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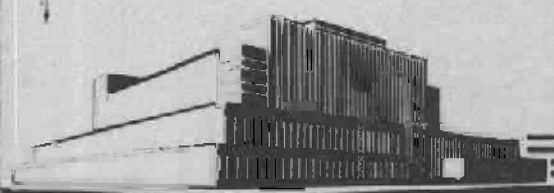

FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

OCCURRENCE OF TENSION WOOD AND RELATED SEASONING DEFECTS IN CALIFORNIA BLACK OAK[1]

By

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Much information has been published [3, 4] on the anatomical characteristics of tension wood and its association with excessive longitudinal shrinkage. Until after this work was begun, however, there had been no reliable information on how readily tension wood could be visually identified in rough lumber, nor had there been any quantitative data on the relation of occurrence of tension wood to log grades and sawing methods. In addition, there was no information on the frequency of seasoning defects associated with tension wood after the kiln drying of hardwood lumber. This kind of information has general application to tree and log characteristics that affect overall wood quality for good utilization of hardwood lumber.

Characteristics of Tension Wood

Tension wood is a peculiar type of wood structure occurring in many hardwood species. Its outstanding characteristic is excessive longitudinal shrinkage that contributes to bowing, crooking, and twisting of hardwood lumber during seasoning.

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[1] In cooperation with the Diamond Match Company, Chico, Calif.

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

[3] Terrell, Bessie Z. Distribution of Tension Wood and Its Relation to Longitudinal Shrinkage in Aspen. Forest Products Laboratory Report No. R1917. 1952.

[4] Wahlgren, H. E. Effect of Tension Wood in a Leaning Eastern Cottonwood. Forest Products Journal 7(6):214-219, June 1957.

When such warping is seen in hardwood lumber, the presence of tension wood is frequently suspected, since that part of a board with tension wood shrinks more along the grain than that part containing typical wood. The amount of warping varies principally with the proportional amounts and the positions of the tension wood in relation to the typical or normal wood structure. Moreover, pieces ripped from essentially flat and straight boards sometimes are seriously warped, because the balance of internal stresses is upset in the original board. Many investigations of tension wood at the Forest Products Laboratory and elsewhere have shown these characteristics to interfere with the satisfactory use of cut stock from hardwood lumber.[5]

Tension wood usually can be visually identified by the presence of projecting or torn fibers generally found in restricted areas on surfaces and edges of most rough hardwood lumber. These areas often have a distinctive silvery sheen or glaucous appearance that also aids in the visual diagnosis of whether tension wood is present in particular boards.

Scope and Plan of Present Research

The extent to which tension wood was visually identified in rough lumber, both green and kiln dried, and its occurrence in relation to log grades were investigated. A grade recovery investigation on California black oak (Quercus kelloggii Newb.), made by Laboratory personnel in cooperation with the Diamond Match Company, Chico, Calif., afforded an excellent opportunity to obtain this information.

The present work was limited to obtaining information on the tension wood in California black oak with respect to (1) frequency of occurrence based on visible characteristics of freshly sawed lumber, and (2) the effects in causing seasoning defects and degrade in kiln-dried lumber. This project was also carried out to supply information on whether tension wood is satisfactorily identified in freshly sawed lumber.

The identification of tension wood boards in the completely described logs can be expected to give subsequent information on the visible characteristics of California black oak logs from which to estimate the potential occurrence of tension wood in factory lumber.

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[5] Pillow, Maxon Y. Effects of Tension Wood in Hardwood Lumber and Veneer. Forest Products Laboratory Report No. R1943. April 1953.

Procedure

The logs were diagramed and graded for the overall project according to the Forest Products Laboratory Hardwood Factory Log Grades. A fourth grouping of logs, grade No. 4, also was set up to include all logs of a quality below the minimum specifications for Forest Products Laboratory Log Grade No. 3.

Three methods of sawing were used: No. 1, the sawyer's choice method; No. 2, centering of the defects on the sawing face; and No. 3, cornering of the defects. The logs were assigned to the sawing methods at random within the log grades and 1-inch diameter classes.

