PREDICTING YIELDS FROM APPALACHIAN RED OAK LOGS AND LUMBER

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ABSTRACT. One utilization problem is in pinpointing how to efficiently and effectively recover usable parts from logs, bolts, and lumber. Yields, which are output divided by input, provide a key to managers who make processing decisions. Research results are applied to indicate yields of graded lumber and dimension stock from graded Appalachian red oak (group) logs. How to calculate yields is shown. Managers may use these applications for developing processing alternatives.

THE WOOD-PROCESSING industry in the United States is about 350 years old. At the turn of the century, raw material was plentiful, cheap, and of good quality. Manpower to process wood was also plentiful and cheap. Profits were up even though, as Scribner *(1914)* warned, "the so-called waste stock is often the measurement of profit or loss in a mill or factory."

Now skilled labor is critically scarce; and labor, equipment, capital and transportation are expensive. Our hardwood supply is adequate, but the trees of desirable species and good quality are not sufficiently available for our increased needs. Furthermore, stumpage, log, and lumber prices are rising, causing a profit squeeze.

Moser *(1967)* spoke for modern scientific processors when he said, "A savings of one percent of raw material (yield) is equal to a savings of ten percent of labor to process the raw material." His statement points out the difference between processors of the past and present. Progressive processors of today speak in terms of "yield" rather than "waste", and they quantify yield knowledge. This, coupled with cost data, helps them avert a profit squeeze.

To be knowledgeable about yields, process planners must know, by volume and quality, their raw-material inputs and their product outputs. For example, a sawmill manager must know the scale, by grades and species, of his logs (inputs) and the volume, by grades and species, of his lumber (output). A dimension-plant manager must know his lumber volumes by grade and species (input), as well as his dimension-stock volumes by grades (output). With these data they can calculate yield percentages by dividing the output by the input.

The ability to predict yields gives planners alternatives on which to make production decisions. With other production data, yield predictions can be applied before the product is produced. Some of these applications follow:

1. Determine raw-material requirements based on product purchase orders.
2. Determine raw-material grade mixes based on product requirements.
3. Estimate raw-material and processing costs.
4. Pinpoint needed lead time from the customer's shipping date back to the raw-material purchase date.
5. Schedule production to meet shipping dates.
6. Check on effectiveness of machines and operators.
7. Develop product values and prices more accurately.
8. Use these data in feasibility studies.

On the other hand, many sawmill and rough mill managers have neither the time nor the talent to develop yield data. To assist them, USDA Forest Service research results are available that give general yield data. The purpose of this paper is to make a small part of the general results more specific. Thus yield data may be used by processors who make lumber and dimension stock from Appalachian red oak (group) logs.

THE PROCESSES

Definitions

A "process" is a series of operations through which a raw material flows to arrive at a product. An "operation" is that part of a process that is accomplished at one work station or by an individual, without radically changing his equipment or work-place arrangement. Furthermore, wood-quality categories, which are identified by grades and specifications, permit the best utilization of the raw material during the process.

To study processes, one must first define the end products. Lumber and dimension stock are chosen as products for discussion for this paper.

Sawmill Process Yields

To develop lumber yields in a sawmill, log data are recorded by the log scaler. Pertinent data needed for each log are species, diameter, net scale (either International ¼-inch or Scribner Decimal C log rules), and grade *(Ostrander et al. 1965)*. By species and log grade, these data are summarized on separate sheets of columnar paper (table 1).

After diameter, number of logs, and net log scale are listed in their respective columns, the dry-lumber volumes are calculated for each diameter class, using tables from Vaughn et al. *(1966)*. That is, multiply net log scale by the plus or minus overrun figure

Table 1.—*Form for calculating lumber yields*[1]

Log diam.	Logs	Net log scale[2]	Overrun (±)	Dry lumber volume	Lumber volume by grades: FAS	Sel.	No. 1 Com.	No. 2 Com.	No. 3A Com.	No. 4B Com.
In.	*No.*	*Bf.*	*Pct.*	*Bf.*	*Bf.*	*Bf.*	*Bf.*	*Bf.*	*Bf.*	*Bf.*
13	33	2,904	2.8	2,985	585	385	776	412	266	519
14	20	2,200	5.1	2,312	812	305	509	294	178	215
27	1	448	−0.6	445	248	35	53	10	43	56
Total	203	33,447	—	33,809	11,809	3,330	9,144	3,620	1,806	3,644
Percent of net log scale			—	—	35.3	10.0	27.3	10.8	5.4	10.9

[1] Example yields are from grade 1 red oak (group) logs.
[2] International ¼-inch log rule.

obtained from this publication. After adding to or subtracting from net log scale, record this in the dry-lumber volume column on the form.

