COMPARING LUMBER YIELDS FROM BOARD-FOOT AND CUBICALLY SCALED LOGS

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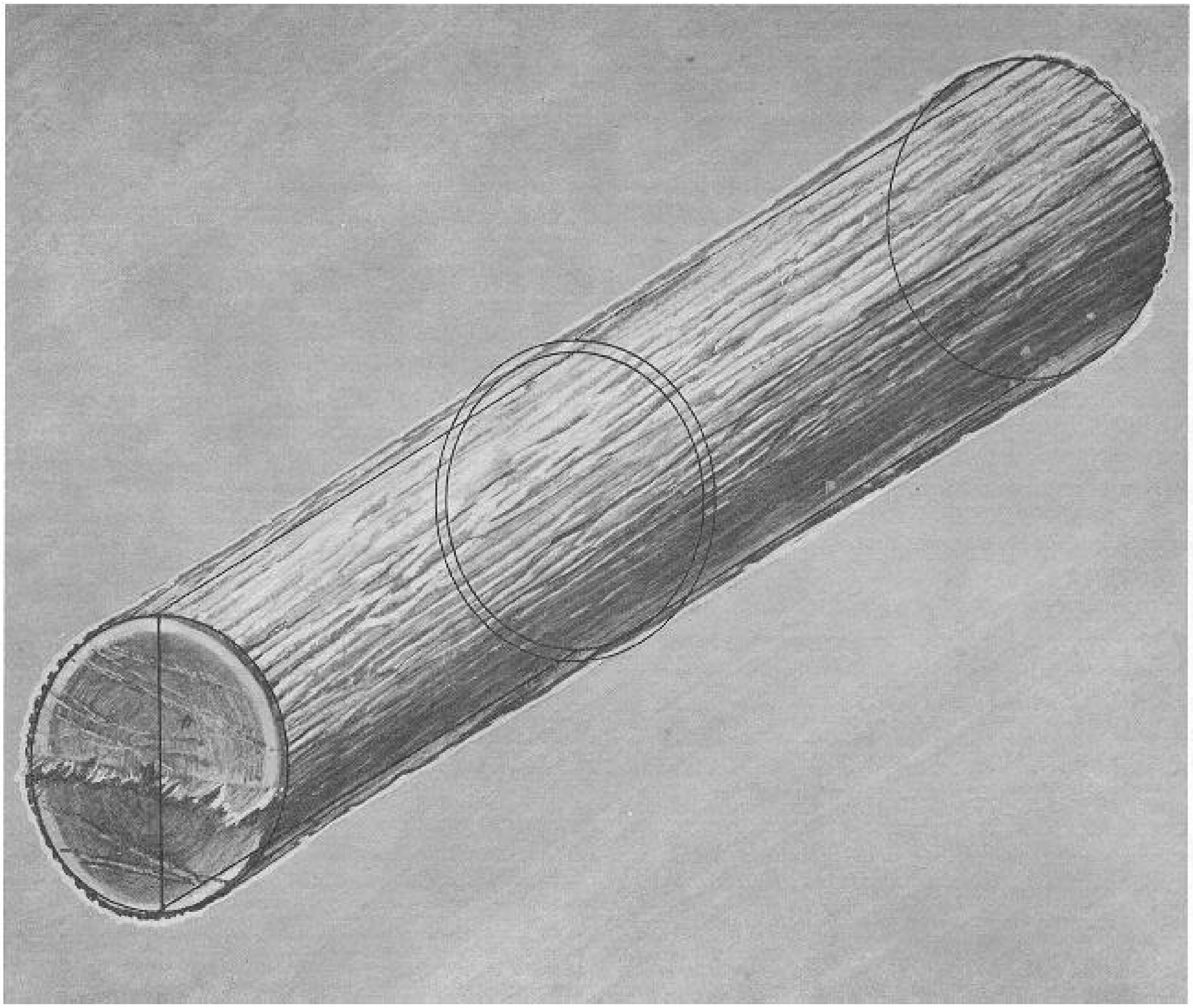

Abstract

Historically, sawtimber has been bought and sold by the board foot, but now cubic scaling of logs and timber has begun and is scheduled to entirely replace board-foot scaling by 1985 in sales from National Forests.

In board-foot scaling of sawlogs, the contents are estimated by measurement of small-end diameter and log length, and reference to log rule. The actual lumber recovered usually exceeds the estimate by a factor known as “overrun.” Increasing taper has been shown to increase overrun when logs have been board-foot scaled. The exact opposite occurs when the logs are cubically scaled.

Through the medium of mathematical modeling, this study defines the degree of change to be expected from either scaling method as taper is increased. Several examples are developed to explain the use of the tabular and graphic data presented.

COMPARING LUMBER YIELDS FROM BOARD-FOOT AND CUBICALLY SCALED LOGS

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Introduction

Historically in North America, the value of individual logs has been expressed in terms of monetary value per board foot of lumber they are expected to yield. Because the valuation normally preceded the. actual sawing of the log to lumber, it was necessary to develop a system of measurement that could estimate the board-foot yield using available log diameter and length information.

Most of the board-foot scale rules (*1*)[3] used in log transactions show estimated volumes somewhat lower than the actual tally of lumber, resulting from sawing the log in all but the most inefficient mills. This difference is commonly known as overrun and may vary from 0 to 400 percent depending on the logs, the mill, and the log rule being used.

Another method of scaling logs, based on their total cubic foot volume, is expected to replace the board-foot rules as a means of establishing fair market value for logs in the near future. The U.S. Forest Service has begun using cubic scaling in some of their timber sales and hopes to be using it exclusively by approximately 1985.

The most widely used of the several mathematical systems for calculating cubic contents of logs is Smalian's formula (7). This formula assumes the cubic contents of a log can be closely estimated by multiplying the average of the areas of the two ends of the log in square feet by the length of the log in feet.

There is a fundamental difference in the two systems that requires full understanding by both buyer and seller if fair market value is to be established.

Basically any differences in taper of logs is ignored when board-foot rules are used, as the log's diameter on the small end and its length are the only variables considered.

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

[3] Italic numbers in parentheses refer to literature cited at end of this report.

When logs are cubically scaled, both end diameters are considered and thus taper is accounted for in calculating the log's cubic volume.

It has been shown by Dobie (2) that although logs with higher tapers yield more lumber for any given small end diameter, they yield less lumber per cubic foot of actual log volume. Stated another way-when logs are to be scaled by board-foot log rules, within reasonable limits, the higher the taper the more lumber the sawmill operator will get for his log investment. On the other hand, if cubic scale is used, his lumber yield per cubic foot of log scale will be reduced as taper increases. Thus, we see taper as an asset on one hand and a liability on the other.

This factor is probably recognized by most people engaged in the sale of timber. What is not known is the actual mathematical relationship of taper to both systems. Because of this, a great deal of uncertainty in trying to establish fair market value for timber sold on a cubic basis-especially in contrast to the board-foot rule basis-will result.

This study has analyzed the problem of taper and defines the degree to which taper affects the yield from logs scaled by both systems.

