A red oak data bank for computer simulations of secondary processing

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Abstract

An extensive data bank for red oak lumber that is compatible with most secondary manufacturing computer simulator tools is now available. Currently, the data bank contains 10,718 board feet in 1,578 boards. The National Hardwood Lumber Association's (NHLA) Special Kiln Dried Rule was used to grade the boards. The percentage of a board's surface measure contained in clear-face cuttings of required sizes can vary considerably depending on whether the board is graded by a computer or a person. Both computer-generated minimum percentages and human-generated optimum clear-face percentages are included in the data bank. The availability of this data bank should provide users confidence that differences between their findings and those of others are attributable to differences in the processes being simulated; the use of this data bank should minimize interstudy sample bias.

The value of computer simulations of hardwood lumber cut-up can be limited if detailed information about the quality of the lumber is not known. A new 4/4 red oak lumber data bank has been developed to provide that information (3). The data bank currently has 10,718 board feet (BF) in 1,578 boards. The No. 1 and No. 2A Common grades are emphasized. The data bank presently contains 198 FAS boards (1 ,804 BF), 209 Selects boards (1, 571 BF), 591 No. 1 Common boards (3,7 19 BF), and 580 No. 2A Common boards (3,624 BF). Additional boards will be added from time to time. A sample of lumber 8 feet and shorter and a sample of No. 3A Common are being prepared. Additional FAS boards will be added later. The data bank should serve as a supply of boards from which appropriate samples can be drawn.

We consider normal grading procedures to provide insufficient quality information for data bank boards. National Hardwood Lumber Association rules (7) assume that over thousands of boards, all quality levels within a grade will be found in the correct proportions. Therefore, human graders determine only whether a board meets the minimum requirements of the highest possible grade. Quality within a grade is not determined.

Data bank boards, however, must stand alone, as relatively few will be used in computer simulation studies. Further, the user may wish to study only the low end of each grade or may have other limited interests. In such cases, knowledge of more narrowly defined quality levels within each grade should be considered.

This report describes the structure of the databank and includes comments on some of the effects of the grading rules on lumber quality evaluation.

Data format

Each board and the defects within it are described (1) by a series of rectangular coordinates (Fig. 1). The first set is the coordinates of the smallest rectangle that encloses the board. For a perfectly rectangular board, these coordinates are the same as those of the board. For boards with crook or taper, the space between the edge of the board and the enclosing rectangle is recorded as void (defect 2). Void and the other defect types are listed in Table 1. Large defects that are not well described by a single rectangle are broken down into a series of smaller rectangles. Figure 1 shows a board with wane (defect 8) that has been broken down in this way.

The heading of each board's data set contains the board's grade, number, defect count, and width. Also given is the percent of the board's surface measure found in the grading cuttings and the number of

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cuttings. An additional quality designation for the Common-grade boards is also given. A "P' designates a board in the high end of the grade, a "Z" a board in the middle, and an "M" the lower end of the grade. These designations aid in the quality sorting process.

We double graded the Common and FAS boards to provide a more complete understanding of each board's quality. The NHLA minimum grade is the grade determined with the computer program ReGS (2). It represents the first solution that meets the requirements of the highest possible grade and, therefore, simulates actual NHLA grading procedures. The percent of the board's surface measure in the grading cuttings and the number of cuttings used is given.

We then graded "to-scale" plots of each board by hand to determine the largest percent of surface measure possible in the greatest number of allowable cuttings. We called this the NHLA maximum grade and also recorded the percent of board surface measure and number of cuttings. ReGS and the data bank in ReGS format are available to enable the reader to check the grade of any given board.

Selects boards were not double graded. Unlike FAS and the Common grades, Selects is graded from the better face. The poorer face can be evaluated in one of three ways and the one determined by ReGS is given (sound back cuttings, 97% rule, or 1 Common back).

Reasons for double grading Common boards

Determining board quality based on percent of surface measure in the grading cuttings can be subjective. People sometimes do not agree on which grading cuttings to use and the computer program may select cuttings that differ from obvious human choices (2,4,5). Using the surface area of the first combination of grading cuttings found that meets the minimum requirements of the grade to establish a within-grade quality level can, therefore, give variable results. And not considered at all are the larger total surface areas that would result if as many cuttings as possible under the rules were used.

