USDA Forest Service Research Paper SE-118 September 1974

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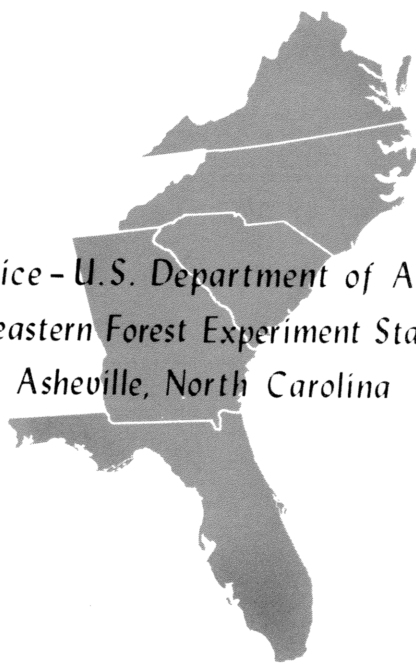

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Total utilization of our harvested timber is increasingly important. Residues which were once wasted and expensive to remove or destroy are now major sources of income. Slabs and edgings in the sawmill industry are an example. Although several studies have dealt with the volume of these residues, most, if not all, involved measurement of the outturn at the sawmill. An estimate of the portion of a log that goes into slabs and edgings, as well as kerf, can also be obtained directly from some of the log rule formulae. This paper illustrates how the International and Scribner Log Rule formulae can be used to estimate the volumes of slabs, edging, and kerf in saw logs, as well as 1-inch boards.

For forest managers primarily interested in the estimated volumes of these components according to the two log rules, tables of component volumes for various log lengths appear on pages 9 through 14. These tables are discussed on page 8. For those interested in the methods of deriving these tables, the equations from which the tables were generated are presented and discussed in the following sections on pages 1 through 8.

THE INTERNATIONAL LOG RULE

The International Rule allows a 2-inch taper in a 16-foot log. Increased lumber output resulting from log taper is accounted for by computing volumes in 4-foot sections and assuming a 1/2-inch increase in small-end diameter for each 4 feet of log length. The rule treats the 4-foot bolt as a cylinder with a volume in cubic feet of

$$V_c = \frac{\pi}{(12)^2} D^2 = 0.021817D^2 \qquad (1)$$

where D is the scaling diameter in inches. At 12 board feet per cubic foot, the total volume of the cylinder in board feet becomes

$$V_b = \frac{\pi}{12} D^2 = 0.261799D^2 . \qquad (2)$$

A portion of this total volume is lost in slabs, edgings, and saw kerf. Clark,[1] developer of the International Rule, also made an allowance for shrinkage. For each 1-inch board, he allowed 1/8 inch for kerf and 1/16 inch for shrinkage. Thus, the total thickness needed for each 1-inch green board is 1 + 1/8 + 1/16 inch, or 19/16 inches. Of this total, 16/19 is saved as boards, slabs, and edgings. He therefore adjusted equation (2) for the loss to kerf and shrinkage as follows:

$$\left(\frac{16}{19}\right) 0.261799D^2 = 0.220463D^2.$$

Clark determined that the volume in slabs and edgings was proportional to the surface of the cylinder. This relationship meant that a constant could be developed which, when multiplied by diameter, would account for these residues. He determined this constant in terms of board feet to be 0.71 for white pine logs. On the assumption that this constant is applicable to other species, he derived a formula for lumber volume of a 4-foot bolt on the basis of a 1/8-inch kerf:

$$V_{b'} = 0.220463D^2 - 0.71D. \tag{3}$$

Because many mills use a 1/4-inch saw, Bruce and Schumacher[2] adjusted equation (3) for the larger kerf. Their allowance for each board was 1 + 1/16 + 4/16 inch, or 21/16 inches, and 16/21 (the amount left after the allowance for kerf and shrinkage) is 90.48 percent of 16/19 (the remainder after the kerf and shrinkage allowance for a 1/8-inch kerf). From this computation, they derived a new equation for lumber volume in board feet on the basis of a 1/4-inch kerf:

$$V_{b''} = 0.9048\ V_{b'} = 0.199467D^2 - 0.642381D. \tag{4}$$

When only the board foot content is considered, the adjustment applied to equation (4) is logically sound. However, as we sought to develop equations for measuring kerf and slab-edging volumes, we observed that the Bruce-Schumacher technique for converting to the 1/4-inch rule adjusted only the board foot allowance for the additional kerf produced by the 1/4-inch saw. Clark, in developing the 1/8-inch rule, adjusted the entire bolt volume for loss to kerf and shrinkage. Although Bruce and Schumacher make no comment about measuring kerf and slab-edging volumes, it seems evident from their adjustment that they were not concerned with estimating these values, and, further, that their adjustment imposes the proposition that slab-edging volume varies with kerf width. Paradoxically, if the adjustment for the 1/4-inch kerf is applied to the entire bolt volume instead of only to lumber volume as in equation (4), we would have to adopt the premise that loss to slabs and edging is the same regardless of kerf width. Because the actual differences between the two approaches are relatively minor and we have no hard evidence on vari-

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[1] Clark, Judson F. The measurement of sawlogs. For. Q. 14(2): 79-93. 1906.

[2] Bruce, Donald, and Schumacher, Francis X. Forest Mensuration. Ed. 3, 434 pp. New York: McGraw-Hill Book Co., Inc. 1950.

ation in slab-edging volume in relation to kerf width, our model is designed to accommodate both Clark's 1/8-inch kerf and Bruce and Schumacher's 1/4-inch kerf.

