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DEVELOPMENT of a COMPUTER METHOD for . . .

PREDICTING LUMBER CUTTING YIELDS

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Development of a Computer Method for Predicting Lumber Cutting Yields

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Introduction

Hardwood lumber could be used more efficiently if more information were available on what yields of specific part sizes can be cut from lumber of various species and grades. An obstacle to providing this information is a lack of standardization in part sizes. Because labor costs continue to increase, the wood-using industry has tended to focus more attention on minimizing man-hours required to produce parts than on maximizing yields from the lumber it cuts up into parts.

Recently, however, an electronic computer program has been developed to determine the grade of lumber that will give the best yield for a list of specific part sizes, and to predict what the yields will be. By furnishing part specifications on punched cards along with the characteristics of the lumber grades in question, a plant manager can find out, before he orders lumber, what grade will give the best yield. Because the computer also shows how many rips and crosscuts must be made to obtain the parts he needs, the plant manager also has a basis for estimating the labor costs to produce these parts from different grades of lumber. Furthermore, the computer can be used to compare yields among boards of specific sizes within one grade.

The importance of the problem is illustrated by the amount of lumber used in manufacture. In 1960, lumber composed 83 percent of the 14.2 billion board feet of the wood used by industry of which 48 percent, or 5.6 billion board feet, was hardwoods. When hardwood lumber is worth $150 per thousand board feet, the annual value of this lumber amounts to about 840 million dollars. A savings of even a few dollars per thousand board feet by utilizing precise yield information to obtain the full potential of the lumber would result in an annual savings of several million dollars.

The computer program was developed in a joint study of the Forest Products Laboratory and the North Central Forest Experiment Station. The objectives were twofold: (1) To develop techniques and procedures for collecting information on defects in hardwood lumber, and (2) to develop an electronic computer program for determining accurately the yields of rough parts (hereafter called cuttings) in the lumber. Both objectives required improved methods of mapping and diagraming the sizes and locations of defects in a board and transferring this information to punchcards in a form suitable for computer analysis.

Papers describing the computer program (Wodzinski and Hahm 1966) and how it can be used by management to determine maximum yield from lumber (Englerth and Dunmire 1966) have already been published.[1] The report presented here describes the procedures for collecting information on defects in hardwood lumber. The study concerns the five top grades of 4/4 hard maple lumber, but the techniques are equally applicable for other hardwood species. The report also shows that the computer program accurately predicted the yield of Clear-One-Face (C1F) cuttings for hard maple lumber.

Past Work

In 1949 the Timber Engineering Company made lumber cutup studies on five hardwood species (National Hardwood Lumber Association 1950). Using No. 2 Common 4/4 lumber, they marked the cuttings in chalk on the boards and presented their results as utility percentages for various sizes of five grades of cuttings. These cuttings, called "Milpak", never gained acceptance by industry.

White (1948) and Wylie[2] determined yields from black walnut and hard maple, respectively,

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[1] *Names and dates in parentheses refer to Literature Cited at the end of this report.*

[2] *Wylie, Aubrey E. A statistical study of small dimension yield from hard maple. Ph. D. thesis, Coll. Forest., State Univ. N.Y. (Syracuse). 1950. 99 pp.*

by chalk-marking the cuttings on the boards. Borkenhagen (1951) made full-scale board diagrams of five softwood species on tracing paper and used transparent templates, representing box parts, to obtain yields. More recently, Thomas (1962), working with a mixture of 12 hardwood species, located defects in air-dry boards by means of a transparent sheet marked into 1x3-inch rectangles. The sheet was placed on the board and an entire rectangular area was considered defective whenever the edges touched or included a defect. The yields were calculated by a Univac computer programed to crosscut first. No allowance was made for saw kerfs.