The Study

The recent development of the Best Opening *Face* (BOF) computer sawing program (*3,4,5*), which can simulate almost any method of softwood log breakdown, has made possible a precise analysis of the effect of taper on yield. The BOF program finds the sawline placement resulting in the maximum yield for any specific log when sawn by a given set of actual or hypothetical sawing conditions. Thus, by specifying all of the sawing conditions and using the BOF program on a given range of log diameters, lengths, and tapers, the effect of taper can be evaluated.

Procedure

The logs studied were of a size commonly converted to softwood dimension lumber in so-called "small log" mills. They ranged in diameter from 5.6 to 20.4 inches by 0.2-inch increments, in length from 8 to 24 feet by 2-foot increments, and in taper from 1 to 5 inches per 16-foot length by l-inch increments. All of the 3,330 log combinations were computer sawn-i.e., by the mathematical modeling of the sawing method, using the full taper fixed fence method. This is the most widely used sawing method in which side lumber and a cant are developed in a plane parallel to one face of the log. The cant is then sawn by suitable means such as a rotary gang in a plane 90° opposed to the first breakdown and also parallel to the outside log face. The cant is processed against a fence at a fixed distance from the first saw in the rotary gang.

Conditions specified in the BOF simulation were as follows: All lumber was edged full length of the flitch allowing a maximum of 25 percent wane according to the National Grading Rule (6). The smallest piece of lumber sawn was 4 inches wide and 8 feet long. The setting increments were 1/16 inch. Headsaw kerf (vertical) was 0.165 inch. Cant breakdown kerf (horizontal) was 0.134 inch. Sawing variation ranged from 0.063 to 0.125 inch (table 1). The BOF program positioned the fence for 4- and 6-inch cants such that a nominal 4-inch by 8-foot face with maximum allowable wane would be produced if the cant had come from a log of 4.6 inches in diameter. On cants 8 inches and larger, the fence position was such that the 4-inch by 8-foot or longer face would be produced if the cant had come from a log 8.8 inches in diameter. These two log diameters are the smallest that will produce an acceptable 4-

Table 1 -Lumber sizes and sizing factor values

Dimension	Nominal	Dry dressed	Dressing allowance[1]	Shrinkage	Sawing variation	Rough green
	- - - - - - - - - - - -	- - - - In.	- - - -	- - - -	- - - -	- - - -
Thickness	1	0.750	0.121	0.027	0.063	0.960
	2	1.500	.098	.049	.063	1.710
Width	4	3.500	.153	.113	.109	3.875
	6	5.500	.153	.175	.109	5.938
	8	7.250	.146	.229	.125	7.750
	10	9.250	.147	.291	.125	9.813
	12	11.250	.148	.352	.125	11.875

[1] Dressing allowances vary because of the necessity of having rough green thickness plus one kerf be a multiple of the 1/16-in. setting increments. In the case of widths, the width (without kerf) must be a 1/16-in multiple. Wood added to obtain the 1/16-in. multiple is removed in the dressing operation.

and 8-inch cant with the sawing conditions used.

Both 4/4-inch and 8/4-inch lumber were cut in the vertical plane but the 4/4 was limited to the first cut on the log and possibly the last cut, if in so doing the recovery was higher than would result from 8/4. On the cant (horizontal plane) for full-taper cant sawing, the 4/4 was limited to the last cut opposite the opening face if it proved advantageous as compared to a final 8/4 cut. All other lumber was 8/4. Widths cut were nominally 4, 6, 8, 10, and 12 inches. The actual widths and thicknesses cut, together with dressing allowances, shrinkage, and sawing variation, are shown in table 1.

The BOF program tried all possible cant sizes for each log. Four- and 6-inch cants had to yield at least two pieces of 8/4, while 8-, 10-, and 12-inch cants had to yield at least three pieces of 8/4. The cant size giving the highest board-foot yield was selected.

Results

There are several ways the results of this study could have been presented. We chose to relate both the cubic and the board-foot scale yields to the mill's present recovery for good logs with 1 inch of taper per 16 feet of length. This choice simplifies the tables because it avoids the situation where both positive and negative correction factors occur in each of the two systems. In other words, it makes the taper adjustment factors all positive for the board-foot scale data and all negative for the cubic scale data. Adjustments can be made from basic tapers other than 1 inch and the methodology is described later.

The effect of taper on board-foot recovery for both board-foot and cubic scaled logs is presented (fig. 1) for representative diameter classes. In addition, for the board-foot scaled logs, four representative lengths are shown (upper half of each graph). Length was not found to be a significant factor in relation to lumber recovery factors (LRF) and so yields for all lengths are combined and the average is shown in the cubic (lower) half of the graph.

The zero or base line (between board-foot scale and cubic scale on the graph) is the yield that a mill would expect if they sawed straight logs with 1 inch of taper per 16 feet of length.

For board-foot yields, the lumber yields calculated by the BOF computer model for each diameter, taper, and length class were divided by the BOF yields developed from logs for each diameter and length but with a constant taper of 1 inch per 16 feet. This gives the ratio termed "Percent of Change" in figure 1. This ratio can then be applied as is shown in the examples that follow to any log rule to estimate changes in yield that a change in taper would give rise to in a diameter and length class.

Cubic foot (LRF) figures were obtained by first computing LRF based on the calculated BOF yields. The BOF yields were calculated in this case for each diameter class (length was not found to be a significant factor in the cubic calculations) again with the taper of 1 inch per 16 feet held constant. "Percent of Change" was then calculated by dividing the LRF's for each taper class by the LRF from the class for 1 inch per 16 feet.

In considering logs scaled by board-foot rules, it is apparent that lumber yields increased rather dramatically as taper increases. For example, in the 10-inch diameter, 16-foot class, the increased recovery with increased taper is: 2-inch taper = 4.8 percent, 3-inch taper = 10.6 percent, 4-inch taper = 17.3 percent, and 5-inch taper = 23.1 percent. It is also evident that this increase is highest for long logs and lowest for shorter logs. Again, in the 10-inch diameter class, the increase in the 5-inch taper class for 24-foot logs is 42.6 percent, the 20-foot logs 33.1 percent, 16-foot logs 23.1 percent, and 12-foot logs 11.7 percent. Yield increases due to taper decrease as diameter increases. As an example, refer to the 16-foot length and 3-inch taper values. At 6-inch diameter, the increased yield is 20.6 percent, at 10 inches it is 10.6 percent, at 16 inches it is 6.6 percent, and at 20 inches it is 5.4 percent.