Through the introduction of the parameter β, equations (3) and (4) for lumber volume can be generalized and expressed in cubic feet as

$$V_{\ell} = \left(\frac{16}{\beta}\right) V_c - \left(\frac{19}{\beta}\right) \gamma D = \frac{0.349066}{\beta} D^2 - \frac{1.124167}{\beta} D \qquad (5)$$

where

β = the number of 1/16-inch units needed to produce a 1-inch board when kerf and shrinkage are considered

and

$\gamma = 0.05916667.$

The γ coefficient is simply Clark's slab-edging coefficient converted to cubic feet,that is,

$\gamma = 0.71/12.$

Equations (3), (4), and (5) were derived by using a cylindrical log model. To establish estimates of kerf and slab-edging volumes, we must consider the difference in volume between a frustum of a cone and a cylinder with the same diameter as that of the small end of the frustum.[3] The cubic foot volume of a 4-foot-long cone frustum is

$$V_f = \frac{4\pi}{(12)^3} (3D^2 + 3D\tau + \tau^2) = 0.021817D^2 + 0.021817(\tau)D + 0.007272(\tau^2) \qquad (6)$$

where τ (taper) represents the difference in inches between the end diameters of the cone frustum. The volume in addition to the cylinder is then the difference between equation (6) and equation (1), or

$$V_d = \frac{4\pi}{(12)^3} (3D^2 + 3D\tau + \tau^2) = 0.021817(\tau)D + 0.007272(\tau^2). \qquad (7)$$

The unadjusted slab-edging volume in cubic feet is given as γD; hence, this residue volume for the cone frustum then becomes

$$V_{se} = \gamma D + \left(\frac{16}{\beta}\right) V_d = 0.059167D + 0.349066\left(\frac{\tau}{\beta}\right) D + 0.116355\left(\frac{\tau^2}{\beta}\right) \qquad (8)$$

[3] There may be debate as to whether a frustum of a cone represents a log, but Clark's specification of a constant increase in diameter per 4-foot increase in the cylinder length implies such a geometric form.

where $\frac{16}{\beta}$ is that portion of V_d not attributable to kerf or shrinkage.

The kerf volume produced when sawing the cone frustum can be calculated in cubic feet according to the generalized equation (5) as

$$V_k = \left(\frac{\beta-16-\sigma}{\beta}\right) V_f - \left(\frac{\beta-19}{\beta}\right) YD$$

$$= \left[0.021817 - \frac{0.349066}{\beta} - 0.021817\left(\frac{\sigma}{\beta}\right)\right] D^2$$

$$+ \left[0.021817(\tau) - 0.349066\left(\frac{\tau}{\beta}\right) - 0.021817\left(\frac{\tau\sigma}{\beta}\right) - 0.059167 + \frac{1.124167}{\beta}\right] D$$

$$+ 0.007272(\tau^2) - 0.116355\left(\frac{\tau^2}{\beta}\right) - 0.007272\left(\frac{\tau^2\sigma}{\beta}\right) \qquad (9)$$

where σ is a parameter representing the number of 1/16-inch units allowed for shrinkage.

To account for the remaining bolt volume, shrinkage can be calculated in cubic feet as

$$V_{sh} = \left(\frac{\sigma}{\beta}\right) V_f = 0.021817\left(\frac{\sigma}{\beta}\right) D^2 + 0.021817\left(\frac{\tau\sigma}{\beta}\right) D$$

$$+ 0.007272\left(\frac{\tau^2\sigma}{\beta}\right). \qquad (10)$$

Equations (5), (8), (9), and (10) account for the entire cubic volume of a 4-foot-long frustum of a cone. To produce volume estimates of the four quantities for logs of varying lengths, an appropriate number of 4-foot units (plus, in some cases, a fraction of a unit) must be summed, with the summation allowing for a uniform increase in the scaling diameter for each additional section. The following equations result:

$$_LV_\ell = 0.087266\left(\frac{L}{\beta}\right) D^2 - \left[0.281042\left(\frac{L}{\beta}\right) - 0.087266\left(\frac{\eta\tau}{\beta}\right)[2L - 4(\eta+1)]\right] D - \left[0.140521\left(\frac{\eta\tau}{\beta}\right)[2L - 4(\eta+1)] - 0.029089\left(\frac{\tau^2}{\beta}\right)[-8\eta^3+3\eta^2(L-2)+2\eta]\right], \qquad (11)$$

$$_LV_k = \left[0.005454\left(\frac{\beta-16-\sigma}{\beta}\right)L\right] D^2 - \left[0.014792\left(\frac{\beta-19}{\beta}\right) L\right.$$

$$- 0.001364\left(\frac{\beta-16-\sigma}{\beta}\right)\tau L^2\Big] D - \Big[0.007396\left(\frac{\eta\tau}{\beta}\right)(\beta-19)[2L$$

$$- 4(\eta+1)] - 0.000114\left(\frac{\beta-16-\sigma}{\beta}\right)\tau^2 L^3\Big] , \qquad (12)$$

$${}_L V_{se} = \left[0.014792(L) + 0.087266\left(\frac{\tau}{\beta}\right)\left(\frac{L^2}{4} - \eta[2L - 4(\eta+1)]\right)\right] D$$

$$+ \Big[0.007396(\eta\tau)[2L - 4(\eta+1)] + 0.029089\left(\frac{\tau^2}{\beta}\right)\Big(\frac{L^3}{16}$$

$$- [-8\eta^3 + 3\eta^2(L-2) + 2\eta]\Big)\Big] , \qquad (13)$$

and

$${}_L V_{sh} = \left[0.005454\left(\frac{\sigma L}{\beta}\right)\right] D^2 + \left[0.001364\left(\frac{\sigma\tau L^2}{\beta}\right)\right] D$$

$$+ \left[0.000114\left(\frac{\sigma\tau^2 L^3}{\beta}\right)\right] \qquad (14)$$

where ${}_L V_\ell$ = board foot volume expressed in cubic feet,

${}_L V_k$ = saw kerf volume in cubic feet,

${}_L V_{se}$ = slab-edging volume (chip volume) in cubic feet,

${}_L V_{sh}$ = shrinkage volume in cubic feet,

L = log length in feet,

η = number of complete 4-foot bolts (i.e., the integer part of $L/4$),

and all other parameters are as previously defined. The method of deriving equations (11), (12), (13), and (14) is presented in the appendix. To produce board foot estimates of lumber volume, equation (11) should be multiplied by 12.

It should be remembered that equations (11), (12), (13), and (14) are based on the following assumptions:

(A) All component volumes are based on 4-foot-long sections and log volumes are obtained by adding an appropriate number of sections plus a fraction of a 4-foot section when log lengths are not multiples of 4,

(B) the geometric shape of the 4-foot sections is a frustum of a cone,

(C) kerf and shrinkage volumes are proportional to bolt volume,

(D) the slab-edging volume is proportional to log circumference, or scaling diameter, and Clark's constant (0.71) developed for sawing white pine logs is applicable to other species.