Procedures

Lumber Variability and Sample Selection

In a study of this type the sample lumber must be representative of the population. To provide a statistically sound basis for selecting the sample, 7,676 4/4 hard maple boards were examined at 20 sawmills throughout the hard maple producing areas. The grade, as defined by the standard inspection rules of the National Hardwood Lumber Association (1966) for hard maple, was verified for each board, and the board width, length, and scale noted. At the same time, the number and size of the grade cuttings were recorded together with the size and number of "extra" cuttings with minimum sizes of 3 by 12 inches or 2 by 18 inches. These "extra" cuttings gave an additional measure of utility over and above grading rule definitions. The number of sample boards needed in each board grade, length-width class, and utility group was determined on the basis of this information.

Most sample boards in all grades were obtained from a mill in northern Indiana; a few in the No. 2 Common and No. 3A Common grades in sizes not available there were obtained from a mill in West Virginia. A complete set of boards in some length-width classes of the poorer grades, however, could not be obtained. For example, boards 12 inches wide and 4 feet long in the No. 2 Common and No. 3A Common grades were rare. A total of 1,580 boards of all grades amounting to 10,380 board feet were used (table 1).

All boards were air-dried when selected.

TABLE 1. — *Number and board measure of 4/4 hard maple boards used to obtain yields by lumber grade and board-length*[1]

Lumber grade	Board-length (feet)							
	4-5	6-7	8-9	10-11	12-13	14-15	16	All lengths
				NUMBER OF BOARDS				
FAS	--	--	24	24	24	24	24	120
Select	--	30	30	32	32	28	28	180
No. 1 Common	56	65	68	68	69	68	61	455
No. 2 Common	62	57	73	78	78	56	53	457
No. 3A Common	67	49	64	51	63	38	36	368
Total	185	201	259	253	266	214	202	1,580
				BOARD-FOOT MEASURE--KILN DRIED				
FAS	--	--	145	182	213	246	293	1,079
Select	--	131	182	222	265	259	295	1,354
No. 1 Common	154	259	362	461	541	655	671	3,103
No. 2 Common	150	198	366	504	608	493	497	2,816
No. 3A Common	156	165	314	286	441	302	364	2,028
Total	460	753	1,369	1,655	2,068	1,955	2,120	10,380

1/ Board widths varied in approximately the same proportions as found at the 20 sawmills visited.

