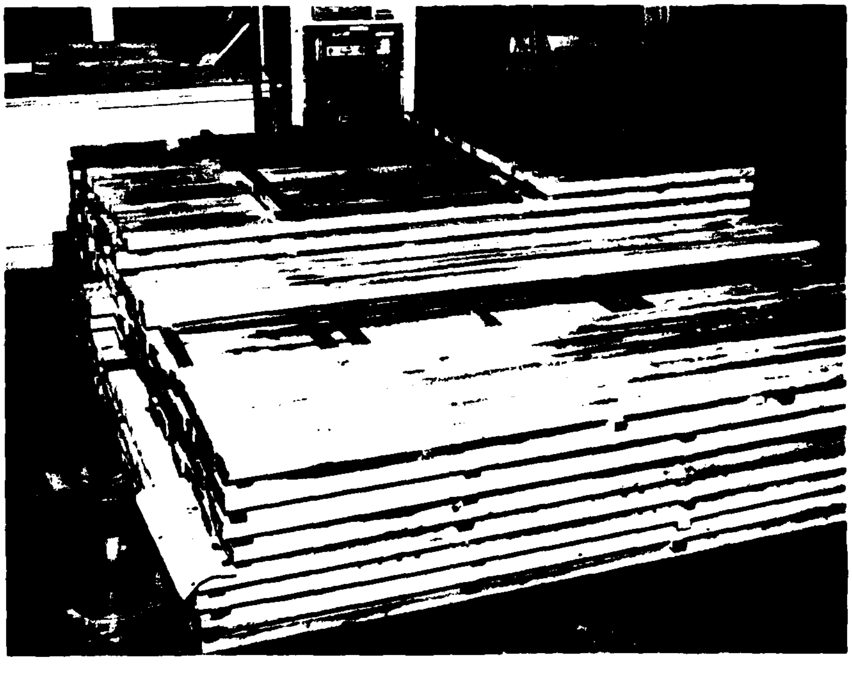

Figure 3.—Furniture cuttings stacked for drying.

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Kiln-drying hardwood dimension parts, by William T. Simpson and James G. Schroeder, Madison, Wis., FPL.

9p. (USDA For. Serv. Res. Pap. FPL 388).

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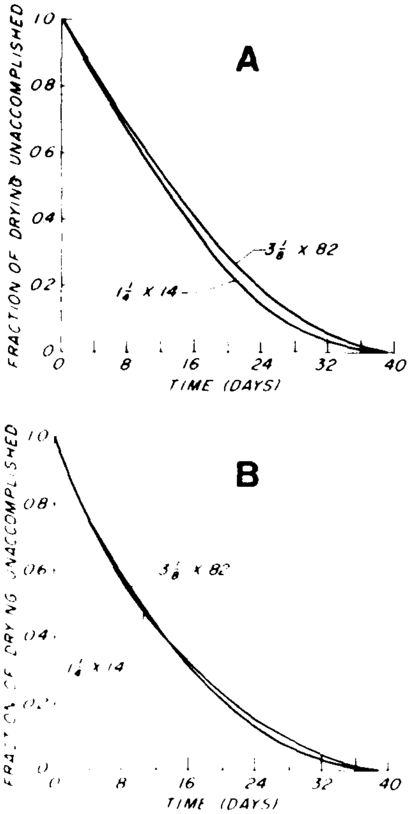

Figure 4.—Drying curves for two cutting sizes—mild kiln schedule: A, end coating; B, no end coating.

(M 148 986, M 148 987)

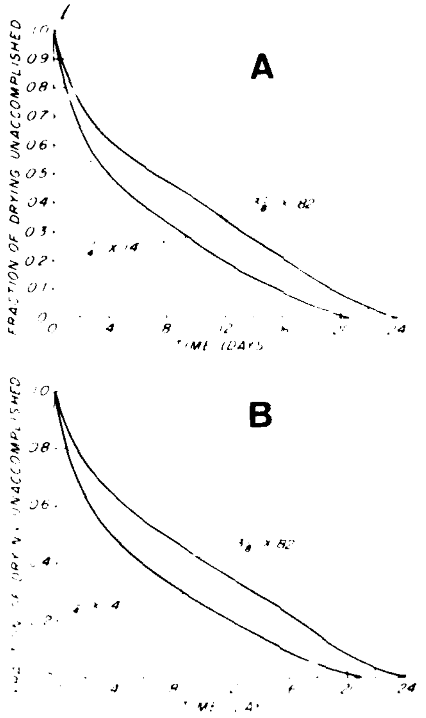

Figure 5.—Drying curves for two cutting sizes—conventional kiln schedule: A, end coating; B, no end coating.

(M 148 988, M 148 991)

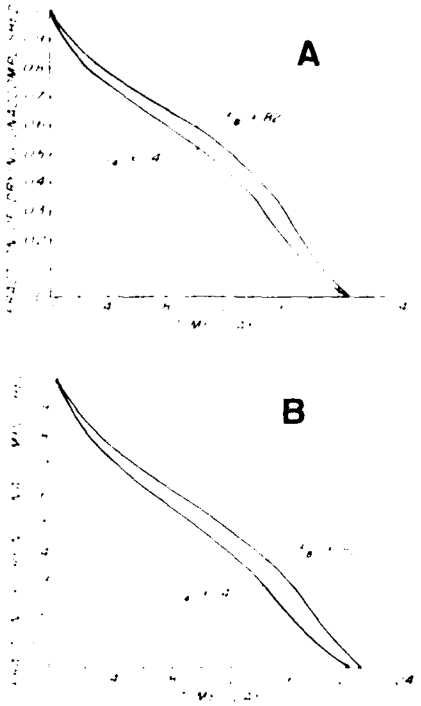

Figure 6.—Drying curves for two cutting sizes—accelerated kiln schedule: A, end coating; B, no end coating.