The data on the occurrence of tension wood in the green lumber in relation to log grades were based on whether its typical surface characteristics were identified by visual examination. The identifying characteristics were a distinctive sheen and the presence of projecting fibers (fuzziness) on edges and surfaces. In addition, obvious bow, crook, or twist in a board was also considered as an identifying characteristic of tension wood. The tension wood lumber was separately tallied according to the log and board numbers of the overall project, so as to use its scale and grade data. All the green lumber was examined after edging and trimming. The tension wood boards were sprayed with paint to facilitate their identification after the final kiln drying.

The data on scale and grade of tension wood lumber were analyzed as percentages of board-foot yields for the respective classes of log grades and sawing methods. This provided the subsequent information on frequencies and distribution of tension wood lumber.

Another examination of finally kiln-dried rough lumber[6] was made to determine the effects of tension wood in causing its typical seasoning defects, such as end splits, bow, crook, and twist. The data tallied for this part of the work included log numbers, whether tension wood was identified in green lumber, kinds of seasoning defects, and any changes in grade after kiln drying.

Occurrence by Log and Lumber Grades

The 589 logs used in this project had an original green lumber scale of 58,558 board-feet, of which 22.6 percent (13,237 board-feet) contained tension wood.

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[6] This part of the investigation was made on a random sample of the total amount of green lumber that was kiln dried and moisture conditioned under the supervision of the California Forest and Range Experiment Station.

Although the number of logs and volume of lumber varied for each log grade, the percentage of tension wood increased successively in log grades No. 1 through 4 (table 1). This trend indicates that certain characteristics responsible for the log grades must be associated in some way with concentrations of tension wood in certain parts of the logs.

It was questioned whether the sawing methods of centering as compared to cornering defects on the sawing faces would affect the amounts of tension wood lumber. One might hypothesize that if the positions of defects are correlated with concentrations of tension wood, centering the defects might minimize the number of boards in which tension wood occurred.

The data on the occurrence of tension wood lumber segregated according to sawing methods showed smaller percentages of lumber scale when sawed with the defects centered (18.6 percent) than when the defects were cornered (23.4 percent) or when the sawyer's choice method was used (25.8 percent). The methods of sawyer's choice and of cornering defects were considered to be quite similar and resulted in similar percentage yields of tension wood (table 2).

When the amount of tension wood lumber was expressed as a percentage of the total scale within each sawing method, the amounts increased successively in log grades Nos. 1, 2, and 3, but decreased in grade No. 4 (fig. 1). When the tension wood lumber was expressed as a percentage of the scale within each log grade, however, a more realistic trend was present. That is, the occurrence of tension wood increased successively in log grades No. 1 through 4 for the sawyer's-choice and centered-defect methods, but when using the cornered-defect method, there was no correlation between log grades and the yields of tension wood (figs. 2, 3, and 4).

Some trends in yields of tension wood lumber were shown by the analyses of the data according to lumber grades for each log grade within a sawing method. For example, in log grades Nos. 1 and 2 relatively large yields of the tension wood lumber were found in either or both the No. 1 and No. 2 Common grades. With log grades Nos. 3 and 4, moreover, the tension wood occurrence was usually greatest in No. 3B Common lumber but also occurred in appreciable amounts in the other Common lumber grades (figs. 2, 3, and 4).

In summary, this phase of the work showed that the occurrence of tension wood was related to the Forest Products Laboratory Hardwood Log Grades and that, sawing methods have an effect on the number of boards containing tension wood.

Variation in Longitudinal Shrinkage

Eighteen boards of random widths and lengths were shipped to the Laboratory for additional investigation. Fourteen boards were selected because they included visually identified tension wood, while four were typical or normal boards. After all the boards were kiln dried and graded for the overall project, longitudinal shrinkage samples were cut across the full width of each board.

The total longitudinal shrinkage of the tension wood boards ranges from 0.105 to 0.747 percent, as estimated over the range from the saturated to the oven-dry condition. The range of the samples from the four typical boards was from 0.042 to 0.346 percent. These data were in general accord with the usual ranges of shrinkage found in other hardwoods.