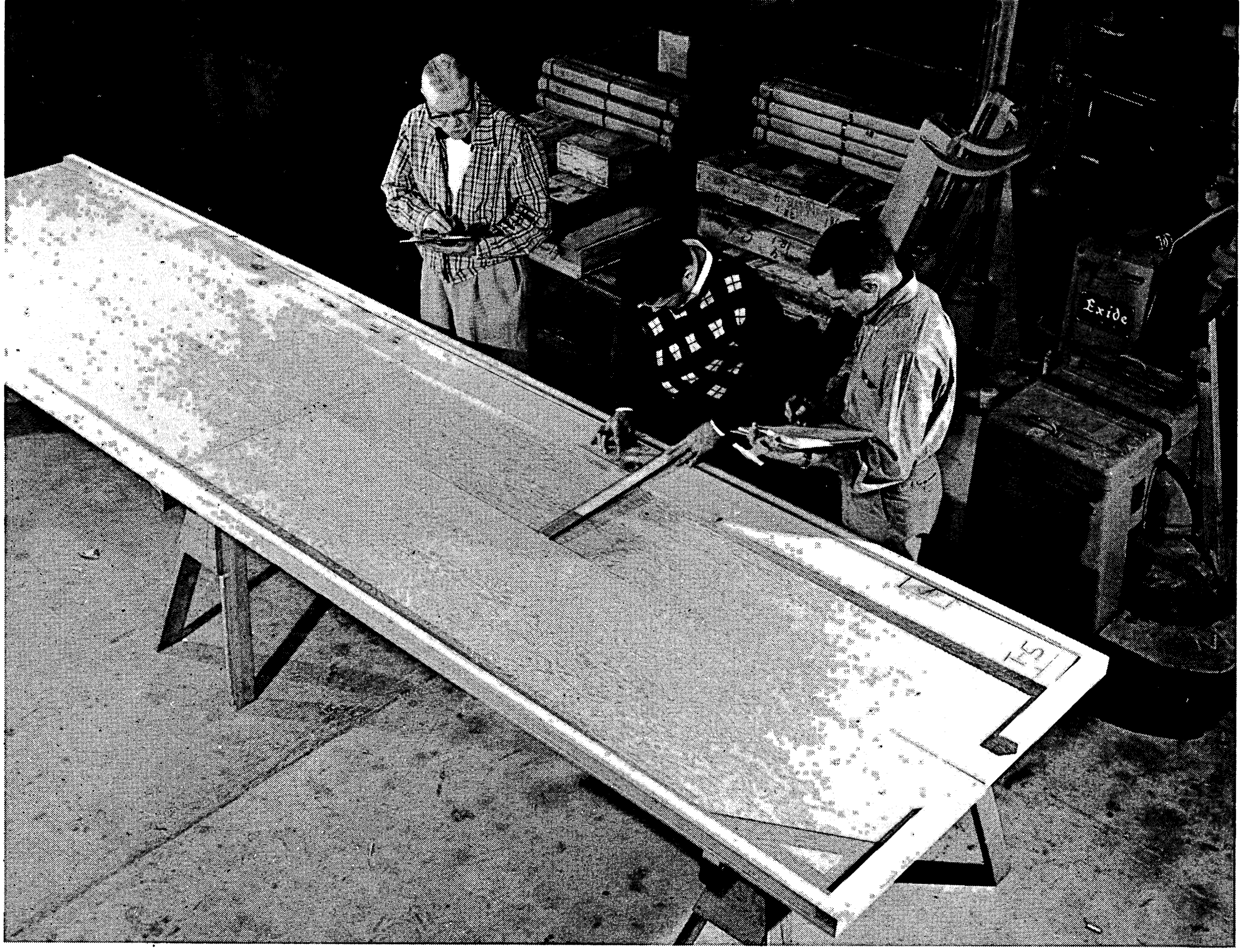

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FIGURE 1. — View of "Grid Mapper." A defect is being located by use of coordinate points on the best face of a board. The board was then turned over and placed on the opposite side of the mapper to locate defects on the poor face.

Defect Recording

The sample boards were checked for grade by a certified National Hardwood Lumber Association inspector both before and after kiln drying to 6 percent moisture content, using a kiln schedule recommended for hard maple. Although stickers were spaced 12 inches apart, some boards warped during kiln drying, especially those in the poorer grades. Badly warped boards were ripped or crosscut or both prior to rough planing the boards to a thickness of 15/16 inch.

Next the defects were coded and recorded for size and kind by the use of a specially made "grid mapper" (fig. 1). The mapper was marked in one-quarter-inch intervals from 0 to 768 along each side to accommodate boards up to 16 feet long, and from 0 to 64 on both sides of one end for boards up to 16 inches wide. The defects were located by coordinate-intersection points to the nearest one-quarter inch. In figure 2 the location of the 1½-inch knot enclosed in a rectangle on the better face of the board is 0-59:10-82; 0 and 10 are the locations on the "y" axis along the board width, and 59 and 82 are the locations on the "x" axis along the board length. All other defects were located in a similar manner. After diagraming the best face, the board was turned over and placed on the opposite side of the mapper and the process was repeated for the poorer face. Here the location of the knot discussed above is 0-60:11-82. Later, coordinates of the defect occurring on both board faces were combined to give one set of coordinates. This was necessary for processing the data by the computer. The combining was done by diagraming each board and its defects on both faces on graph paper at a scale of 1 to 5.