(M 148 989, M 148 990)

4.6 percent between the driest and the wettest sample board. This spread in final moisture content was accomplished with no formal equalization period. Apparently these slow drying schedules inherently accomplish equalization.

The disparity in drying times between the small and the large cutting is more pronounced in the conventional schedule (fig. 5*A,B*). The smaller cutting reached final moisture content in 21 days, but the larger cutting required 24 days. Because schedules were controlled on the slowest drying sample boards, the entire load actually required 24 days to dry. After equalization the average final moisture content was 6 percent, with a spread of 4.2 percent between the wettest and the driest samples.

The accelerated schedule also showed some difference in drying rate between the large and the small sample boards (fig. 6*A,B*). However, the time to the final moisture content did not differ greatly. After slightly more than 21 days, including equalization, average final moisture content was 7.2 percent with a 6.4 percent moisture content difference between the wettest and the driest sample.

Quality Assessment—Laboratory Evaluation

The quality of the dried cuttings was evaluated for number of end checks, longest end check, bow, twist, cup, and crook. Each of the defects was analyzed by a 3 by 2 factorial analysis of variance to determine if kiln schedule or end treatment affected quality. From each of the

6 combinations of these factors, 10 pieces of each of the 13 cutting sizes were selected at random for measurement of end checking or warp. The average value of these defects is listed in table 5. End checking was not severe, with a range of 0.15 to 0.25 end checks per end (about one piece in five pieces with any end checks). From average values in table 6, end coating appears effective in reducing the number of end checks; however, the difference is not statistically significant.

Table 5.—Average drying defects in furniture cuttings kiln-dried by mild, conventional, and accelerated schedules

End *coating*	Number of end checks per end	Length of longest end check	Bow	Twist	Cup	Crook
		In.	In./ft of length	In./ft of length	In./in. of width	In./ft of length
			MILD			
With	0.177	2.53	0.114	0.0219	0.00756	0.151
Without	.252	2.45	.161	.0226	.00804	.119
			CONVENTIONAL			
With	.169	1.95	.083	.0187	.02123	.143
Without	.219	1.34	.087	.0143	.00943	.113
			ACCELERATED			
With	.150	1.62	.073	.0112	.00622	.099
Without	.215	1.88	.072	.0182	.01079	.115

Of all of the other defects, crook was the most apparent and the most severe. Average values ranged from 0.10 to 0.15 inch per foot of length. For short pieces this is not excessively large, but on the 80-inch-long cuttings this amounts to 1/2 to 1 inch of crook. Bow and twist were less severe; because compensation for them in use can be made more easily than for crook, they may be insignificant.

The results of the analysis of variance showed kiln schedule affected bow, but neither kiln schedule nor end treatment had a significant effect on number of checks, length of longest end check, or amount of twist, cup, or crook. There is no apparent reason why kiln schedule should have an effect on the amount of bow but no effect on the other forms of warp.

Quality Assessment—Plant Evaluation

The ultimate measure of quality of the dried cuttings is their suitability for the final product—interior frame parts of upholstered furniture. All of the dried parts were shipped back to Marimont and evaluated for acceptability by plant personnel. Mill rejection was evaluated by a 3 by 2 factorial design to determine if kiln schedule or end treatment had a significant effect. The results of the analysis showed no significant difference in rejection rate.

Although kiln schedule and end treatment had no effect on rejection rate, cutting size did (table 6). The rejection rate of the 80- to 82-inch cuttings was far greater than for the other cuttings; the average was between 35 to 45 percent, and was almost exclusively caused by crook. Also, the widest cutting (5-1/4 in.) showed a rejection rate of 25.9 percent, primarily because of cup. An additional factor in the mill rejection rate is that certain of the long cuttings must be straight or almost straight. The quality of the 5-1/4-inch-wide cutting was also critical, and little deviation from the warp-free condition could be tolerated.

Despite some end checks, no cuttings were rejected at the mill because of them. The small end-trim allowance included in the rough dimension can absorb some end checking. Some cuttings were rejected for end splits associated with pith or shake, but most of these were the type present before drying.

Table 6.—Relation of cutting size to mill rejection rate

Cutting size		Rejection rate
In.	In.	Pct
14	1-1/4	3.9
14-7/16	1-1/8	3.2
16-1/2	2	.7
21	3-1/2	2.6
22-1/2	1-1/8	2.9
26-7/16	3-1/8	1.8
28-7/16	2	9.5
29-1/2	2-3/4	7.9
31	5-1/4	25.9
80	2	40.0
80	3-1/8	34.2
82-3/16	2-3/4	45.7
82-3/16	3-1/4	39.0

Summary and Conclusions

The level of mill rejects of furniture cuttings dried in this investigation is obviously too high to be tolerable. Crook in the long cuttings and cup in the wide cuttings were the major reasons for rejection. Other shorter and narrower cuttings had a much lower rejection rate—one that probably could be tolerated. Although some end checking occurred, and there was some evidence that end coating would reduce this occurrence, end checking caused no rejections. Other drying defects, such as honeycomb or surface checking, were practically nonexistent regardless of kiln schedule. Because kiln schedule did not significantly affect quality, the use of accelerated drying schedules for drying interior frame parts apparently is feasible. Regardless of the kiln schedule used, successful commercial drying of long or wide cuttings, or of both, from lumber cut from small, low-grade bolts will require special measures to control warp. This may also be true for similar cuttings from standard No. 2 Common lumber. The authors plan further investigations to evaluate effects of load restraints or of variations in stacking, or of both, as solutions to this problem of warp.

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