As an example of how equations (11), (12), (13), and (14) can be used, consider equation (11) and the parameter values

L = 4 feet,

β = twenty-one 1/16-inch units per board,

η = 1 complete 4-foot section, and

τ = 0.5 inch of taper per 4 feet of log length (equivalent to 2-inch taper for 16-foot log).

Substituting these values into equation (11) and multiplying by 12 yields the equation for lumber volume in board feet for a 1/4-inch kerf and a 4-foot bolt as given by Bruce and Schumacher (see equation (4)):

$$_{4}V_{\ell}\ (12) = 0.1995D^2 - 0.6424D. \qquad (15)$$

Equations for estimating the volumes of saw kerf, slabs and edging, and shrinkage can be similarly developed from equations (12), (13), and (14). Implicit in all of these equations are the assumptions that the lumber product consists only of 1-inch boards and that σ equals one 1/16-inch unit per board. Additional modification of equations (11) through (14) can be made to allow for variable board thickness and the scant sawing practices of today.

THE SCRIBNER LOG RULE

The Scribner Log Rule is based on diagrams of circles, with a 1/4-inch kerf allowance for each 1-inch board plotted. In the construction of the rule, no taper was recognized, that is, the log was considered to be a 16-foot cylinder with a diameter equal to that of the small end of the log. The board foot contents of logs of the same diameter are, therefore, directly proportional to log length.

Although in the construction of the rule no thought was given to curve form and its relationship to volume, plotted Scribner values define a parabolic curve.[4] Using the method of least squares, Bruce and Schumacher fitted a curve to the Scribner values and produced the following equation for estimating the volume of a 16-foot log in board feet:

[4] Bruce and Schumacher, loc. cit.

$$ {}_{16}V_{\ell} = 0.79D^2 - 1.98D - 4.3 \quad (16) $$

where D equals the scaling diameter.

Although values calculated from this equation deviate slightly from the original Scribner volumes for a 16-foot log, over a wide range the deviations are no greater than those produced by rounding the original Scribner values to the nearest 10 feet to produce the Decimal C Rule.

Because board foot content is directly proportional to length under the Scribner Rule, it is legitimate to reduce equation (16) to the volume for a 1-foot section in cubic feet:

$$ {}_{1}V_{\ell} = \frac{0.790}{(16)(12)} D^2 - \frac{1.98}{(16)(12)} D - \frac{4.3}{(16)(12)} $$

$$ = 0.004115D^2 - 0.010312D - 0.022396. \quad (17) $$

Therefore, the equation for the lumber volume of an L-foot-long log in cubic feet is

$$ {}_{L}V_{\ell} = 0.004115(L)D^2 - 0.010312(L)D - 0.022396(L). \quad (18) $$

The cubic foot volume for an L-foot-long frustum is

$$ {}_{L}V_{f} = 0.005454(L)D^2 + 0.005454(L^2\delta)D + 0.001818(L^3\delta^2) \quad (19) $$

where δ equals the difference in diameter between the ends of any 1-foot section of a frustum and by definition is constant for any of these sections.

If we consider kerf to be proportional to bolt volume as with the International Rule, we have for the cubic foot volume of kerf resulting from sawing the frustum

$$ {}_{L}V_{k}^{*} = (0.2)\,{}_{L}V_{f} = 0.001091(L)D^2 + 0.001091(L^2\delta)D $$

$$ + 0.000364(L^3\delta^2) \quad (20) $$

where all parameters are as previously defined. Added to the above quantity is an allowance for kerf produced when the boards are edged. This additional kerf is obviously a function of the number of boards sawn. The approximate number of boards produced (b) is equal to the ratio of wood going to lumber (0.8) times the width between the slabs on opposite sides of the log, where both slabs are such that the last pass of the saw produces a board of the acceptable minimum width ($w_m = 4$):

$$ b = (0.8)\sqrt{D^2 - w_m^2}\,. \quad (21) $$

Multiplying the estimated number of boards (b) by the kerf volume from each board and adding this quantity to equation (20) produces the estimate for the total volume of kerf in cubic feet:

$$ {}_L V_k = {}_L V_k^{*} + \frac{2L}{(12)^2 (4)} b = 0.001091(L)D^2 + 0.001091(L^2 \delta)D $$

$$ + 0.000364(L^3 \delta^2) + 0.002778(L \sqrt{D^2 - 16}) \ . \qquad (22) $$

Subtracting the lumber and kerf volumes from the frustum volume produces the slab-edging volume in cubic feet:

$$ {}_L V_{se} = 0.000248(L)D^2 + \left[0.004363(L^2 \delta) + 0.010312(L) \right] D $$

$$ + 0.001454(L^3 \delta^2) + 0.022396(L) $$

$$ - 0.002778(L \sqrt{D^2 - w_m^2}) \ . \qquad (23) $$

As with the International Rule, the Scribner Rule can be adapted to varying degrees of taper.

VOLUMES OF SAW-LOG RESIDUES

The volumes of saw-log residues as determined by the equations derived from the International and Scribner Rules can be directly compared by referring to tables 1 and 2. A taper increase of 0.5 inch per 4 feet of log length was used with each log rule. The relative volumes vary according to the length of log produced. This variation results because the International Rule for calculating board foot volume allows for an increase in diameter with each 4-foot increase in log length whereas the Scribner Rule makes no allowance for such an increase. Thus, the proportion of the log volume converted to lumber increases with log length by the International Rule but decreases by the Scribner Rule. Consequently, the percentage of the log volume going into slabs and edgings decreases slightly with log length by the International Rule but increases by the Scribner Rule. The same relationships of course apply to slab-edging volumes per thousand board feet. With both the International and Scribner Rules, however, the percentage of the log volume going to kerf varies only slightly with log length.