Evaluation of Kiln-Dried Lumber

An evaluation was made of the presence and the effect of tension wood after final kiln drying. It was made on a dried sample typical of the total supply of green lumber after it had been kiln dried. The lumber consisted of 26 fork-lift units and was located at Chico, Calif. This evaluation had two purposes. First to record the seasoning defects, such as bow, crook, twist, and end splits, usually related to tension wood and the respective amounts of lumber involved. Second, to determine whether the tension wood was readily detected by visual characteristics in rough, dry lumber so as to assess the adequacy and completeness of the identification of tension wood in the green lumber. The boards were regraded so that any degrading effect of tension wood on the dry lumber grade was determined. Of the 26 units, 12 units were shed dried, while another 14 units were air dried before final kiln drying. All of the 26 units were given a final moisture conditioning treatment after kiln drying.

The same surface characteristics that were used to identify tension wood in the green lumber were also observed in the examinations of the dry lumber, that is, the silvery sheen, projecting fibers and obvious bow, crook, or twist. The 26 units had a total lumber scale of 22,749 board-feet of which 6,135 board-feet were recorded as containing tension wood. The 5,375 board-feet of lumber that was diagnosed in the green condition as containing tension wood still showed its surface characteristics after drying (table 3). An additional 760 board-feet of lumber with tension wood was found in the 26 units after drying, although not identified in the green lumber.

Exclusive of that 760 board-feet of lumber, this sample of 26 units had nearly the same percentage of lumber containing tension wood (23.6 percent) as that originally identified in the green condition (22.6 percent) for the total amount of lumber (see tables 1 and 3).

The typical seasoning defects were seen in approximately 64 percent, 3,929 board-feet, of the 6,135 board-feet of kiln-dried lumber with tension wood. Analysis of these data on seasoning defects within lumber grades shows a fairly narrow range from 57.7 to 68.6 percent with no apparent trends among the grades (table 4). Some seasoning defects, such as localized bow and crook, were found in boards that did not contain tension wood but were associated with grain deviations.

Of the 64 percent of tension wood lumber with seasoning defects, crook accounted for 48 percent with end splits and bow accounting for 11 and 6 percent, respectively (table 5). Because a few boards had both end splits and crook, the percentages listed in table 5 total 101.5 percent.

The relatively small occurrence of bow in this dry lumber suggests that piling with adequate stickering tended to minimize this type of seasoning defect. Apparently crook in the boards is more difficult to control as evidenced by the greater occurrence of crook than of bow in this sample.

In spite of the percentage of seasoning defects found in this research, only two boards were reduced in grade because of seasoning defects associated with tension wood. This amount of degrade probably results from both the tolerance limits of warp permitted in hardwood grades of factory lumber and the size of the board in question. That is, a board 18 inches by 12 feet with a green grade of FAS and that has developed a 2-inch crook after kiln drying would not be reduced in dry grade because of the crook. However, another board 8 inches by 8 feet with a 2-inch crook and graded FAS would likely be reduced to No. 1 or No. 2 Common grade. Both the grade and the size of the board determine the tolerance limits permitted for seasoning defects.

Summary of Results and Conclusions

This study showed that the 589 logs had an original green scale of 58,558 board-feet, of which 22.6 percent contained tension wood. Examination of the data resulted in the following conclusions:

The occurrence of tension wood is related in a broad way to the Forest Products Laboratory Hardwood Log Grades. This relationship indicates that certain characteristics responsible for the log grades must be associated in some way with concentrations of tension wood in certain parts of the logs.

Of the three sawing methods used, the one in which the defects were centered in the sawing faces yielded less lumber containing tension wood than did the two methods in which the defects were positioned at the edges of the sawing faces.

The longitudinal shrinkage of samples taken across the full width of selected tension wood boards ranged from 0.105 to 0.747 percent, while that of the samples from boards without tension wood was 0.042 to 0.346 percent. This is in general accord with ranges of this property commonly found in other hardwoods and accounts for much of the warping observed in the kiln-dried lumber.

Visual inspection of 22,749 board-feet of lumber after kiln drying indicated that boards in the green condition diagnosed as containing tension wood still showed the same surface characteristics after drying; namely, silvery sheen and projecting fibers. The inspection of the lumber after kiln drying also showed that 64 percent of the lumber with tension wood had seasoning defects, principally crook. Only two boards were reduced in grade because of the seasoning defects associated with tension wood. The small amount of degrade is apparently associated with both the tolerance limits of warp permitted in hardwood grades of factory lumber and the size of the board in question.