Specifications Given to the Computer

To permit a valid comparison, the specifications given to the computer for yield determination were similar to those used in marking and cutting the boards. The computer is capable of quickly calculating all possible combinations of cuttings, whereas only a few can be plotted manually. To simplify the procedure of manual plotting, cutting length was given more weight by squaring it to give length^2 x width (L^2W). For example, a 4x30-

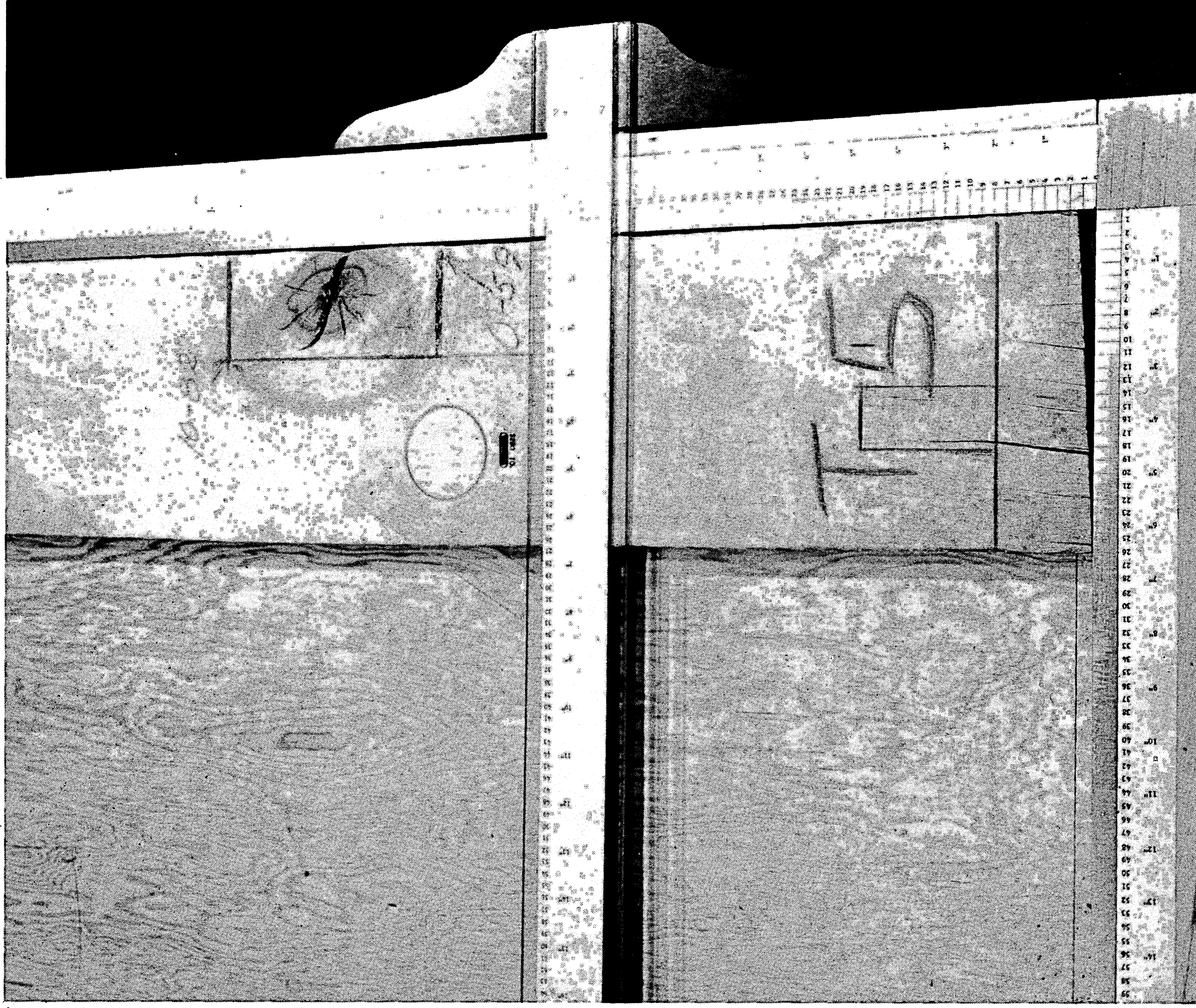

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FIGURE 2. — A knot enclosed in a rectangle with coordinate points 0-59 and 10-82.

inch cutting ($30^2 \times 4 = 3600$) is chosen over one 2x40 inches ($40^2 \times 2 = 3200$). Where the product of L^2W of two cuttings were identical, priority was given to the longest cutting. The cutting having the second largest L^2W product was then located and removed and so on until all cuttings in a board were found.