Table 1.--Volumes of lumber, kerf, shrinkage, and slabs and edging for various log lengths as determined by the International 1/4-Inch Log Rule[1]

8-FOOT LOG

Diameter (inches)	Lumber			Kerf		Shrinkage		Slab-edging		Slab-edging/1,000 board feet
	Board feet	Cubic feet	Percent of total	Cubic feet	Percent of total	Cubic feet	Percent of total	Cubic feet[2]	Percent of total	Cubic feet
6	8	0.63	33.0	0.29	15.2	0.09	4.8	0.87	45.6	115.11
7	12	.97	38.2	.40	15.7	.12	4.8	1.01	39.7	86.57
8	17	1.38	42.3	.53	16.1	.16	4.8	1.15	35.2	69.35
9	22	1.86	45.5	.67	16.4	.19	4.8	1.29	31.6	57.84
10	29	2.40	48.1	.83	16.6	.24	4.8	1.43	28.7	49.61
11	36	3.01	50.3	1.01	16.9	.28	4.8	1.57	26.2	43.42
12	44	3.68	52.2	1.20	17.0	.34	4.8	1.70	24.2	38.61
13	53	4.42	53.7	1.41	17.2	.39	4.8	1.84	22.4	34.75
14	63	5.23	55.1	1.64	17.3	.45	4.8	1.98	20.9	31.60
15	73	6.10	56.3	1.89	17.4	.52	4.8	2.12	19.6	28.97
16	84	7.04	57.3	2.15	17.5	.58	4.8	2.26	18.4	26.74
17	97	8.05	58.3	2.43	17.6	.66	4.8	2.40	17.4	24.83
18	109	9.12	59.1	2.73	17.7	.73	4.8	2.54	16.4	23.18
19	123	10.26	59.9	3.04	17.7	.82	4.8	2.68	15.6	21.73
20	138	11.47	60.5	3.37	17.8	.90	4.8	2.81	14.9	20.45
21	153	12.74	61.1	3.72	17.9	.99	4.8	2.95	14.2	19.32
22	169	14.08	61.7	4.09	17.9	1.09	4.8	3.09	13.5	18.30
23	186	15.48	62.2	4.47	18.0	1.19	4.8	3.23	13.0	17.38
24	203	16.96	62.7	4.87	18.0	1.29	4.8	3.37	12.5	16.56
25	222	18.49	63.1	5.29	18.0	1.40	4.8	3.51	12.0	15.80
26	241	20.10	63.5	5.72	18.1	1.51	4.8	3.65	11.5	15.12
27	261	21.77	63.9	6.17	18.1	1.62	4.8	3.78	11.1	14.49
28	282	23.51	64.2	6.64	18.1	1.74	4.8	3.92	10.7	13.91
29	304	25.31	64.6	7.13	18.2	1.87	4.8	4.06	10.4	13.37
30	326	27.18	64.9	7.63	18.2	2.00	4.8	4.20	10.0	12.88

10-FOOT LOG

Diameter (inches)	Board feet	Cubic feet	Percent of total	Cubic feet	Percent of total	Cubic feet	Percent of total	Cubic feet	Percent of total	Cubic feet
6	10	0.85	34.4	0.38	15.3	0.12	4.8	1.10	44.4	107.45
7	15	1.29	39.5	.52	15.8	.16	4.8	1.27	38.8	81.89
8	22	1.81	43.4	.67	16.1	.20	4.8	1.44	34.4	66.14
9	29	2.42	46.5	.86	16.4	.25	4.8	1.61	30.9	55.46
10	37	3.11	49.1	1.06	16.7	.30	4.8	1.78	28.1	47.75
11	47	3.88	51.2	1.28	16.9	.36	4.8	1.95	25.7	41.92
12	57	4.74	53.0	1.52	17.0	.43	4.8	2.12	23.7	37.36
13	68	5.67	54.5	1.79	17.2	.50	4.8	2.29	22.0	33.69
14	80	6.70	55.8	2.08	17.3	.57	4.8	2.46	20.6	30.68
15	94	7.80	57.0	2.38	17.4	.65	4.8	2.64	19.3	28.16
16	108	8.99	58.0	2.71	17.5	.74	4.8	2.81	18.1	26.02
17	123	10.26	58.9	3.06	17.6	.83	4.8	2.98	17.1	24.19
18	139	11.61	59.8	3.44	17.7	.93	4.8	3.15	16.2	22.59
19	157	13.05	60.5	3.83	17.7	1.03	4.8	3.32	15.4	21.20
20	175	14.57	61.2	4.24	17.8	1.13	4.8	3.49	14.6	19.96
21	194	16.17	61.8	4.68	17.9	1.25	4.8	3.66	14.0	18.86
22	214	17.86	62.3	5.14	17.9	1.36	4.8	3.83	13.4	17.88
23	236	19.63	62.8	5.61	18.0	1.49	4.8	4.00	12.8	16.99
24	258	21.48	63.3	6.11	18.0	1.62	4.8	4.17	12.3	16.19
25	281	23.42	63.7	6.64	18.0	1.75	4.8	4.34	11.8	15.46
26	305	25.44	64.1	7.18	18.1	1.89	4.8	4.52	11.4	14.79
27	330	27.54	64.5	7.74	18.1	2.03	4.8	4.69	11.0	14.18
28	357	29.72	64.8	8.33	18.2	2.18	4.8	4.86	10.6	13.62
29	384	31.99	65.1	8.93	18.2	2.34	4.8	5.03	10.2	13.10
30	412	34.34	65.4	9.56	18.2	2.50	4.8	5.20	9.9	12.62

continued

See footnotes at end of table.

Table 1.--Volumes of lumber, kerf, shrinkage, and slabs and edging for various log lengths as determined by the International 1/4-Inch Log Rule[1] (continued)