When the lumber yield per cubic foot (LRF) is evaluated in terms of the effect of taper and diameter, it is found that the results are quite opposite. Again, referring to the 10-inch diameter graph (fig. 1), logs with 2 inches of taper yield 5.7 percent less per

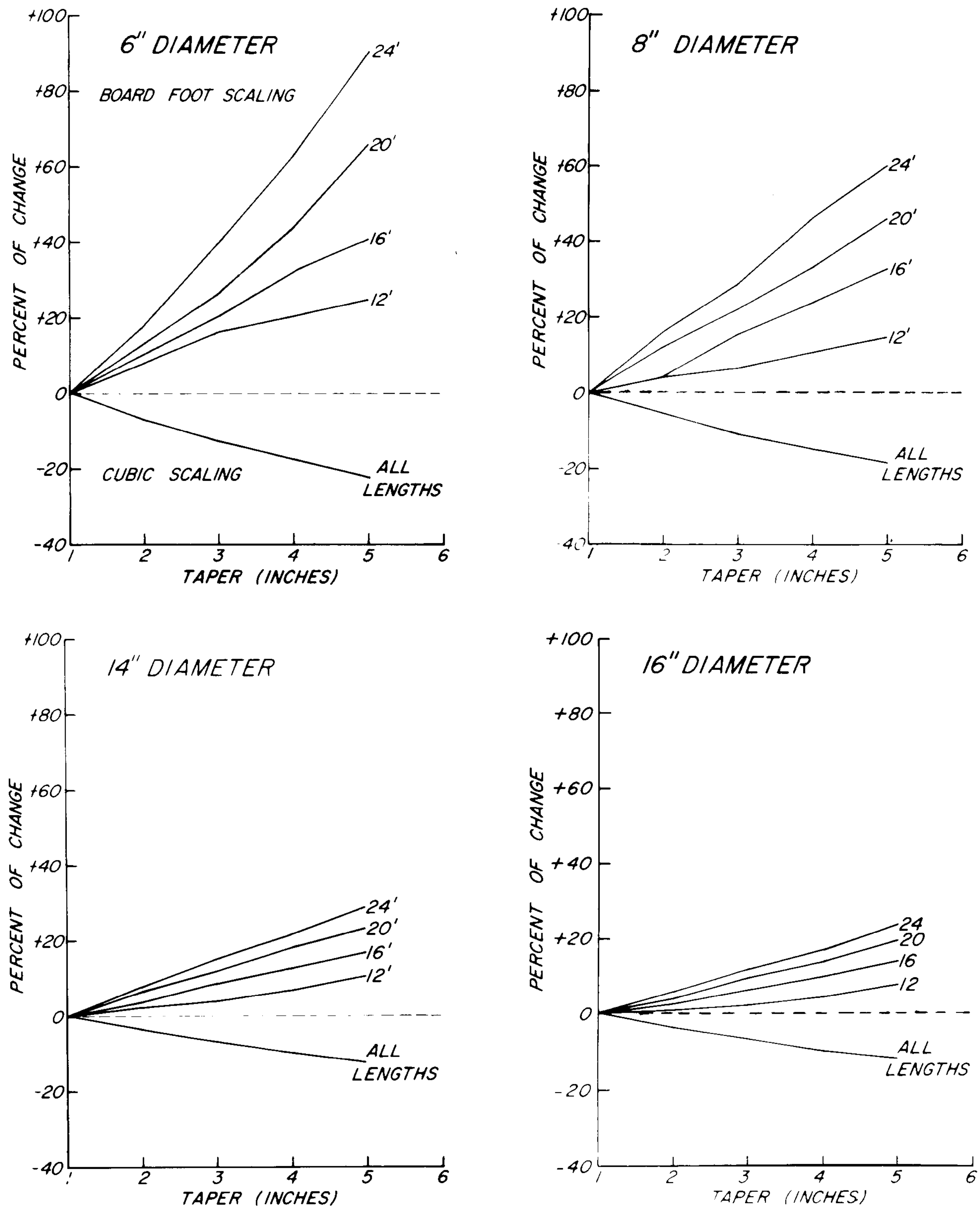
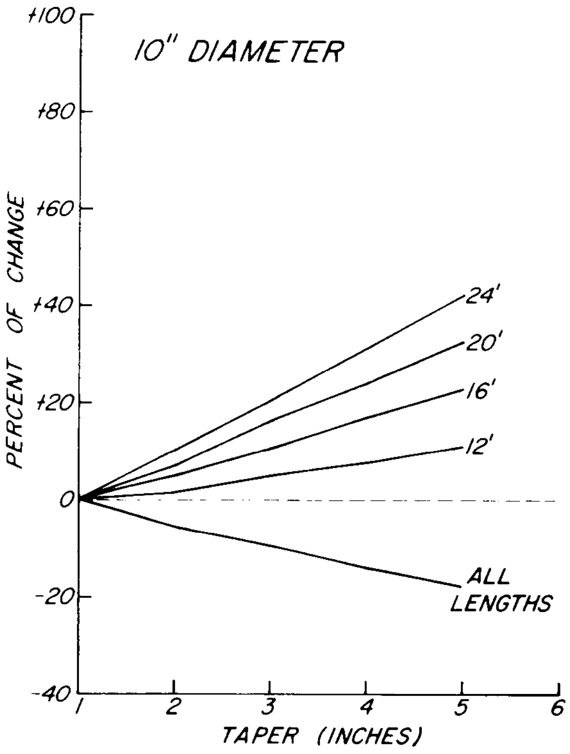
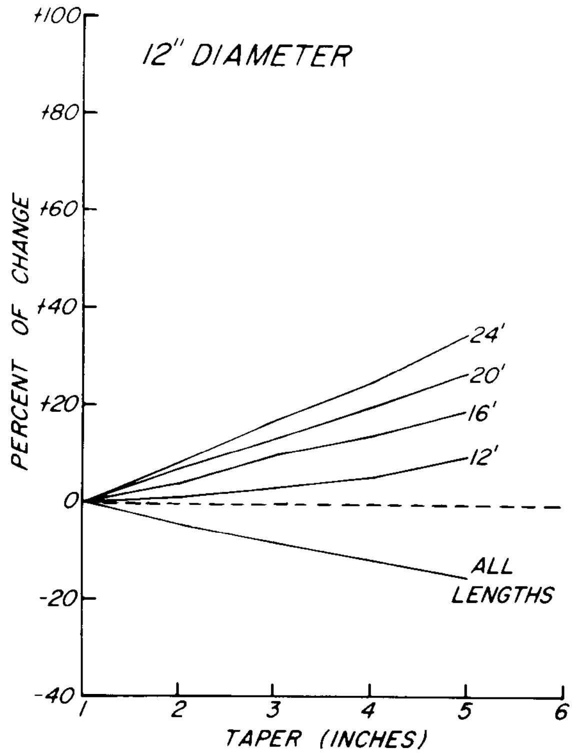
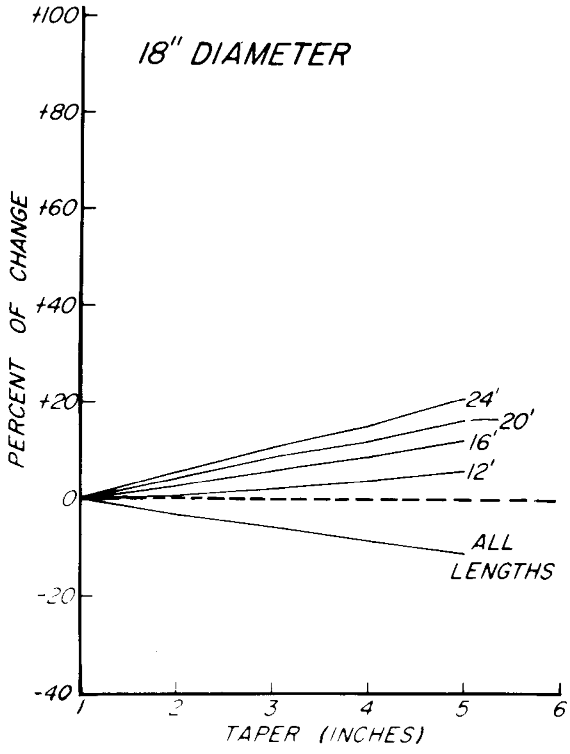
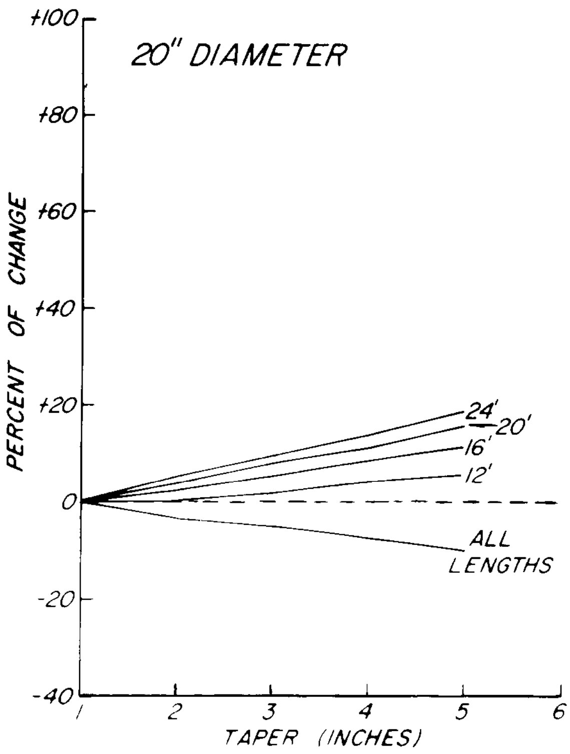