Recommended Investigations

From the results of investigating California black oak, an analysis was made of the need for further information on the characteristics of tension wood that affect lumber quality. For example, these data showed that tension wood was present in nearly one-quarter of the lumber. More than one-half of this tension wood lumber had seasoning defects that might decrease its usefulness, even though the factory lumber grades were not reduced. Since the tension wood was identified by visual examination, it logically can be regarded and treated as other defects that control lumber quality. But the important information presently lacking is how much does tension wood affect the yields of satisfactory cut stock from factory lumber, and will tension wood cause subsequent warping of the finished pieces.

Processing studies are therefore recommended to obtain quantitative data on the affects of tension wood on the yields and quality of cut stock from factory lumber. To get this information, selection should be made of lumber with and without tension wood that had been kiln dried and thoroughly moisture conditioned. An appraisal will be made of the amount and location of tension wood within the lumber, as well as the type and amount of seasoning defects present. The shape and dimensions of the cut stock will be taken into account, since

relatively long and narrow pieces tend to warp more than short and wide pieces. Analysis of such information will determine the susceptability of warping in cut stock from boards containing visible tension wood.

Another inquiry is needed on the apparent relation of log grading criteria to occurrence of tension wood, since the lumber with tension wood was more often in the low log grades than in the high grades. Variations in the occurrence of tension wood in lumber should be compared with the log diagrams that were used in the grade-recovery project to determine the criteria responsible for the particular grades of the logs. With this kind of information, it would be possible to recognize the presence of tension wood in the log form. If such recognition were possible, the most practical sawing method could be chosen to minimize the production of lumber containing tension wood.

Searches such as these, which help to evaluate the occurrence and affect of tension wood, are necessary if we are to attain good utilization of hardwood lumber.

Table 1.--Total lumber yield and amount of tension wood for each log grade

Log grade	Logs	Total scale	Tension wood scale	Tension wood
	No.	Bd.-ft.	Bd.-ft.	Percent
1	30	6,985	1,318	18.9
2	134	19,084	3,814	20.0
3	244	21,582	5,153	23.9
4	181	10,907	2,952	27.1
Total	589	58,558	13,237	22.6

Table 2.--Total lumber yield and amount of tension wood for each sawing method

Sawing method	Logs	Total lumber scale	Total tension wood	Tension wood
	No.	Bd.-ft.	Bd.-ft.	Percent
Sawyer's choice (No. 1)	194	18,703	4,824	25.8
Centering defects (No. 2)	195	19,005	3,532	18.6
Cornering defects (No. 3)	200	20,850	4,881	23.4

Table 3.--Scale and percentage within grades of the lumber in 26 units that had tension wood. Estimation was by visual examination both when the lumber had been green and after it had been kiln dried

Type of tally	Lumber grades												All grades	
	FAS		Select		No. 1 Common		No. 2 Common		No. 3A Common		No. 3B Common			
	Bd.-ft.	Percent	Bd.-ft.	Percent	Bd.-ft.	Percent	Bd.-ft.	Percent	Bd.-ft.	Percent	Bd.-ft.	Percent	Bd.-ft.	Percent
Tally when green	240	20.9	149	45.2	1,309	22.4	1,357	20.6	1,092	27.1	1,228	25.5	5,375	23.6
Additional tally after kiln drying	41	3.6	7	2.1	160	2.7	189	2.9	200	5.0	163	3.4	760	3.4
Tally of total tension wood	281	24.5	156	47.3	1,469	25.1	1,546	23.5	1,292	32.1	1,391	28.9	6,135	27.0
Total scale	1,147		330		5,855		6,581		4,027		4,809		22,749	

Table 4.--Tension wood lumber with seasoning defects (splits, bow, crook, and twist)

Type of tally	Defects present in lumber by grade												All grades	
	FAS		Select		No. 1 Common		No. 2 Common		No. 3A Common		No. 3B Common			
	Bd.-ft.	Percent	Bd.-ft.	Percent	Bd.-ft.	Percent	Bd.-ft.	Percent	Bd.-ft.	Percent	Bd.-ft.	Percent	Bd.-ft.	Percent
Lumber with seasoning defects	162	57.7	97	62.2	1,003	68.3	949	61.4	886	68.6	832	59.8	3,929	64.0
Total tension wood lumber	281		156		1,469		1,546		1,292		1,391		6,135	