Diameter (inches)	Lumber			Kerf		Shrinkage		Slab-edging		Slab-edging/1,000 board feet
	Board feet	Cubic feet	Percent of total	Cubic feet	Percent of total	Cubic feet	Percent of total	Cubic feet[2]	Percent of total	Cubic feet
					12-FOOT LOG					
6	13	1.07	34.9	0.47	15.4	0.15	4.8	1.35	43.9	104.85
7	19	1.61	39.8	.64	15.8	.19	4.8	1.55	38.4	80.50
8	27	2.25	43.6	.83	16.2	.25	4.8	1.76	34.2	65.31
9	36	2.98	46.7	1.05	16.5	.30	4.8	1.97	30.8	54.93
10	46	3.82	49.2	1.30	16.7	.37	4.8	2.17	28.0	47.40
11	57	4.76	51.4	1.57	16.9	.44	4.8	2.38	25.7	41.68
12	70	5.79	53.1	1.86	17.1	.52	4.8	2.58	23.7	37.19
13	83	6.93	54.7	2.18	17.2	.60	4.8	2.79	22.0	33.57
14	98	8.16	56.0	2.53	17.3	.69	4.8	3.00	20.6	30.59
15	114	9.50	57.2	2.90	17.4	.79	4.8	3.20	19.3	28.10
16	131	10.93	58.2	3.29	17.5	.89	4.8	3.41	18.1	25.98
17	150	12.47	59.1	3.72	17.6	1.00	4.8	3.62	17.1	24.16
18	169	14.10	59.9	4.16	17.7	1.12	4.8	3.82	16.2	22.58
19	190	15.84	60.6	4.64	17.8	1.24	4.8	4.03	15.4	21.19
20	212	17.67	61.3	5.14	17.8	1.37	4.8	4.23	14.7	19.97
21	235	19.61	61.9	5.66	17.9	1.51	4.8	4.44	14.0	18.87
22	260	21.64	62.5	6.21	17.9	1.65	4.8	4.65	13.4	17.89
23	285	23.77	63.0	6.78	18.0	1.80	4.8	4.85	12.9	17.01
24	312	26.01	63.4	7.38	18.0	1.95	4.8	5.06	12.3	16.21
25	340	28.34	63.9	8.01	18.1	2.11	4.8	5.27	11.9	15.48
26	369	30.77	64.3	8.66	18.1	2.28	4.8	5.47	11.4	14.82
27	400	33.30	64.6	9.34	18.1	2.45	4.8	5.68	11.0	14.21
28	431	35.94	65.0	10.04	18.2	2.63	4.8	5.88	10.6	13.64
29	464	38.67	65.3	10.77	18.2	2.82	4.8	6.09	10.3	13.12
30	498	41.50	65.6	11.52	18.2	3.01	4.8	6.30	10.0	12.64
					14-FOOT LOG					
6	16	1.34	36.1	0.57	15.4	0.18	4.8	1.59	42.8	99.00
7	24	1.98	40.8	.77	15.9	.23	4.8	1.83	37.6	76.86
8	33	2.74	44.5	1.00	16.2	.29	4.8	2.07	33.5	62.80
9	43	3.62	47.5	1.26	16.5	.36	4.8	2.30	30.2	53.08
10	55	4.61	49.9	1.55	16.7	.44	4.8	2.54	27.5	45.96
11	69	5.72	52.0	1.86	16.9	.52	4.8	2.78	25.3	40.52
12	83	6.95	53.7	2.21	17.1	.62	4.8	3.02	23.3	36.23
13	99	8.29	55.2	2.59	17.2	.72	4.8	3.26	21.7	32.76
14	117	9.75	56.5	2.99	17.3	.82	4.8	3.50	20.3	29.90
15	136	11.32	57.6	3.43	17.4	.94	4.8	3.73	19.0	27.49
16	156	13.01	58.6	3.89	17.5	1.06	4.8	3.97	17.9	25.45
17	178	14.82	59.5	4.39	17.6	1.19	4.8	4.21	16.9	23.68
18	201	16.74	60.3	4.91	17.7	1.32	4.8	4.45	16.0	22.15
19	225	18.78	61.0	5.47	17.8	1.47	4.8	4.69	15.2	20.80
20	251	20.94	61.7	6.05	17.8	1.62	4.8	4.93	14.5	19.61
21	279	23.21	62.3	6.66	17.9	1.77	4.8	5.16	13.9	18.54
22	307	25.60	62.8	7.31	17.9	1.94	4.8	5.40	13.3	17.59
23	337	28.11	63.3	7.98	18.0	2.11	4.8	5.64	12.7	16.73
24	369	30.73	63.8	8.68	18.0	2.29	4.8	5.88	12.2	15.95
25	402	33.47	64.2	9.41	18.1	2.48	4.8	6.12	11.7	15.23
26	436	36.32	64.6	10.17	18.1	2.68	4.8	6.36	11.3	14.58
27	471	39.29	65.0	10.96	18.1	2.88	4.8	6.59	10.9	13.99
28	509	42.38	65.3	11.78	18.2	3.09	4.8	6.83	10.5	13.44
29	547	45.58	65.6	12.64	18.2	3.31	4.8	7.07	10.2	12.93
30	587	48.90	65.9	13.51	18.2	3.53	4.8	7.31	9.9	12.46

continued

See footnotes at end of table.

Table 1.--Volumes of lumber, kerf, shrinkage, and slabs and edging for various log lengths as determined by the International 1/4-Inch Log Rule[1] (continued)

16-FOOT LOG

Diameter (inches)	Lumber			Kerf		Shrinkage		Slab-edging		Slab-edging/1,000 board feet
	Board feet	Cubic feet	Percent of total	Cubic feet	Percent of total	Cubic feet	Percent of total	Cubic feet[2]	Percent of total	Cubic feet
6	19	1.60	36.5	0.68	15.5	0.21	4.8	1.86	42.3	96.44
7	28	2.35	41.1	.91	15.9	.27	4.8	2.13	37.2	75.41
8	39	3.24	44.8	1.18	16.3	.34	4.8	2.40	33.2	61.89
9	51	4.25	47.7	1.48	16.5	.42	4.8	2.68	30.0	52.47
10	65	5.40	50.1	1.81	16.8	.51	4.8	2.95	27.4	45.53
11	80	6.68	52.1	2.17	16.9	.61	4.8	3.23	25.1	40.21
12	97	8.10	53.8	2.57	17.1	.72	4.8	3.50	23.3	36.00
13	116	9.65	55.3	3.01	17.2	.83	4.8	3.77	21.6	32.59
14	136	11.33	56.6	3.47	17.4	.95	4.8	4.05	20.2	29.77
15	158	13.14	57.7	3.97	17.5	1.08	4.8	4.32	19.0	27.39
16	181	15.09	58.7	4.51	17.6	1.22	4.8	4.59	17.9	25.37
17	206	17.17	59.6	5.08	17.6	1.37	4.8	4.87	16.9	23.63
18	233	19.38	60.4	5.68	17.7	1.53	4.8	5.14	16.0	22.11
19	261	21.73	61.1	6.32	17.8	1.69	4.8	5.41	15.2	20.77
20	290	24.21	61.8	6.99	17.8	1.87	4.8	5.69	14.5	19.58
21	322	26.82	62.4	7.69	17.9	2.05	4.8	5.96	13.9	18.53
22	355	29.56	62.9	8.43	17.9	2.24	4.8	6.24	13.3	17.58
23	389	32.44	63.4	9.20	18.0	2.44	4.8	6.51	12.7	16.72
24	425	35.45	63.9	10.00	18.0	2.64	4.8	6.78	12.2	15.94
25	463	38.59	64.3	10.84	18.1	2.86	4.8	7.06	11.8	15.24
26	502	41.87	64.7	11.71	18.1	3.08	4.8	7.33	11.3	14.59
27	543	45.28	65.1	12.62	18.1	3.31	4.8	7.60	10.9	13.99
28	586	48.82	65.4	13.56	18.2	3.55	4.8	7.88	10.6	13.45
29	630	52.50	65.7	14.53	18.2	3.80	4.8	8.15	10.2	12.94
30	676	56.31	66.0	15.54	18.2	4.06	4.8	8.42	9.9	12.47