Figure 1.—This series of graphs compares the effect of taper on absolute board-foot yield when logs are scaled by conventional board-foot log rules (above the "0" y axis) and on LRF (below the "0" axis) when logs are scaled cubically for logs of 6 to 20 inches in diameter.









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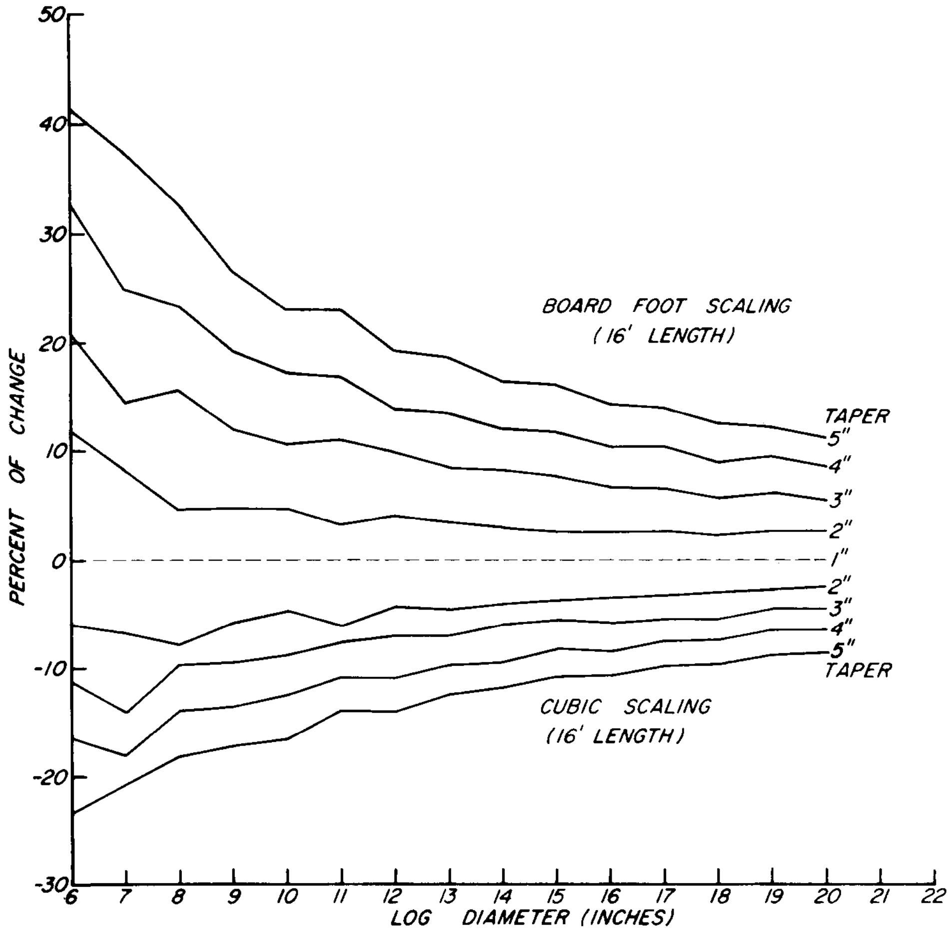

Figure 2.–The effect of log diameter on the absolute yield when logs are scaled by conventional board-foot log rules (above the "0" y axis) and on the LRF when the logs are cubically scaled for taper of 1 to 5 inches per 16 feet. All logs are 16 feet in length. **(M 146 627)**

cubic foot than logs with 1 inch of taper; with 3 inches of taper the loss is 9.3 percent, with 4 inches of taper 13.6 percent, increasing to 17.3 percent with 5 inches of taper. Losses decrease as diameter increases. Considering the 3-inch taper class as an example, the loss for 6 inches in diameter is 12.4 percent, for 10-inch diameter 9.3 percent, for 16-inch diameter 6.3 percent, and at 20 inches the loss is 5.0 percent.

It should be emphasized that all values shown are changes in the recovery compared to logs with l-inch taper per 16 feet.

Figure 2 summarizes the yield gains and losses by l-inch diameter classes for the 16-foot log length and taper classes of 1 to 5 inches per 16 feet. Again, the "0" base line is the yield from logs with l-inch taper per 16 feet. It is quite obvious that gains from board-foot scaled logs and losses in cubic foot logs are highest at the smallest diameter and lowest for the largest diameter. For example, gains in board-foot-scaled 5-inch-taper logs decline from 41.2 percent at 6 inches to 11.2 percent at 20 inches. Comparable values for cubically scaled logs are –23.3 percent at 6-inch diameter and -8.7 percent at 20-inch diameter.

The actual percentages of additional lumber yield with increasing taper for all the study logs are shown in table 2. The reduction percentages for increasing taper when logs are cubically scaled are presented in table 3.

The actual board foot and LRF data from which the percentages were calculated are given in table 4.

The LRF and board-foot values in table 4

Table 2.–Increase in board-foot yields for logs 6 to 20 inches in diameter, 8 to 24 feet in length, and with taper 1 to 5 inches per 16 feet. The yield at I-inch taper is used as the baseline. All yields are expressed as percentages.