Table 5.--Scale of tension wood boards according to seasoning defects in all lumber grades for 26 units of California black oak lumber

Scale	No defects	Bow	Crook		End splits
			1-inch boards	2- to 3-inch boards	
In bd.-ft.	2,206	387	1,876	1,068	689
Percentagewise[1]	36.0	6.3	30.6	17.4	11.2

[1]Percentages total 101.5 because some boards had end splits and crooks.

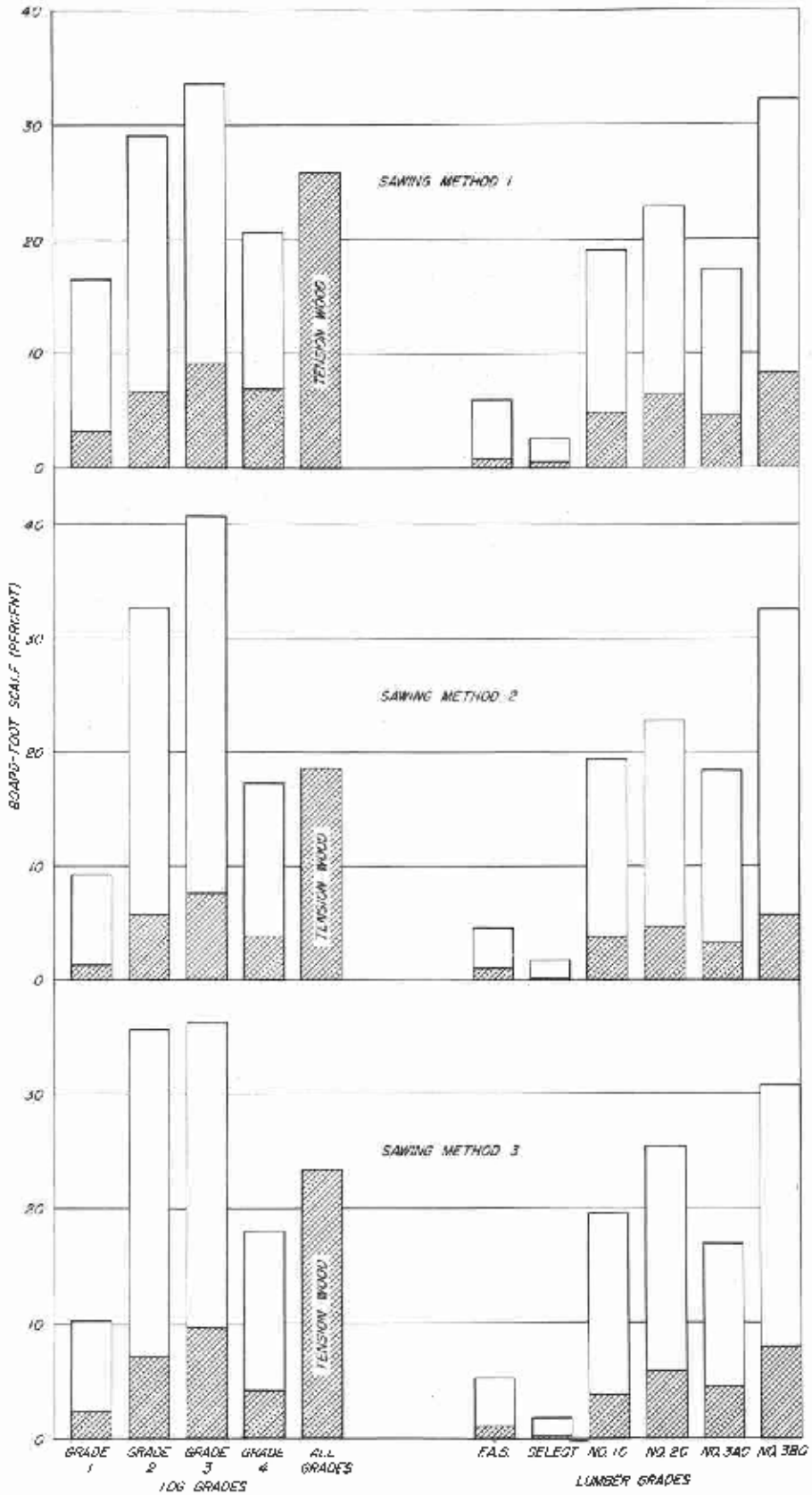

Figure 1. --Distribution of tension wood according to log and lumber grades and the three sawing methods used; (1) Sawyer's choice, (2) centering, and (3) cornering defects. Tension wood is expressed as the percentage of total scale for each method.