The saw kerfs were placed so that the cuttings could always be removed either by crosscutting or ripping or both. The width of saw kerfs was ¼ inch since that is the smallest unit used in the study. This approximates that used in industry for crosscutting, but is slightly larger than ripping kerfs.

One hundred size choices were permitted in the cutting instructions: 10 cutting widths from 1½ inches to 6 inches at ½-inch intervals for all grades, and 10 cutting lengths as follows (in inches):

Lumber grade

FAS and Select	*No. 1C*	*No. 2C*	*No. 3AC*
10	10	10	10
20	20	15	14
30	30	20	18
40	40	25	22
50	45	30	26
60	50	35	30
70	55	40	34
80	60	45	38
90	65	50	42
96	70	55	46

Because shorter length cuttings are expected in the poorer lumber grades, the range of lengths for these was narrower. Cuttings were marked on the boards of all five grades; but when the computer program for the three top grades worked satisfactorily, it was concluded that the other two grades need not be tested. Moreover, only C1F cuttings were programmed, although the defect data did not preclude obtaining yield data of other grades of cuttings.

Defect data, plus tables indicating the size and kind of defects permissible on each face of each grade of cutting, permitted the computer to choose the priority cuttings in a board. For example, C1F grade cuttings allow some defects on the poor face only, while such defects are permissible on both faces of sound grade cuttings (table 2).

Comparison of Yields

As might be expected, slightly higher yields were obtained by the computer, which finds every possible combination of cutting sizes while obtaining maximum yield, in contrast to the more limited possibilities by manual board marking:

	Percent yield obtained by —	
Lumber grade	*Marking boards*	*Computer*
FAS	78.1	80.7
Select	75.0	76.2
No. 1 C	67.8	68.1
No. 2 C	61.8	[1]
No. 3 AC	49.1	[1]

[1] No computer analysis was made.

The differences between the two methods were small, however — only 0.3 percent for the No. 1 Common grade, 2.6 percent for the FAS grade, and 1.2 percent for the Select grade. The important consideration is that the computer program was accurate.

The computer not only obtained somewhat better yields, but it also found a larger number of cuttings in the larger sizes. That is, it found more cuttings with a greater product of L^2W. Thus, in the FAS and Select grades, it obtained 77 and 52 6x96-inch cuttings, respectively, as compared to 48 and 35 obtained by board marking. Likewise, in the No. 1 Common grade the computer obtained 114 6x70-inch cuttings compared to 83 obtained by board marking.

The yields obtained by using the L^2W concept may be somewhat smaller than those obtainable by using LW, a concept used in other studies. For example, a 2x60-inch cutting with a L^2W product of 7,200 would be chosen over a 4x40-inch cutting with a product of 6,400. But the 4x40-inch cutting contains 40 square inches more than the 2x60-inch cutting.

A large variety of cutting sizes were obtained by using the L^2W concept of delineating the cuttings. Few, if any, commercial operations would consider using such cutting instructions. These are reported to demonstrate the versatility and the accuracy of the computer program to find all possible cutting combinations.

The computer also indicated the saw cuts needed to remove the cuttings and whether the boards should be crosscut or ripped as the first operation. For boards 8 inches or less in width, a high percentage of the boards were crosscut first regardless of the lumber grade (table 3). No clear distinction was noted for boards 8¼ to 10 inches wide; but more than 70 percent or more of the boards wider than 10 inches were ripped first.