Note: The percentages of total volume for the various components at each diameter do not total 100 because a 3-inch trim allowance was included on all log lengths when calculating slab-edging and kerf volumes but omitted when calculating board foot volumes. The latter also deviate slightly, in some instances, from published values because some coefficients were not rounded at the same points as in the original rule.

[1] The component values can be calculated for any desired diameter and log length.

[2] When the slab volume is converted to chips by chipping head-rigs, these estimates should be increased by 19 percent and the kerf estimates reduced by the calculated amount.

Table 2.--Volumes of lumber, kerf, and slabs and edging for various log lengths as determined by the Scribner 1/4-Inch Log Rule[1]

8-FOOT LOG

Diameter (inches)	Lumber			Kerf		Slab-edging		Slab-edging/1,000 board feet
	Board feet	Cubic feet	Percent of total	Cubic feet	Percent of total	Cubic feet[2]	Percent of total	Cubic feet
6	6	0.51	26.7	0.49	25.4	0.90	47.1	147.16
7	10	.86	33.6	.64	25.2	1.02	40.1	99.45
8	15	1.27	38.8	.81	24.9	1.15	35.1	75.46
9	21	1.74	42.8	1.00	24.5	1.28	31.4	61.08
10	27	2.29	45.9	1.21	24.2	1.41	28.4	51.54
11	35	2.90	48.5	1.43	23.9	1.56	26.0	44.75
12	43	3.57	50.6	1.67	23.7	1.70	24.1	39.68
13	52	4.31	52.4	1.93	23.4	1.85	22.5	35.75
14	61	5.12	54.0	2.20	23.2	2.00	21.1	32.62
15	72	5.99	55.3	2.50	23.1	2.16	19.9	30.07
16	83	6.93	56.4	2.81	22.9	2.32	18.9	27.94
17	95	7.93	57.4	3.14	22.7	2.49	18.0	26.16
18	108	9.00	58.3	3.49	22.6	2.66	17.2	24.63
19	122	10.14	59.1	3.85	22.5	2.83	16.5	23.30
20	136	11.34	59.9	4.24	22.4	3.01	15.9	22.15
21	151	12.60	60.5	4.64	22.3	3.20	15.3	21.13
22	167	13.94	61.1	5.06	22.2	3.38	14.8	20.23
23	184	15.34	61.6	5.50	22.1	3.57	14.4	19.42
24	202	16.80	62.1	5.95	22.0	3.77	13.9	18.70
25	220	18.33	62.6	6.43	21.9	3.97	13.5	18.05
26	239	19.93	63.0	6.92	21.9	4.17	13.2	17.45
27	259	21.59	63.4	7.43	21.8	4.38	12.9	16.91
28	280	23.32	63.7	7.95	21.7	4.59	12.6	16.41
29	301	25.11	64.1	8.50	21.7	4.81	12.3	15.96
30	324	26.97	64.4	9.06	21.6	5.03	12.0	15.54

10-FOOT LOG

Diameter (inches)	Board feet	Cubic feet	Percent of total	Cubic feet	Percent of total	Cubic feet	Percent of total	Cubic feet
6	8	0.64	25.8	0.62	25.1	1.20	48.4	156.15
7	13	1.07	32.7	.82	25.0	1.36	41.5	105.61
8	19	1.58	37.9	1.03	24.7	1.52	36.4	80.16
9	26	2.18	41.9	1.27	24.4	1.70	32.6	64.89
10	34	2.86	45.1	1.53	24.1	1.88	29.6	54.74
11	43	3.62	47.7	1.81	23.8	2.06	27.2	47.51
12	54	4.46	49.9	2.11	23.6	2.26	25.2	42.10
13	65	5.39	51.8	2.43	23.4	2.45	23.6	37.91
14	77	6.40	53.3	2.78	23.2	2.65	22.1	34.57
15	90	7.49	54.7	3.15	23.0	2.86	20.9	31.85
16	104	8.66	55.9	3.54	22.8	3.07	19.8	29.58
17	119	9.91	57.0	3.95	22.7	3.29	18.9	27.67
18	135	11.25	57.9	4.39	22.6	3.51	18.1	26.03
19	152	12.67	58.7	4.84	22.5	3.74	17.3	24.62
20	170	14.17	59.5	5.32	22.3	3.98	16.7	23.38
21	189	15.76	60.2	5.82	22.2	4.21	16.1	22.29
22	209	17.42	60.8	6.35	22.1	4.46	15.6	21.32
23	230	19.17	61.3	6.90	22.1	4.71	15.1	20.46
24	252	21.00	61.9	7.46	22.0	4.96	14.6	19.69
25	275	22.91	62.3	8.06	21.9	5.22	14.2	18.98
26	299	24.91	62.8	8.67	21.8	5.48	13.8	18.35
27	324	26.99	63.2	9.30	21.8	5.75	13.5	17.77
28	350	29.15	63.5	9.96	21.7	6.03	13.1	17.23
29	377	31.39	63.9	10.64	21.7	6.31	12.8	16.75
30	405	33.71	64.2	11.35	21.6	6.59	12.6	16.29

continued

See footnotes at end of table.