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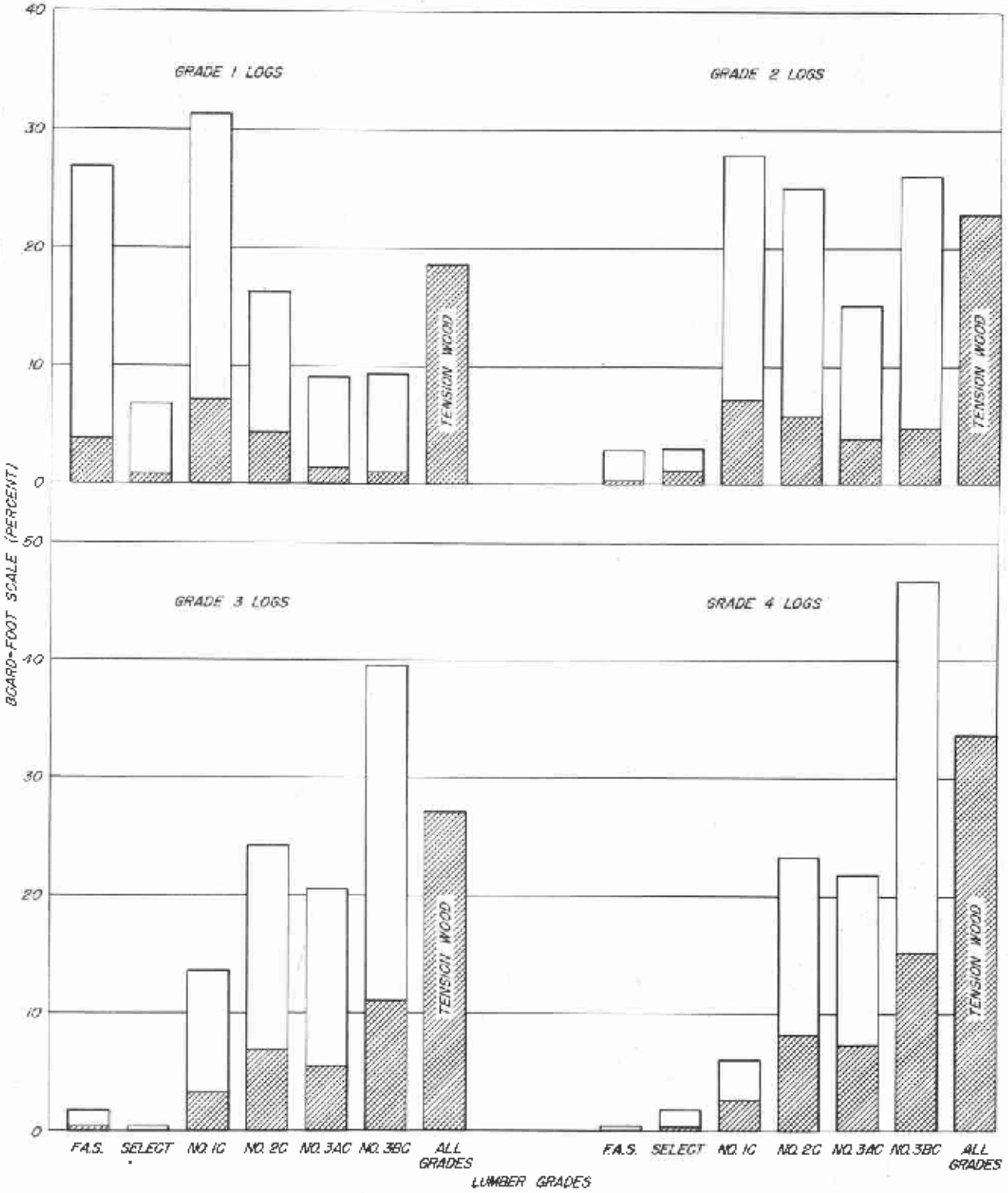

Figure 2. --Distribution of tension wood according to lumber grades within each log grade for sawing method No. 1, sawyer's choice.