PERCENTAGE YIELD ABOVE YIELD AT 1 INCH TAPER LEVEL

DIAMETER	TAPER	LENGTH (FT.)								
(IN.)	(IN.)	8	10	12	14	16	18	20	22	24
6.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	.0	10.5	8.3	10.3	11.8	15.4	13.3	16.0	18.2
	3	.0	10.5	16.7	17.2	20.6	25.6	26.7	30.0	40.0
	4	.0	15.8	20.8	27.6	32.4	35.9	44.4	56.0	63.6
	5	.0	15.8	25.0	37.9	41.2	53.8	66.7	78.0	90.9
7.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	.0	.0	5.7	4.8	8.3	9.1	11.3	13.0	14.5
	3	.0	3.4	8.6	9.5	14.6	16.4	22.6	30.4	35.5
	4	.0	6.9	17.1	19.0	25.0	32.7	38.7	44.9	51.3
	5	.0	10.3	17.1	23.8	37.5	45.5	51.6	60.9	72.4
8.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	.0	.0	4.3	5.5	4.7	9.7	12.2	15.6	16.0
	3	.0	.0	6.4	9.1	15.6	20.8	22.0	26.7	28.0
	4	.0	5.1	10.6	20.0	23.4	29.2	32.9	41.1	46.0
	5	.0	7.7	14.9	27.3	32.8	41.7	46.3	55.6	60.0
9.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	.0	2.0	1.6	2.8	4.8	7.4	9.5	10.3	10.9
	3	.0	2.0	4.9	9.7	12.0	16.0	19.0	21.4	24.0
	4	.0	4.0	9.8	15.3	19.3	24.5	29.5	33.3	37.2
	5	.0	6.0	14.8	19.4	26.5	33.0	39.0	45.3	49.6
10.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	.0	.0	1.3	3.3	4.8	4.2	6.0	7.4	9.9
	3	.0	1.6	5.2	7.7	10.6	12.6	16.5	18.2	20.4
	4	.0	3.1	7.8	13.2	17.3	20.2	24.1	26.4	31.5
	5	.0	4.7	11.7	17.6	23.1	27.7	33.1	36.5	42.6
11.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	.0	1.3	1.1	1.8	3.2	4.9	7.5	9.0	10.8
	3	.0	1.3	3.2	7.3	11.1	14.0	16.4	18.1	20.6
	4	.0	2.6	6.4	11.8	16.7	20.3	23.9	26.6	29.9
	5	.0	5.1	10.6	16.4	23.0	26.6	32.1	35.6	39.7
12.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	.0	.0	.9	2.3	4.0	5.8	6.8	7.1	7.7
	3	.0	1.1	2.7	6.8	9.9	11.1	13.1	15.1	16.7
	4	.0	2.2	5.3	9.8	13.9	17.0	19.9	22.6	24.9
	5	.0	4.3	9.7	14.4	19.2	23.4	27.2	30.7	34.8
13.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	.0	.9	2.3	2.6	3.4	4.5	5.4	7.3	8.1
	3	.0	1.8	3.8	6.5	8.5	10.4	12.9	13.7	15.8
	4	.0	3.7	7.6	11.0	13.6	16.4	17.9	21.0	22.8
	5	.0	4.6	9.9	14.3	18.6	20.9	25.0	28.2	31.3

PERCENTAGE YIELD ABOVE YIELD AT 1 INCH TAPER LEVEL

DIAMETER (IN.)	TAPER (IN.)	LENGTH (FT.)								
		8	10	12	14	16	18	20	22	24
14.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	.0	.8	2.0	2.2	2.9	4.7	6.1	6.9	7.3
	3	.0	1.6	3.3	5.6	8.2	9.8	11.5	13.5	14.5
	4	.0	3.1	6.5	10.6	12.1	15.4	17.6	19.8	21.1
	5	.0	3.9	9.8	12.8	16.4	19.7	22.6	26.0	28.4
15.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	.0	.7	1.1	2.4	2.5	4.5	6.0	6.6	7.4
	3	.0	1.4	4.0	5.3	7.6	9.7	11.3	12.0	13.7
	4	.0	2.7	5.6	10.1	11.8	14.1	16.3	18.0	19.8
	5	.0	3.4	8.5	12.6	16.0	19.0	21.7	24.0	26.9
16.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	.0	.0	1.0	1.3	2.6	3.6	4.1	4.5	6.0
	3	.0	1.2	2.5	4.6	6.6	8.1	9.9	11.0	12.2
	4	.0	1.2	4.9	7.6	10.3	12.0	14.2	15.5	17.3
	5	.0	2.4	7.9	11.3	14.3	16.8	20.1	21.8	24.5
17.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	.0	.0	.9	1.9	2.6	3.2	4.4	5.6	6.2
	3	.0	.5	2.2	4.1	6.5	7.7	9.3	10.7	12.2
	4	.0	1.6	3.9	7.8	10.4	11.7	13.4	14.9	17.1
	5	.0	2.1	6.5	10.4	14.0	16.0	17.5	20.5	22.8
18.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	.0	.9	.4	1.7	2.3	3.3	3.7	4.6	5.1
	3	.0	1.4	1.9	3.6	5.5	7.4	8.5	9.3	10.2
	4	.0	1.4	3.8	6.9	8.9	11.3	12.1	13.7	15.1
	5	.0	2.3	6.2	9.6	12.4	14.8	16.7	18.8	20.8
19.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	.0	.8	1.0	1.8	2.6	3.2	3.9	4.5	5.1
	3	.0	1.3	2.4	4.5	6.0	7.1	8.7	9.5	10.1
	4	.0	2.1	4.9	7.8	9.4	10.8	12.0	14.0	14.8
	5	.0	2.9	6.3	10.1	12.2	14.3	16.1	18.3	19.9
20.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	.0	.4	.6	1.3	2.6	3.1	3.7	4.5	4.8
	3	.0	.8	2.2	3.7	5.4	6.8	8.0	8.7	9.5
	4	.0	1.5	4.1	6.7	8.6	10.4	11.2	12.6	13.7
	5	.0	3.0	5.6	8.8	11.2	13.7	15.4	17.0	18.6

Table 3.–Reduction in LRF or board-foot yield per cubic foot of scaled log for logs 6 to 20 inches in diameter, 8 to 24 feet in length, and with taper 1 to 5 inches per 16 feet. All percentages are calculated assuming yields from l-inch taper logs as the baseline.