Table 2.--Volumes of lumber, kerf, and slabs and edging for various log lenghts as determined by the Scribner 1/4-Inch Log Rule[1] (continued)

12-FOOT LOG

Diameter (inches)	Lumber			Kerf		Slab-edging		Slab-edging/1,000 board feet
	Board feet	Cubic feet	Percent of total	Cubic feet	Percent of total	Cubic feet[3]	Percent of total	Cubic feet
6	9	0.77	24.9	0.77	25.0	1.52	49.6	165.60
7	15	1.28	31.8	1.00	24.8	1.73	42.7	112.06
8	23	1.90	36.9	1.27	24.6	1.94	37.7	85.07
9	31	2.62	41.0	1.55	24.3	2.16	33.9	68.85
10	41	3.43	44.2	1.86	24.0	2.39	30.8	58.06
11	52	4.34	46.9	2.20	23.8	2.63	28.4	50.37
12	64	5.36	49.1	2.57	23.5	2.87	26.3	44.62
13	78	6.47	51.0	2.96	23.3	3.12	24.6	40.16
14	92	7.68	52.6	3.37	23.1	3.37	23.1	36.60
15	108	8.98	54.1	3.82	23.0	3.63	21.9	33.69
16	125	10.39	55.3	4.29	22.8	3.90	20.8	31.27
17	143	11.90	56.4	4.78	22.7	4.17	19.8	29.23
18	162	13.50	57.4	5.31	22.5	4.45	18.9	27.49
19	182	15.20	58.2	5.86	22.4	4.74	18.1	25.98
20	204	17.01	59.0	6.43	22.3	5.03	17.5	24.66
21	227	18.91	59.7	7.03	22.2	5.33	16.8	23.49
22	251	20.91	60.4	7.66	22.1	5.63	16.3	22.46
23	276	23.00	60.9	8.32	22.0	5.95	15.7	21.54
24	302	25.20	61.5	9.00	22.0	6.26	15.3	20.71
25	330	27.50	62.0	9.71	21.9	6.59	14.8	19.96
26	359	29.89	62.4	10.45	21.8	6.91	14.4	19.28
27	389	32.38	62.9	11.21	21.8	7.25	14.1	18.65
28	420	34.98	63.2	12.00	21.7	7.59	13.7	18.09
29	452	37.67	63.6	12.82	21.7	7.94	13.4	17.56
30	485	40.46	64.0	13.66	21.6	8.29	13.1	17.08

14-FOOT LOG

Diameter (inches)	Board feet	Cubic feet	Percent of total	Cubic feet	Percent of total	Cubic feet	Percent of total	Cubic feet
6	11	0.89	24.1	0.92	24.8	1.88	50.7	175.41
7	18	1.50	30.8	1.20	24.7	2.14	43.9	118.74
8	27	2.22	36.0	1.51	24.4	2.40	38.9	90.13
9	37	3.05	40.0	1.84	24.2	2.67	35.1	72.94
10	48	4.00	43.3	2.21	23.9	2.95	32.0	61.49
11	61	5.07	46.0	2.61	23.7	3.24	29.5	53.32
12	75	6.25	48.3	3.03	23.5	3.54	27.4	47.21
13	91	7.54	50.2	3.49	23.3	3.84	25.6	42.46
14	107	8.96	51.9	3.98	23.1	4.16	24.1	38.68
15	126	10.48	53.4	4.50	22.9	4.48	22.8	35.58
16	145	12.12	54.6	5.05	22.8	4.80	21.6	33.01
17	167	13.88	55.7	5.63	22.6	5.14	20.6	30.84
18	189	15.75	56.7	6.25	22.5	5.48	19.7	28.98
19	213	17.74	57.6	6.89	22.4	5.83	18.9	27.37
20	238	19.84	58.5	7.56	22.3	6.18	18.2	25.96
21	265	22.06	59.2	8.27	22.2	6.54	17.6	24.72
22	293	24.39	59.9	9.01	22.1	6.91	17.0	23.62
23	322	26.84	60.5	9.77	22.0	7.29	16.4	22.64
24	353	29.40	61.0	10.57	21.9	7.67	15.9	21.75
25	385	32.08	61.6	11.40	21.9	8.07	15.5	20.95
26	418	34.87	62.0	12.26	21.8	8.46	15.1	20.23
27	453	37.78	62.5	13.15	21.7	8.87	14.7	19.56
28	490	40.81	62.9	14.08	21.7	9.28	14.3	18.96
29	527	43.94	63.3	15.03	21.6	9.70	14.0	18.40
30	566	47.20	63.6	16.01	21.6	10.13	13.7	17.88

continued

See footnotes at end of table.

Table 2.--Volumes of lumber, kerf, and slabs and edging for various log lengths as determined by the Scribner 1/4-Inch Log Rule[1] (continued)

16-FOOT LOG

Diameter (inches)	Lumber			Kerf		Slab-edging		Slab-edging/1,000 board feet
	Board feet	Cubic feet	Percent of total	Cubic feet	Percent of total	Cubic feet[2]	Percent of total	Cubic feet
6	12	1.02	23.3	1.08	24.6	2.27	51.8	185.54
7	21	1.71	29.9	1.40	24.5	2.58	45.1	125.62
8	30	2.53	35.0	1.76	24.3	2.90	40.1	95.34
9	42	3.49	39.1	2.15	24.1	3.23	36.2	77.13
10	55	4.57	42.4	2.57	23.8	3.57	33.1	64.99
11	70	5.79	45.2	3.03	23.6	3.92	30.5	56.33
12	86	7.14	47.5	3.52	23.4	4.27	28.4	49.85
13	103	8.62	49.4	4.05	23.2	4.64	26.6	44.82
14	123	10.23	51.1	4.61	23.0	5.01	25.0	40.80
15	144	11.98	52.6	5.21	22.9	5.39	23.7	37.51
16	166	13.85	53.9	5.84	22.7	5.78	22.5	34.78
17	190	15.86	55.1	6.51	22.6	6.18	21.5	32.47
18	216	18.00	56.1	7.21	22.5	6.59	20.5	30.50
19	243	20.27	57.0	7.95	22.4	7.00	19.7	28.79
20	272	22.67	57.9	8.72	22.3	7.43	19.0	27.29
21	303	25.21	58.6	9.53	22.2	7.86	18.3	25.97
22	334	27.87	59.3	10.37	22.1	8.30	17.7	24.80
23	368	30.67	60.0	11.25	22.0	8.74	17.1	23.76
24	403	33.60	60.6	12.17	21.9	9.20	16.6	22.82
25	440	36.66	61.1	13.12	21.9	9.66	16.1	21.97
26	478	39.85	61.6	14.10	21.8	10.14	15.7	21.19
27	518	43.18	62.0	15.12	21.7	10.62	15.3	20.49
28	560	46.63	62.5	16.18	21.7	11.10	14.9	19.84
29	603	50.22	62.9	17.27	21.6	11.60	14.5	19.25
30	647	53.94	63.2	18.40	21.6	12.11	14.2	18.70

Note: The percentages of total volume for the various components at each diameter do not total 100 because a 3-inch trim allowance was included on all log lengths when calculating slab-edging and kerf volumes but omitted when calculating board foot volumes. The latter also deviate slightly, in some instances, from published values because some coefficients were not rounded at the same points as in the original rule.