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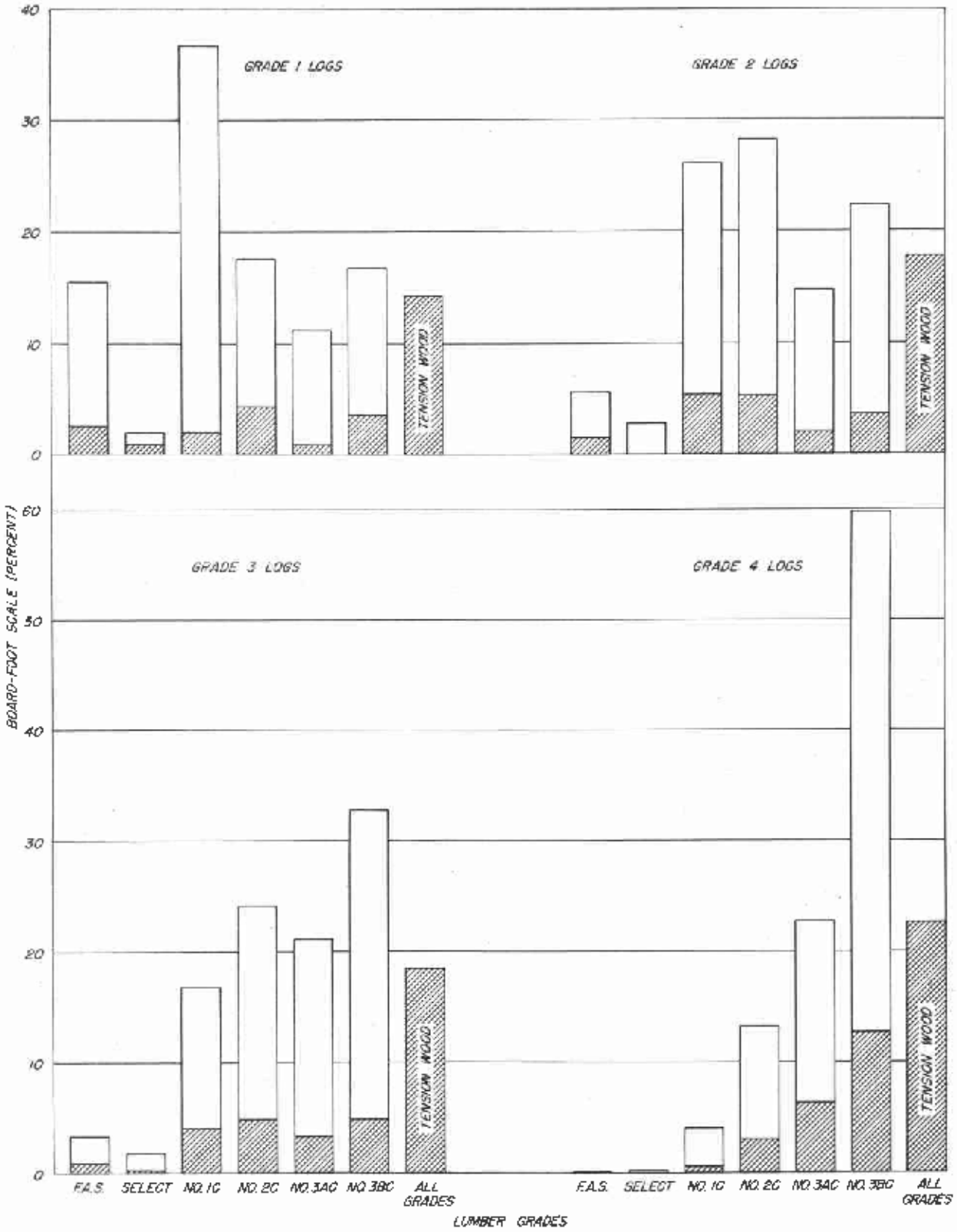

Figure 3. --Distribution of tension wood according to lumber grades within each log grade for sawing method No. 2, centering defects.