PERCENTAGE LRF BELOW LRF AT 1 INCH TAPER LEVEL

DIAMETER (IN.)	TAPER (IN.)	LENGTH(FT.)								
		8	10	12	14	16	18	20	22	24
6.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	-7.9	-5.0	-7.8	-4.6	-5.9	-5.2	-6.9	-7.6	-7.3
	3	-15.2	-12.0	-10.8	-10.2	-11.2	-12.1	-14.7	-15.3	-12.9
	4	-21.7	-17.6	-18.0	-16.1	-16.5	-19.8	-18.2	-17.1	-16.5
	5	-27.7	-23.9	-24.1	-20.7	-23.3	-22.2	-20.5	-20.8	-19.8
7.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	-6.9	-8.5	-5.5	-5.9	-6.7	-6.2	-7.1	-6.9	-6.8
	3	-13.2	-13.9	-11.8	-12.3	-14.0	-14.2	-13.2	-10.2	-9.8
	4	-19.0	-18.2	-15.4	-16.2	-17.9	-15.9	-15.6	-15.7	-16.1
	5	-24.4	-22.9	-21.6	-22.1	-20.6	-19.7	-20.9	-20.4	-20.0
8.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	-6.0	-5.5	-6.3	-6.6	-7.7	-5.4	-3.2	-2.2	-3.4
	3	-11.7	-12.5	-12.2	-12.0	-9.8	-8.4	-8.8	-9.1	-10.2
	4	-17.0	-16.5	-16.0	-13.6	-13.9	-14.2	-13.9	-13.0	-13.6
	5	-21.8	-20.5	-19.8	-17.1	-18.0	-16.9	-17.8	-17.4	-18.8
9.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	-5.4	-6.1	-6.7	-6.5	-5.8	-4.4	-4.8	-5.1	-5.6
	3	-10.5	-11.0	-11.2	-9.0	-9.4	-9.2	-9.3	-9.8	-9.7
	4	-15.2	-15.6	-14.5	-13.5	-13.5	-13.1	-13.3	-13.8	-14.4
	5	-19.7	-19.3	-18.3	-17.6	-17.0	-17.5	-17.9	-18.0	-19.0
10.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	-4.9	-5.0	-6.0	-5.2	-4.8	-6.4	-6.6	-6.2	-5.4
	3	-9.5	-10.2	-9.6	-9.5	-8.8	-9.3	-8.7	-9.4	-10.0
	4	-13.8	-13.5	-13.4	-12.6	-12.4	-13.3	-13.9	-14.8	-14.6
	5	-18.0	-17.2	-16.6	-16.0	-16.4	-16.8	-17.3	-18.6	-18.8
11.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	-4.4	-4.6	-5.9	-6.1	-6.1	-5.6	-4.0	-3.5	-2.6
	3	-8.7	-9.2	-10.2	-9.0	-7.4	-7.2	-7.0	-7.4	-7.4
	4	-12.7	-13.0	-13.0	-11.6	-10.8	-10.8	-11.2	-11.8	-11.9
	5	-16.5	-16.1	-15.9	-14.9	-13.7	-14.8	-14.7	-15.5	-16.2
12.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	-4.1	-4.3	-5.3	-5.0	-4.3	-3.7	-3.8	-4.2	-4.7
	3	-8.0	-8.3	-8.8	-7.8	-6.9	-7.6	-8.1	-8.1	-8.5
	4	-11.7	-12.1	-11.9	-11.3	-10.8	-11.0	-11.4	-12.1	-12.8
	5	-15.3	-14.6	-14.1	-13.9	-14.0	-14.1	-14.9	-15.8	-16.2
13.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	-3.8	-3.8	-3.9	-4.2	-4.5	-4.1	-4.1	-3.5	-3.7
	3	-7.4	-7.1	-7.3	-6.6	-6.9	-6.7	-6.5	-7.3	-7.8
	4	-10.8	-10.2	-9.7	-9.2	-9.8	-9.7	-10.9	-11.1	-12.2
	5	-14.2	-13.3	-12.7	-12.4	-12.4	-13.4	-13.9	-14.4	-15.7

PERCENTAGE LRF BELOW LRF AT 1 INCH TAPER LEVEL

DIAMETER (IN.)	TAPER (IN.)					LENGTH (FT.)				
		8	10	12	14	16	18	20	22	24
14.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	-3.5	-3.7	-3.7	-4.2	-4.1	-3.5	-3.0	-3.0	-3.4
	3	-6.9	-7.2	-7.5	-6.9	-6.0	-6.5	-6.6	-6.4	-7.1
	4	-10.1	-9.8	-9.5	-8.5	-9.4	-8.9	-9.6	-10.1	-11.1
	5	-13.2	-13.0	-11.3	-12.0	-11.8	-12.6	-13.4	-13.8	-14.8
15.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	-3.3	-3.7	-3.9	-3.4	-3.8	-3.1	-2.6	-2.6	-2.7
	3	-6.4	-6.8	-6.1	-6.5	-5.6	-5.5	-5.5	-6.3	-6.7
	4	-9.5	-9.7	-9.2	-7.8	-8.2	-8.5	-9.1	-9.6	-10.5
	5	-12.4	-12.3	-11.3	-10.7	-10.7	-11.4	-12.3	-13.0	-13.7
16.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	-3.1	-3.9	-3.9	-4.0	-3.5	-3.4	-3.6	-4.0	-3.6
	3	-6.0	-6.6	-6.6	-6.0	-5.9	-5.9	-5.9	-6.3	-6.8
	4	-8.9	-9.8	-8.8	-8.6	-8.4	-8.8	-9.3	-10.4	-11.1
	5	-11.7	-12.5	-10.7	-10.2	-10.7	-11.2	-11.5	-12.9	-13.6
17.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	-2.9	-3.4	-3.3	-3.3	-3.3	-3.3	-3.0	-2.6	-2.7
	3	-5.7	-6.2	-6.2	-6.1	-5.4	-5.5	-5.5	-5.6	-5.9
	4	-8.4	-8.7	-8.8	-7.6	-7.5	-8.0	-8.9	-9.4	-9.7
	5	-11.1	-11.6	-10.6	-10.1	-9.8	-10.4	-11.8	-12.1	-12.9
18.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	-2.7	-2.5	-3.6	-3.2	-3.0	-3.0	-3.3	-3.1	-3.2
	3	-5.4	-5.5	-5.9	-5.8	-5.5	-5.2	-5.5	-6.0	-6.5
	4	-8.0	-8.4	-8.2	-7.6	-7.5	-7.6	-8.6	-9.3	-9.8
	5	-10.5	-10.9	-9.8	-9.7	-9.6	-10.2	-11.1	-11.8	-12.7
19.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	-2.6	-2.6	-2.9	-2.8	-2.7	-2.6	-2.8	-2.7	-2.7
	3	-5.1	-5.2	-5.3	-4.7	-4.6	-4.7	-4.7	-5.1	-5.7
	4	-7.6	-7.6	-6.7	-6.3	-6.4	-7.2	-7.9	-7.9	-9.0
	5	-10.0	-9.8	-9.0	-8.3	-8.8	-9.6	-10.5	-10.9	-11.8
20.0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	2	-2.5	-2.7	-3.2	-3.1	-2.4	-2.5	-2.5	-2.5	-2.7
	3	-4.9	-5.4	-5.3	-5.0	-4.6	-4.5	-4.5	-5.2	-5.6
	4	-7.2	-7.5	-7.1	-6.5	-6.4	-6.7	-7.5	-8.1	-8.9
	5	-9.5	-9.2	-9.0	-8.6	-8.7	-9.0	-9.7	-10.7	-11.5

Table 4.–Actual board-foot yields and Lumber Recovery Factors (LRF) for all logs computer sawn by BOF in the study.