Further, while each grade has a starting lower limit (e.g., for No. 2A Common boards containing 2 ft. or more of surface measure, at least 50% of the surface

TABLE 1. — *Board defects and code numbers.*

Defect	Code No.
Void[a]	2
Pith	3
Decay	4
Shake	5
Pith-related tear or split	6
Wane and/or scant wood thickness owing to bark	8
Bark pocket	10
Unsound knot	12
Sound knot	15
Incipient decay and objectionable stain	18
Bud trace with bark	20
Split	24
Worm holes	
Grub and other holes 1/4 in. and over	11
Shot worm hole; greater than 1 /16 in., less than 1/4 in.	111
Pin worm hole: 1/16 in. or less	211

[a]The space between the edge of the board and the smallest rectangle enclosing the board, caused by crook. taper, or differential shrinkage.

GRADE 1CZ[a] BOARD NUMBER 544 1CPR[b] TOTAL NUMBER OF DEFECTS 17

MEASURED BOARD WIDTH 24[c] GRADING: 73-2[d] 86-4[e]

0- 0	25-769[f]		
24-176	25-320[g]	1[h]	2[i]
23-220	24-256	1	8
22-256	24-287	1	8
23-287	24-320	1	8
0-426	5-477	1	8
0-477	4-493	1	8
0-493	1-540	1	2
1-493	3-511	1	8
1-511	2-531	1	8
24-359	25-442	1	8
0-539	1-597	1	2
24-681	25-769	1	2
12-727	14-729	1	12
20- 0	21- 11	2	24
11-161	12-162	2	12
1-472	3-485	2	24
3-485	4-496	2	24

[a] NHLA Minimum grade
[b] NHLA Maximum grade--"R" indicates a board taken from 2nd or 3rd mill
[c] 1/4-inch units
[d] Percent of board surface measure and number of grading cuttings–minimum grade
[e] Percent of board surface measure and number of grading currings–maximum grade
[f] Lower left (left column) and upper right corner (right column) coordinates of rectangle enclosing the board (1/4-inch units); Y coordinate is first in each column set
[g] Defect lower left and upper right corner coordinates; Y coordinate is first
[h] Board face: 1= grading face; 2= back face
[i] Defect code (Table 1)

Note: Grades are represented as follows:
OFS=FAS
OSL=Selects
1C=No. 1 Common
2C=No. 2A Common
P,Z,M (Grading-cuttings surface area):

	No. 1 Common (%)	No. 2A Common (%)
M	67-71	50-54
Z	72-78	55-61
P	79 and above	62 and above

Figure 1. — Data bank format.

measure must occur in clear-face cuttings), there is no specified upper limit. Because of rounding, clear-face cutting percentages in excess of 100 can occur. And because of the way the rules are written, it is not unusual to find boards in the Common grades with percentages greater than the minimum requirements of the next highest grade.

When the percentage of surface measure in the grading cuttings equals or exceeds the amount required for the next highest grade, there can be many reasons why the board is not placed in that higher grade. For example, the surface area may not be in cuttings of the correct size and/or number. For FAS and Selects, there are limitations on knot size, the length and slope of splits, the allowable amounts of wane, and the amount of defective area in the first foot of each end. There are also pith limits for FAS, Selects, and No. 1 Common.

What double grading shows

Less than 10 percent (17 of 198) of the FAS boards could produce higher maximum grading surface areas than those found by the computer. This was expected. FAS requires long grading cuttings and it is not at all likely that an extra cutting will be found. Changes in grading surface area were minor and usually resulted from dividing a wide cutting into two narrow cuttings and extending the length of one beyond a stopper defect.

The ranges of data bank quality shown in Table 2 allow some interesting speculation concerning the utility of No. 1 and No. 2A Common. These grades may have more utility than a casual reading of their definitions would suggest. About 80 percent of the No. 1 and No. 2A Common boards were of low or middle quality and most of these were low when the ReGS NHLA minimum grades were determined. But when those same boards were graded using as many grading cuttings as possible, about 80 percent were of middle or high quality and most of these were high. It is interesting to note that about 60 percent of all No. 2A Common boards had maximum grading cutting surface area percentages of 62 percent or more. That is, 6 out of 10 No. 2A Common maximum grading cutting surface areas were no more than 5 percent below the lower limit for No. 1 Common.

Another factor contributing to increased utility is the relative absence of pith in No. 1 and No. 2A Common. Relative, that is, to the amount allowed in each board by the grading rules. Each No. 1 Common board may contain an aggregated length of pith up to 1/2 the length of the board. For No. 2A Common, there are no pith restrictions (except that pith cannot occur in the grading cuttings). In practice, however, pith occurs infrequently in both grades. Only 54 of 591 No. 1 Common and 108 of 580 No. 2A Common contained any pith. Most of those with pith contained less than 2 feet of pith in the aggregate.