Next, multiply the dry-lumber volume in each diameter class by the NHLA grade yields shown in the publication. Record these volumes under each respective grade column on the form. Finally, sum each column at the bottom of the page and calculate the percentage yields by lumber grades. This is done by dividing the total lumber volume per grade by the total net log scale and multiplying by 100. This results in the lumber yields by grades for the mix of diameters in the log sample. Then follow the same procedure for other log grades and species.

We developed lumber grade yields from a representative sample of red oak (group) logs that were delivered to Appalachian sawmills *Goho and Wysor 1970* and table 2). These may be used by Appalachian lumber producers for long-term factory-grade lumber yields. However, if not representative of a producer's log diameters, the yields should be calculated by using the techniques previously explained.

Table 2.—*Predicted air-dry lumber yields from Appalachian red oak (group) logs*
(Percent of net International log scale)

Lumber grade	U. S. Forest Service log grades		
	1	2	3
FAS	35.3	8.0	1.0
Select	10.0	5.3	0.6
No. 1. Common	27.3	32.1	16.2
No. 2 Common & SW	10.8	20.0	23.1
No. 3A Common	5.4	9.6	12.5
N. 3B Common	10.9	22.9	43.5
Total[1]	99.7	97.9	96.9

[1] May equal more than 100 percent because of overrun, as well as timbers and sound square-edge produced but not included. These are circular headsaw yields. For bandsaw yields, add 5 percent.

Rough Mill Process Yields

Prediction techniques are also available for determining dry dimension-stock yields from graded lumber. Based on cutting bills

Table 3.—*Form for calculating dimension yields*[1]

Cutting length	Volume required	Yields: Cumulative	Yields: Adjustment	Yields: Individual	Dry lumber required	Cutting volume: Obtained	Cutting volume: Short	Cutting volume: Excess
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
In.	*Bf.*	*Pct.*	*Pct.*	*Pct.*	*Bf.*	*Bf.*	*Bf.*	*Bf.*
65	100	51	0	51	196	100	0	0
40	100	65	0	14	—	27	73	0
24	100	71	0	6	—	12	88	0
16	100	73½	0	2½	—	5	95	0
Subtotal	400	—	—	73½	[2]196	144	—	—
40	73	59	0	59	124	73	0	0
16	85	71	0	71	119	85	0	0
Total	400	—	—	—	554	400	—	—

[1] Cutting bill of equal volume requirements of ¾-inch clear-one face cuttings 2 inches and wider from FAS red oak (group) lumber.

[2] Total optimum yield $= \frac{400}{554} \times 100 = 72.2$ percent of lumber required.

and purchase-order requirements, yields for different cutting lengths may be estimated from published charts in *FPL 118 (Englerth and Schumann 1969)*. The techniques are comprehensive so that yields of dimension by lengths and widths, either random or fixed, are obtainable.

To derive desired yields, use the recommended form (table 3) as an example, as follows: the volume requirements by cutting lengths shown in columns (1) and (2) are based on purchase-order requirements. Yield data entered on the form in columns (3), (4), and (5) are explained in *FPL 118*. Dividing the individual yield (51 percent) of the longest cutting in column (5) into the volume requirements (100 bf.) for the longest cutting in column (2) gives the lumber required (196 bf.) to yield the 65-inch cuttings. Then, multiply the lumber required (196 bf.) by each of the individual yield percentages in column (5), and enter these in column (7). To obtain either columns (8) or (9), subtract the volumes in column (7) from the volumes in column (2).

In most cases, succeedingly shorter cutting lengths will require additional lumber volume. So prepare another form, but transpose the shortages in column (8) to column (2). Prepare enough tables until the lumber requirements for the shortest cutting in the cutting bill are completed.

For the example shown in table 3, four tables are required. Finally sum up columns (2), (6), and (7) in a total line at the bottom of the form. After the total in column (7) is divided by the total in column (6) and multiplied by 100, total optimum yield is obtained.

By using the same cutting bill, other tables may be prepared for yields from the other lumber grades and grade mixes. These yields are shown in table 4.

Table 4.—*Predicted dimension yields from kiln-dried 4/4-inch Appalachian red oak (group) lumber*[1]

(Percent of dry lumber volume)

Lumber grade	Grade mix	Dimension yields
FAS	100.0	72.2
Select	100.0	68.6
FAS	25.0	
Select	25.0	67.8
No 1 Common	50.0	
No. 1 Common	100.0	66.3
FAS	29.5	60.2
No. 2 Common	70.5	
No. 1 Common	47.8	60.3
No. 2 Common	52.2	
No. 2 Common[2]	100.0	54.9
No. 3A Common[3]	100.0	38.8

[1] See cutting bill in table 3.

[2] Cannot yield appreciable volume of 65-inch-long cuttings.

[3] Cannot yield appreciable volume of 65- and 40-inch-long cuttings.

Sawmill-Rough Mill Process Yields

Some dimension manufacturers are successfully producing dimension stock directly from logs. Other lumber producers are considering the addition of rough mills and dry kilns next to their sawmills.