DIAMETER (IN.)	TAPER (IN.)	YIELD AND LRF								
		LENGTH (FT.)								
		8	10	12	14	16	18	20	22	24
6.0	1	15	19	24	29	34	39	45	50	55
		9.00	9.06	9.22	9.16	9.21	9.27	9.33	9.27	9.18
	2	15	21	26	32	38	45	51	58	65
		8.28	8.61	8.51	8.74	8.67	8.79	8.69	8.56	8.51
	3	15	21	28	34	41	49	57	65	77
		7.63	7.97	8.22	8.23	8.18	8.15	7.96	7.86	7.99
	4	15	22	29	37	45	53	65	78	90
		7.04	7.46	7.56	7.69	7.69	7.44	7.63	7.69	7.67
	5	15	22	30	40	48	60	75	89	105
		6.51	6.89	7.00	7.26	7.07	7.21	7.42	7.34	7.37
7.0	1	22	29	35	42	48	55	62	69	76
		9.71	10.06	9.91	9.86	9.91	9.77	9.74	9.67	9.63
	2	22	29	37	44	52	60	69	78	87
		9.04	9.20	9.37	9.28	9.25	9.16	9.05	9.00	8.98
	3	22	30	38	46	55	64	76	90	103
		8.43	8.66	8.73	8.64	8.53	8.38	8.46	8.68	8.69
	4	22	31	41	50	60	73	86	100	115
		7.86	8.23	8.38	8.26	8.14	8.21	8.23	8.15	8.08
	5	22	32	41	52	66	80	94	111	131
		7.34	7.75	7.76	7.68	7.87	7.84	7.71	7.69	7.70
8.0	1	31	39	47	55	64	72	82	90	100
		10.38	10.33	10.31	10.19	10.19	10.07	10.02	9.92	9.93
	2	31	39	49	58	67	79	92	104	116
		9.76	9.76	9.65	9.51	9.40	9.53	9.70	9.70	9.59
	3	31	39	50	60	74	87	100	114	128
		9.17	9.04	9.05	8.96	9.19	9.22	9.13	9.02	8.92
	4	31	41	52	66	79	93	109	127	146
		8.62	8.62	8.66	8.81	8.77	8.65	8.62	8.63	8.58
	5	31	42	54	70	85	102	120	140	160
		8.12	8.21	8.27	8.44	8.36	8.37	8.23	8.19	8.06
9.0	1	41	50	61	72	83	94	105	117	129
		10.98	10.70	10.70	10.58	10.52	10.45	10.40	10.36	10.32
	2	41	51	62	74	87	101	115	129	143
		10.39	10.05	9.98	9.90	9.92	9.99	9.90	9.84	9.75
	3	41	51	64	79	93	109	125	142	160
		9.83	9.53	9.50	9.63	9.53	9.49	9.44	9.34	9.32
	4	41	52	67	83	99	117	136	156	177
		9.31	9.04	9.15	9.15	9.11	9.08	9.02	8.93	8.84
	5	41	53	70	86	105	125	146	170	193
		8.82	8.64	8.74	8.73	8.73	8.62	8.54	8.50	8.36
10.0	1	50	64	77	91	104	119	133	148	162
		11.09	11.00	10.97	10.92	10.80	10.83	10.80	10.79	10.70
	2	50	64	78	94	109	124	141	159	178
		10.55	10.45	10.31	10.35	10.29	10.14	10.09	10.12	10.12
	3	50	65	81	98	115	134	155	175	195
		10.04	9.88	9.91	9.88	9.85	9.82	9.87	9.77	9.63
	4	50	66	83	103	122	143	165	187	213
		9.56	9.52	9.50	9.54	9.46	9.40	9.30	9.19	9.14
	5	50	67	86	107	128	152	177	202	231
		9.10	9.11	9.15	9.17	9.03	9.02	8.93	8.78	8.69

YIELD AND LRF

DIAMETER (IN.)	TAPER (IN.)	LENGTH (FT.) 8	10	12	14	16	18	20	22	24
11.0	1	62 11.28	78 11.22	94 11.16	110 11.06	126 10.96	143 10.90	159 10.80	177 10.77	194 10.67
	2	62 10.78	79 10.70	95 10.50	112 10.38	130 10.29	150 10.29	171 10.36	193 10.39	215 10.39
	3	62 10.31	79 10.19	97 10.02	118 10.07	140 10.15	163 10.12	185 10.04	209 9.96	234 9.88
	4	62 9.85	80 9.76	100 9.71	123 9.77	147 9.78	172 9.72	197 9.59	224 9.49	252 9.41
	5	62 9.42	82 9.41	104 9.38	128 9.42	155 9.46	181 9.29	210 9.21	240 9.09	271 8.94
12.0	1	73 11.27	93 11.24	113 11.25	132 11.19	151 11.08	171 11.02	191 10.98	212 10.95	233 10.92
	2	73 10.81	93 10.75	114 10.66	135 10.63	157 10.60	181 10.61	204 10.56	227 10.49	251 10.41
	3	73 10.37	94 10.30	116 10.26	141 10.31	166 10.32	190 10.18	216 10.09	244 10.06	272 10.00
	4	73 9.95	95 9.88	119 9.91	145 9.92	172 9.89	200 9.81	229 9.72	260 9.62	291 9.52
	5	73 9.55	97 9.59	124 9.67	151 9.64	180 9.53	211 9.46	243 9.35	277 9.22	314 9.16
13.0	1	87 11.37	109 11.29	131 11.24	154 11.18	177 11.16	201 11.11	224 11.05	248 11.01	272 10.98
	2	87 10.95	110 10.86	134 10.80	158 10.72	183 10.66	210 10.66	236 10.60	266 10.62	294 10.58
	3	87 10.54	111 10.49	136 10.42	164 10.44	192 10.39	222 10.36	253 10.33	282 10.20	315 10.13
	4	87 10.14	113 10.14	141 10.15	171 10.15	201 10.07	234 10.03	264 9.84	300 9.78	334 9.65
	5	87 9.76	114 9.79	144 9.81	176 9.79	210 9.77	243 9.62	280 9.51	318 9.42	357 9.26
14.0	1	101 11.49	127 11.42	153 11.36	180 11.34	207 11.28	234 11.24	261 11.19	288 11.12	317 11.10
	2	101 11.08	128 10.99	156 10.94	184 10.86	213 10.82	245 10.84	277 10.85	308 10.79	340 10.72
	3	101 10.70	129 10.60	158 10.51	190 10.56	224 10.61	257 10.51	291 10.45	327 10.41	363 10.31
	4	101 10.32	131 10.30	163 10.28	199 10.38	232 10.22	270 10.24	307 10.11	345 10.00	384 9.86
	5	101 9.97	132 9.94	168 10.08	203 9.98	241 9.95	280 9.82	320 9.68	363 9.59	407 9.46
15.0	1	118 11.64	147 11.54	177 11.47	207 11.41	238 11.35	269 11.31	300 11.26	333 11.25	364 11.19
	2	118 11.25	148 11.11	179 11.02	212 11.02	244 10.91	281 10.96	318 10.97	355 10.95	391 10.89
	3	118 10.89	149 10.75	184 10.77	218 10.67	256 10.71	295 10.69	334 10.64	373 10.54	414 10.44
	4	118 10.53	151 10.42	187 10.42	228 10.52	266 10.42	307 10.35	349 10.24	393 10.17	436 10.01
	5	118 10.19	152 10.12	192 10.17	233 10.19	276 10.13	320 10.02	365 9.88	413 9.79	462 9.65