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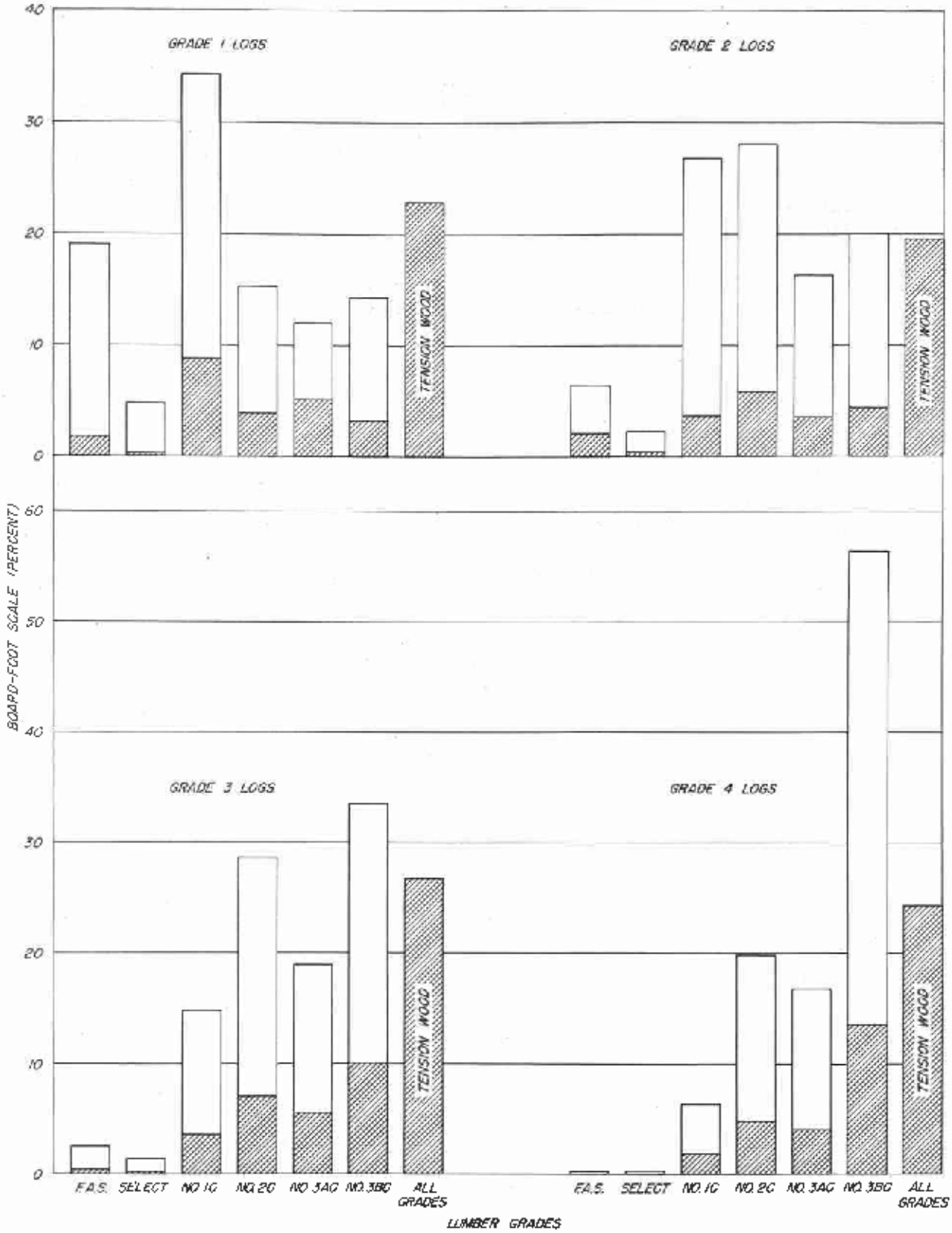

Figure 4.--Distribution of tension wood according to lumber grades within each log grade for sawing method No. 3, cornering defects.

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