For these processors, estimating dimension yields for a specific cutting bill from graded logs is now feasible. Table 5 indicates predicted dimension yields from graded Appalachian red oak (group) logs. Some yield applications are listed previously. Thus processors have production alternatives that can

Table 5.—*Predicted dimension yields from Appalachian red oak (group) logs*[1] *2 inches and wider, 16 inches and longer*

(In percent of net log scale)

Lumber grade	Dimension yields by log grades—		
	1	2	3
FAS	25.5	5.8	0.7
Select	6.9	3.6	.4
No. 1 Common	18..1	21.3	10.7
No. 2 Common	5.9	11.0	12.7
Subtotal	56.4	41.7	24.5
No. 3A Common[2]	2.1	3.7	4.9
Total	58.5	45.4	29.4

[1] Derived from yields in tables 1 and 3. For example, yield of FAS lumber (0.353) in grade-1 logs is multiplied by yield of dimension (0.772) in FAS lumber. Converted to percent, the product is 25.5.

[2] Dimension stock is not ordinarily made from No. 3A Common lumber.

be tailored to their end-product requirements.

Dimension Directly from Short Roundwood

Ideally, lumber sizes should be tailored to the needs of the rough mill. The control of lumber lengths begins in the woods when trees are bucked into logs. Some processors and researchers recommend the manufacture of short logs or bolts directly into dimension. In one case, it was found that logs from lower-grade hard maple trees were 25 to 45 percent more valuable when processed directly from bolts into dimension stock rather than from logs into graded lumber and then into dimension stock *(Hamilton 1970)*.

Other research work concerns processing woods and logging residues of high-value species into dimension. In West Virginia, sprout black cherry trees that would not have been logged led Koch et al. *(1968)* to remark that the direct processing method "offers considerable possibilities." Likewise, the North Central Forest Experiment Station found that black walnut logging residue in southern Illinois contained "a wealth of dimension stock." Yield work continues there on immature cherry trees and logging residue. Short-log processing research is also under way at the Northeastern Forest Experiment Station's Forest Products Marketing Laboratory at Princeton, West Virginia.

These processing methods are receiving considerable attention by research. More information will be available in the next few years.

ACCURACY

Throughout this paper, the word "predicted" precedes the yield percentages. Since they are based on sample data, the percentages are not always accurate during a short-term production run. Over the long term, they will give good estimates.

Specialists who apply lumber-yield information are emphatic when they say, "The hardwood log grades . . . have proved accurate time and again for estimating lumber quality" *(Martens 1965)*. Or "Thus far, the yields have always worked out reasonably well, especially for such small samples" *(Screpetis and Carpenter 1970)*. Furthermore, the Northern Hardwood and Pine Manufacturers Association adopted log-grading rules that are based on Forest Service hardwood log grades *(Stump 1970)*.

Predicting dimension yields, on the other hand, is more refined than predicting lumber yields. In-plant experience has shown the charts to be accurate within 3 to 5 percent *(Dunmire and Englerth 1970; Schumann and Huber 1969)*. Because the charts published in *FPL 118* are based on a representative sample of kiln-dried 4/4-inch hard maple lumber, correction factors are used to change the optimum yields to practical yields for industrial practice. For example, yields of clear-2-side dimension stock are about 2 percent less than yields of clear-1-side dimension stock. Although not in-plant tested, percent reductions may be made to total yields for dimension stock with thicknesses greater than 4/4-inches:

Grade	*Lumber thickness, in inches* 5/4	6/4	8/4
FAS	2	3	4
Select	3	4	5
No. 1 Common	3	4	5
No. 2 Common	4	5	6

Little information is available about yield differences between species. Generally the charts may be used for lumber inspected according to the standard rules of the National Hardwood Lumber Association. For No. 2 Common lumber, use the charts only for species that require clear-face cuttings to make grade rather than sound cuttings. Specifically, no percentage reductions are made by some dimension firms for soft maple and red and white oak lumber. Reductions are being made for the following species: white ash, cherry, and hard maple—3 percent; and birth and pecan—5 percent. The use of the charts is precluded in warp-prone species such as cottonwood and aspen, as well as stained lumber, mismanufactured lumber and dimension, and dimension whose color is important.

We have a lot to learn about predicting dimension yields. But we have the base, *FPL-118*, from which to work. To help verify correction factors, we volunteer to act as a clearing house for yield data from industry.

PROCESS PLANNING

Controlling the flow of raw material through processes depends on the knowledge of raw-material quality. Some companies are planning and controlling this flow. Perhaps now is the time for other companies to practice quality and production control by aiming toward the objectives of progressive process planning. These objectives are: (1) conserve the raw material, (2) engineer the process, (3) meet the specifications of the product, and (4) reduce production costs.

Specialists are available to help meet these objectives. Consultants, as well as State and Federal utilization specialists, are ready to help processors adopt research results. Together they can define more precisely the quality of the raw material that will encourage the growth and development of the forestry-based enterprises.

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