YIELD AND LRF

DIAMETER (IN.)	TAPER (IN.)	LENGTH (FT.)								
		8	10	12	14	16	18	20	22	24
16.0	1	135 11.75	169 11.66	203 11.60	238 11.55	273 11.50	309 11.45	344 11.40	381 11.40	417 11.36
	2	135 11.39	169 11.21	205 11.14	241 11.09	280 11.09	320 11.07	358 10.99	398 10.94	442 10.95
	3	135 11.04	171 10.89	208 10.83	249 10.85	291 10.81	334 10.78	378 10.73	423 10.68	468 10.58
	4	135 10.70	171 10.52	213 10.57	256 10.56	301 10.53	346 10.44	393 10.34	440 10.21	489 10.10
	5	135 10.38	173 10.21	219 10.36	265 10.37	312 10.27	361 10.16	413 10.09	464 9.92	519 9.82
17.0	1	153 11.82	192 11.73	230 11.64	269 11.60	308 11.54	349 11.51	389 11.48	429 11.41	469 11.36
	2	153 11.48	192 11.32	232 11.26	274 11.21	316 11.16	360 11.13	406 11.14	453 11.12	498 11.06
	3	153 11.15	193 11.01	235 10.92	280 10.89	328 10.91	376 10.88	425 10.84	475 10.77	526 10.70
	4	153 10.83	195 10.71	239 10.62	290 10.72	340 10.68	390 10.59	441 10.46	493 10.35	549 10.26
	5	153 10.51	196 10.36	245 10.41	297 10.43	351 10.41	405 10.32	457 10.12	517 10.04	576 9.90
18.0	1	171 11.79	215 11.76	260 11.75	303 11.68	347 11.61	391 11.57	437 11.54	483 11.51	529 11.47
	2	171 11.47	217 11.47	261 11.33	308 11.31	355 11.26	404 11.22	453 11.16	505 11.15	556 11.11
	3	171 11.16	218 11.12	265 11.05	314 11.00	366 10.97	420 10.97	474 10.91	528 10.81	583 10.73
	4	171 10.85	218 10.78	270 10.79	324 10.79	378 10.74	435 10.69	490 10.54	549 10.44	609 10.35
	5	171 10.56	220 10.48	276 10.59	332 10.55	390 10.49	449 10.38	510 10.27	574 10.15	639 10.02
19.0	1	190 11.80	238 11.72	287 11.68	335 11.63	385 11.61	435 11.58	485 11.55	535 11.49	587 11.47
	2	190 11.50	240 11.42	290 11.34	341 11.30	395 11.30	449 11.28	504 11.22	559 11.18	617 11.16
	3	190 11.20	241 11.12	294 11.06	350 11.08	408 11.07	466 11.03	527 11.00	586 10.90	646 10.81
	4	190 10.91	243 10.84	301 10.90	361 10.89	421 10.86	482 10.75	543 10.63	610 10.58	674 10.44
	5	190 10.63	245 10.57	305 10.63	369 10.66	432 10.58	497 10.47	563 10.34	633 10.24	704 10.12
20.0	1	213 11.91	266 11.83	320 11.80	374 11.74	428 11.67	483 11.63	538 11.59	595 11.58	652 11.55
	2	213 11.61	267 11.51	322 11.42	379 11.37	439 11.39	498 11.34	558 11.30	622 11.29	683 11.24
	3	213 11.32	268 11.20	327 11.17	388 11.15	451 11.14	516 11.10	581 11.06	647 10.98	714 10.90
	4	213 11.05	270 10.94	333 10.96	399 10.98	465 10.93	533 10.85	598 10.71	670 10.64	741 10.52
	5	213 10.78	274 10.74	338 10.73	407 10.73	476 10.66	549 10.58	621 10.46	696 10.34	773 10.22

are the theoretical maximum yields and are not normally attained by sawmills. However, because the BOF program modeled the sawing to maximize yield under all conditions, any percentages or ratios derived from them-such as those in tables 2 and 3–are valid. Thus, beginning with an actual known yield value from a mill, such as overrun, and applying the percentage or ratio from tables 2, 3, or 4, will yield a valid prediction of the expected yield.

How to Use This Information

The authors feel the most important use of this information by industry will be to more precisely predict the expected lumber volume on a timber sale when it is measured and offered on a cubic foot basis. Most, if not all, mills know what their overrun is at present and the average taper of the logs that produced this overrun. Armed with these two items of basic information and tables 2, 3, and 4, it is possible to predict the board,-foot yield per cubic foot for logs with differing average taper.

Some examples follow.

Example 1: Assume a mill in which Scribner Scale is being used, overrun is 40 percent, average taper is 1 inch per 16-foot log length, the average log diameter is 13 inches, and the average log length is 16 feet. This means that actual recovery on this average log is 100-board feet Scribner Scale and 40-board feet overrun for a total of 140 board feet. If another timber sale is offered where the logs contain more taper-say 3 inches per 16 feet–how much less lumber should be expected per cubic foot of log volume? Referring to the 3-inch taper figure for 13-inch diameter and 16-foot length (table 3) we find that the expected yield is reduced by 6.9 percent. This means that the same number of cubic feet that are currently yielding 140 board feet with l-inch taper will yield only 130.3 board feet if the logs have 3 inches of taper:

$$140 - [140 \times .069] = 130.3$$

Example 2: Given the same situation as in Example 1 except that the timber offered for sale averages 10 inches in diameter, how much less yield per cubic foot can be expected?

First, look up in table 4 of the LRF for 13-inch diameter, 16-foot log with 1-inch taper (11.16). Next, look up the LRF for a 10-inch diameter, 16-foot log with 3 inches of taper (9.85). The indicated reduction is 11.7 percent:

$$\frac{11.16 - 9.85}{11.16} \times 100 = 11.7 \text{ percent.}$$

Example 3: Calculate the expected reduction in yield per cubic foot between two stands of timber-the first of which averages 13 inches and 2 inches of taper and the second of which averages the same diameter but 4 inches of taper-, assuming both will be cut into mostly 16-foot logs. Look up in table 3 the appropriate percentage reduction values for both average logs as compared to l-inch taper. They are -4.5 and -9.8 percent. This means that the 2-inch taper log yields 95.5 percent (100 - 4.5), as much per cubic foot as the l-inch taper log, and the 4-inch taper log yields 90.2 percent. Thus the loss can be calculated as:

$$\frac{95.5 - 90.2}{95.5} = 5.5 \text{ percent}$$

Example 4: In buying timber based on board-foot scale, table 2 and table 4 can be used to predict the added recovery that results from increasing levels of taper. Assume the mill is currently cutting logs averaging 12 inches in diameter, 16 feet in length, and with an average of l-inch taper per 16 feet and overrun based on Scribner Scale with these logs is 50 percent. A timber sale is offered whose logs average 11 inches in diameter, 16 feet in length, and 4 inches of taper. What change in overrun should be expected?

The Scribner Log Scale of the 12-inch log is 80 board feet and the 11-inch log is 70. In table 4 we find the expected board-foot yield of the 12-inch log to be 151 board feet. The current overrun of 50 percent added to the log scale of 80 feet indicates the mill is actually getting 123 board feet: (80 + [80 × 50 percent]). This means current yield in the mill is 79.5 percent of the maximum $\frac{120}{151} \times$

100 percent). The yield shown in table 4 for an 11-inch log with 4 inches taper per 16 feet is 147 board feet. Applying the 79.5 percent efficiency figure indicates this log will actually saw out 117 board feet (.795 × 147) in this mill. Thus, the indicated overrun is 67 percent ($\frac{117 - 70}{70} = 67$). This is an increase in overrun of 17 percent (67 - 50).

The examples given here are based on using the average log in each situation for prediction purposes. Some degree of error is present. It is a well known fact that the scale of the log which has the average diameter, length, and taper of a sample is not quite the same as the average of all the individual log scale volumes. Somewhat more accurate predictions can be made if the log samples, both the mill's current logs and those to be compared, are treated by their individual length, diameter, and taper classes.

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