TABLE 2. — *Quality distribution* for *No. 1 and No. 2A Common lumber boards.*

NHLA grade	*Low* quality[a]	Middle quality[b]	High quality[c]	Total
	. .	. ..(%)		
lC Minimum[d]	44	35	21	100
lC Maximum[e]	19	**30**	**51**	100
2AC Minimum[d]	47	37	16	100
2AC Maximum[e]	13	26	61	100

[a] Low quality: 1 C = 67 to 71 percent clear-face cuttings surface area; 2C = 50 to 54 percent clear-face cuttings surface area.
[b] Middle quality: 1 C = 72 to 78 percent clear-face cuttings surface area: 2C = 55 to 61 percent clear-face cuttings surface area,
[c] High quality: 1 C = 79 percent and above clear-face cuttings surface area: 2C = 62 percent and above clear-face cuttings surface area.
[d] Minimum: based on minimum number of cuttings required to achieve grade. Determined with computer program ReGS.
[e] Maximum: based on number of cuttings up to or including maximum number allowed. Determined by hand from to-scale plots.

Overview of data bank boards

We found the supply of hardwood boards to be much narrower than anticipated. Our initial sampling scheme for No. 1 and No. 2A Common boards was based on a pattern used by Lucas and Catron in 1973 (6) for No. 2A Common. Their average board width was about 9 inches. Starting in southern West Virginia, we failed to find sufficient numbers of wide boards. We then visited mills in northern West Virginia and western Pennsylvania. When enough wide boards in all lengths still could not be found, additional narrow

TABLE 3. — *FAS board size distributions.*

	Width class (in.)											
Standard length	4	5	6	7	8	9	10	11	12	13	No. of boards	Board feet
(ft.)												
4	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
6	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
7	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
8	- -	- -	4	2	3	2	- -	- -	- -	- -	11	54
9	- -	- -	2	1	1	4	1	- -	- -	- -	9	56
10	- -	- -	2	5	10	9	4	4	- -	- -	34	250
11	- -	- -	- -	1	1	1	- -	- -	- -	- -	3	24
12	- -	- -	4	6	13	15	6	2	1	- -	47	407
13	- -	- -	- -	- -	1	1	- -	2	- -	- -	4	44
14	- -	- -	8	8	4	8	8	5	1	- -	42	425
15	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
16	- -	- -	12	6	11	5	6	5	3	- -	48	544
Total	- -	- -	32	29	44	45	25	18	5	- -	198	1,804

boards were purchased. These additional purchases represented only a small percentage of the narrow No. 1 and No. 2A Common lumber that was available. In the end, our average width for No. 2A Common was about 7 inches.

Because we took all the wide Common boards (8 in. and wider) that we could find and only a small percentage of the narrow boards, our data bank does not reflect the population of lumber widths available on the open market. Proportionally, the data bank contains more wide boards and fewer narrow boards than should be expected. However, recall that the data bank is intended to be used as a source of smaller samples for specific studies. Our limited sample of FAS and Selects boards will be expanded in the near future.

The length and width distributions for the FAS,

TABLE 4. — *Selects board distributions.*

Standard length	Width class (in.) 4	5	6	7	8	9	10	11	12	13	No. of boards	Board feet
(ft.)												
4	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
6	1	6	8	3	2	- -	- -	- -	- -	- -	20	63
7	- -	3	--	- -	- -	- -	- -	- -	- -	- -	3	9
8	- -	5	- -	5	2	1	0	1	1	- -	15	74
9	- -	1	2	1	3	1	1	- -	- -	- -	9	51
10	1	5	5	9	6	3	5	3	2	- -	39	263
11	1	- -	- -	1	1	1	- -	1	- -	- -	5	37
12	3	2	10	11	11	5	4	1	1	- -	48	367
13	- -	- -	- -	- -	- -	1	- -	- -	- -	- -	1	10
14	- -	3	5	5	8	7	6	2	1	- -	37	364
15	- -	- -	1	- -	- -	- -	- -	- -	- -	- -	1	7
16	1	3	6	5	5	6	5	- -	- -	- -	31	326
Total	7	28	37	40	38	25	21	8	5	- -	209	1,571

TABLE 5. — *No. 1 Common size distributions.*

Standard length	Width class (in.) 4	5	6	7	8	9	10	11	12	13	No. of boards	Board feet
(ft.)												
4	- -	2	4	5	2	2	3	1	1	- -	20	54
5	- -	4	3	5	5	- -	- -	- -	- -	- -	17	49
6	2	18	18	10	6	3	3	2	- -	- -	62	214
7	2	13	6	- -	1	1	2	1	1	- -	27	103
8	3	11	16	19	19	10	10	2	3	- -	93	478
9	- -	- -	4	10	3	- -	- -	1	1	1	20	120
10	1	30	24	19	7	11	11	9	2	- -	114	715
11	- -	6	4	- -	2	- -	- -	- -	- -	- -	12	68
12	2	32	21	14	6	11	5	2	7	1	101	732
13	1	1	- -	2	- -	- -	- -	- -	- -	- -	4	27
14	- -	19	9	9	2	15	4	5	3	- -	66	610
15	- -	- -	- -	- -	1	- -	- -	- -	- -	- -	1	10
16	- -	16	10	8	7	6	2	5	- -	- -	54	539
Total	11	152	119	101	61	59	40	28	18	2	591	3,719