[1] The component values can be calculated for any desired diameter and log length. However, as log length increases, the percentage of log volume going to slabs increases.

[2] When the slab volume is converted to chips by chipping head-rigs, these estimates should be increased by 20 percent and the kerf estimates reduced by the calculated amounts.

DISCUSSION

Estimates of slabs, edging, and kerf from these procedures may be questioned because the log is treated as a frustum of a cone. Admittedly, log form is not so constant, but this fact has not prevented use of the board foot predictions from log rules based on this concept. It may also be suggested that estimates of slabs, edging, and kerf from the methods presented here will be inaccurate when a combination of 1-inch boards and dimension material is sawn; but, again, the same can be said for the accepted log rules, which estimate board feet only in terms of 1-inch boards. The acceptableness of lumber estimates based on log rules should carry over to the estimates of the volumes of residues.

An obvious advantage of these extensions of the International and Scribner Log Rules is that the equations for predicting volume are flexible with regard to log taper. This flexibility can be particularly advantageous with species that have excessive taper or with older stands of many species where taper is minimal in the bottom portion of the merchantable stem. If so desired, rules can be constructed by log position in the tree. The primary benefit from such a scheme with the International Rule would be increased precision in estimating board foot volume; with the Scribner Rule, more accurate estimates of slab and kerf volumes would be obtained. As an added feature, if taper curves are available for a species,[5] then the estimated taper from these curves can be used in the equations for predicting the volume of components. Volume tables could be constructed on this basis.

Several points about these extensions of the two log rules should be emphasized: (A) The volumes of slabs, edging, and kerf as estimated by the International Log Rule should apply if the logs are bucked into lengths that eliminate most of the sweep and crook and are carefully and properly sawn. (B) The volumes of slabs and edging as estimated by the International Rule will be the minimum to expect; less careful sawing practices will produce more residue volume. (C) These techniques can be adapted to any degree of taper with both rules and also to varying kerf width with the International Rule. (D) If taper curves are available for a species, both International and Scribner Rules for estimating volumes of board feet, slabs and edgings, and kerf can be constructed by individual log position in the tree. (E) Establishment of taper curves by diameter-height classes will permit construction of tables expressing 100 percent of the tree volume in veneer or board feet, chip volume, kerf, and topwood (the merchantable portion of a tree remaining after removal of a primary product).

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[5] Bennett, Frank A., and Swindel, Benee F. Taper curves for planted slash pine. Southeast. For. Exp. Stn., USDA For. Serv. Res. Note SE-179, 4 pp. 1972.

APPENDIX

Equations (11), (12), (13), and (14) for estimating the component volumes for the International Log Rule are obtained by adding volumes from an appropriate number (η) of 4-foot bolts, plus a fraction of a bolt, with equations (5), (8), (9), and (10) used as the bolt volumes for the respective components. For each added bolt, the scaling diameter is increased by one unit of the taper (τ). A general statement of the above summation procedure is as follows. Let a general expression for any component volume from a 4-foot-long bolt be

$$V = aD^2 + bD + cD\tau + d\tau^2 . \qquad \text{(A1)}$$

Then the component volume for a L-foot-long log is

$$\begin{aligned}
{}_L V = & \sum_{i=1}^{\eta} (a[D + (i-1)\tau]^2 + b[D + (i-1)\tau] + c[D + (i-1)\tau]\tau \\
& + d\tau^2) + (\frac{L-4\eta}{4}) (a[D + \eta\tau]^2 + b[D + \eta\tau] + c[D + \eta\tau](\frac{L-4\eta}{4})\tau \\
& + d(\frac{L-4\eta}{4})^2 \tau^2) \\
= & a(\eta D^2 + 2 \sum_{i=1}^{\eta} (i-1)D\tau + \sum_{i=1}^{\eta} (i-1)^2 \tau^2) + b(\eta D + \sum_{i=1}^{\eta} (i-1)\tau) \\
& + c(\eta D\tau + \sum_{i=1}^{\eta} (i-1)\tau^2) + d\, \eta\tau^2 + a[D + \eta\tau]^2 (\frac{L-4\eta}{4}) \\
& + b[D + \eta\tau](\frac{L-4\eta}{4}) + c[D + \eta\tau](\frac{L-4\eta}{4})^2 \tau + d(\frac{L-4\eta}{4})^3 \tau^2 ,
\end{aligned} \qquad \text{(A2)}$$

where

$\frac{L - 4\eta}{4}$ = the fraction of a 4-foot bolt needed to complete the log length L,

$$\sum_{i=1}^{\eta} (i-1) = \frac{\eta(\eta-1)}{2}$$

and

$$\sum_{i=1}^{\eta} (i-1)^2 = \frac{2\eta^3 - 3\eta^2 + \eta}{6} .$$

☆U.S. G.P.O.: 1974— 640-938/416

Bennett, Frank A., and Lloyd, F. Thomas
1974. Volume of saw-log residues as calculated from log rule formulae. Southeast. For. Exp. Stn., USDA For. Serv. Res. Pap. SE-118, 16 p.

The formulae used in constructing the International and Scribner Log Rules were extended to include the estimation of the volumes of slabs, edging, and saw kerf. These techniques were adapted to allow varying log taper for both rules and varying kerf thicknesses for the International Rule. Volume tables of lumber and residues according to the two rules are presented for various log lengths. As reliable taper curves become available for various species, the described techniques can also be adapted to provide volume tables for board feet, slabs, edging, kerf, and topwood, thereby accounting for total tree volume.

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