TABLE 2. — *Classification of defects that may or may not be permitted on the clear and sound faces of clear one-face hard maple cuttings; + means permitted; — means not permitted*

Code	Defect	Clear face		Sound face	
		Go	No go	Go	No go
B	Bark pocket		-	[1] 1-4	5
BL&C	Burl and check		-	+	
BP	Bird peck		-	1-4	5
C	Surface checks		-	+	
CB	Cross break		-		-
CG	Cross grain		-		-
CW	Callus wood	+		+	
D	Distorted grain		-		-
DH	Dog hole		-		-
DM	Mechanical damage		-		-
E	End trim		-		-
FN	Felling notch		-		-
FT	Felling tearout		-		-
H	Heartwood	+		+	
HL	Holes, large worm		-	1-4	5
HM	Holes, medium worm		-	+	
HP	Holes, pinworm		-	+	
HS	Holes, shot		-	+	
HT	Holes, tap		-		-
KC	Knot cluster		-	1-4	5
KH	Knot, loose, decayed or hole		-	1-2	3
KS	Knot, sound tight	1	2	+	
MC	Machine - chipped or torn grain		-	+	
MP	Machine snipe		-		-
MS	Mineral streak	+		+	
MS&C	Mineral streak and check		-	+	
MT	Machine tearout		-		-
P	Pith		-		-
PF	Pith fleck	+		+	
PF&C	Pith fleck and check		-	+	
R	Rot, dote, decay		-		-
S	Sap stain		-	+	
SB	Brown stain	+		+	
SH	Shake		-		-
SL	Saw line		-		-
SP	Split		-		-
SS	Scar, sound		-	+	
ST	Sticker stain		-	+	
SU	Scar, unsound		-		-
SW	Sapwood	+		+	
TH	Thin		-		-
TS	Tap stain	+		+	
V	Void		-		-
W	Wane		-		-
WK	Warp - crook, wavy edge		-		-

[1] Size 1 = 1/8 inch, 2 = 1/4 inch, 3 = 3/8 inch, 4 = 1/2 inch, 5 = 5/8 inch. Uncoded defects are more than size 5.

TABLE 3. — *Percentage of 4/4 hard maple boards that were cross cut or ripped as the first operation according to L^2W basis of obtaining yield*

Lumber grade	Board width (inches)					
	3 - 4	4-1/4 - 6	6-1/4 - 8	8-1/4 - 10	10-1/4 - 12	12-1/4+
FAS						
Cross cut	--	--	83	58	27	21
Ripped	--	--	17	42	73	79
Select						
Cross cut	--	100	91	55	29	23
Ripped	--	0	9	45	71	77
No. 1 Common						
Cross cut	100	99	88	65	23	12
Ripped	0	1	12	35	77	86
No. 2 Common						
Cross cut	100	91	76	44	23	37
Ripped	0	9	24	56	77	63
No. 3A Common						
Cross cut	100	87	69	41	12	25
Ripped	0	13	31	59	88	75

Discussion and Summary

A system of locating defects in a board by intersecting coordinate points was developed and a computer program devised that used these points to locate all possible clear areas in the board. The computer determined the yields by placing any given size or sizes of cuttings in these clear areas, and furthermore stated the type, location, and number of saw cuts. The computer improved slightly on the manual act of extracting such cuttings from a board. This was demonstrated conclusively in the yields obtained from a representative sample of 4/4 hard maple lumber in the FAS, Select, and No. 1 Common lumber grades.

Yields given are for C1F cuttings where priority is given to length by using length of the cutting squared times the width (L^2W). The computer gave a yield of 80.7 percent for the FAS grade, 76.2 percent for Selects, and 68.1 percent for No. 1 Common. In comparison, the yields of these grades, respectively, by marking the boards were 78.1, 75.0, and 67.8 percent.

The results indicate that, by using the computer program, a plant manager can obtain an accurate estimate of the cutting yields to be expected from any specific grades and board sizes of hard maple lumber. He need only supply the cutting specifications and data on the sizes and grades of lumber he expects to use. Defect data are not yet available, however, on other species of hardwood lumber.

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