TABLE 6. — *No. 2A Common board size distributions.*

Standard length	Width class (in.) 4	5	6	7	8	9	10	11	12	13	No. of boards	Board feet
(ft.)												
4	- -	1	1	2	- -	1	- -	- -	1	- -	6	17
5	1	1	2	- -	- -	- -	- -	- -	- -	- -	4	10
6	- -	6	6	5	3	1	2	- -	- -	- -	23	80
7	1	2	2	2	2	- -	- -	1	- -	- -	10	41
8	2	30	30	21	13	14	18	3	3	- -	134	679
9	- -	3	5	5	- -	- -	- -	- -	- -	- -	13	63
10	4	41	31	34	12	10	2	1	- -	- -	135	768
11	- -	3	1	1	- -	- -	- -	- -	- -	- -	5	28
12	- -	31	28	23	9	6	1	5	1	- -	104	718
13	- -	5	2	1	- -	- -	- -	- -	- -	- -	8	52
14	2	39	12	10	5	9	3	4	1	- -	85	681
15	1	1	- -	1	- -	1	- -	- -	- -	- -	4	35
16	3	18	7	5	8	5	2	- -	1	- -	49	452
Total	14	181	127	110	52	47	28	14	7	- -	580	3,624

Selects, No. 1 Common, and No.2A Common lumber contained in the data bank are given in Tables 3 through 6. It should be noted that no Selects were purchased at any of the mills. Our Selects boards came from the FAS and No. 1 Common purchases.

Under NHLA rules, all lengths are in terms of standard feet (consecutive whole feet from 4 through 16 ft.). Any inches of overlength are ignored (although grading cuttings may extend into any overlength). The rules state that odd lengths of 5, 7, 9, 11, 13, and 15 feet are allowed up through 50 percent of the total number of boards. This implies that odd lengths are allowed but not preferred. Very few 13 and 15 footers were found and most of these were mismanufactured 14 and 16 footers. While more odd lengths were found in the shorter odd-length groups in No. 1 Common and No. 2A Common, the overall manufacturing preference for even lengths seems clear.

Use of the Special Kiln Dried Rule

All lumber was kiln-dried and skip-planed to facilitate marking of defects but was still graded as rough lumber. NHLA's Special Kiln Dried Rule was used because it counts all defects and treats each board as if it were air-dried (NHLA 1990). This rule states that each kiln-dried board will be graded as if it were air-dried and that it will be graded with all defects counted. Such grading is a much better predictor of utility than when the Standard Kiln Dried Rule is used. The Standard Rule states that checks and warp shall not be considered defects nor shall any attempt be made to distinguish between checks and warp that may have been present before kiln-drying. Thus, a severely crooked board that is also severely checked and contains cup and end splits would be graded as a straight board without these defects under the Standard Rule. Yields from such boards will often be lower than the grade might suggest.

Some producers of green or air-dried lumber may question a data bank based on the use of the Special Kiln Dried Rule. Questions have been raised about whether kiln-drying will change sound knots to unsound knots and adversely affect the lumber grades. We have found that kiln-drying does not have an adverse effect on lumber grades owing to a change in knot soundness. In red oak, most knots are unsound to begin with. A sound green knot that becomes unsound when dried must be uniquely placed to affect the grade. In a study of over 1,700 knots in a 656-board sample, we found only 1 knot to be so uniquely placed.

Obtaining the data bank

The availability of this data bank should allow researchers to shorten the length of time required to answer their research questions and give them confidence that differences between their findings and those of other users are attributable to differences in the processes being simulated; the use of this data bank should minimize interstudy sample bias.

For a free copy of the data bank and a full written description, please write to Forest Service 1992 Red Oak Lumber Data Bank, Forestry Sciences Laboratory, Rt. 2, Box 562-B, Princeton, WV 24740; or fax 304-425-1476. Please specify the size of diskette required. The data are in a format suitable for direct use in GR-1ST, a computer program that allows an analysis of the gang-rip- first roughmill. The databank also is available formatted for the ReGS computer grading program. Please request GR-1ST, ReGS, and/or the ReGS formatted data bank by name.

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