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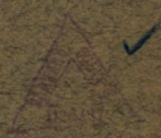
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BULLETIN No. 5



# A Discussion of Log Rules

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Their Limitations and Suggestions  
for Correction



CALIFORNIA  
STATE PRINTING OFFICE  
1915



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STATE BOARD OF FORESTRY

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# A Discussion of Log Rules

Their Limitations and Suggestions  
for Correction

BY  
H. E. MCKENZIE



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## PREFACE

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THE lumberman is beginning to realize the necessity for standardizing the methods employed in handling his industry. We recognize the problem of standardization as a broad one and feel that the following discussion of log rules is an appropriate contribution to the solution of a problem which influences both the commercial handling of lumber and the scientific study of forest products. There is an unquestionable need for a standard rule for the accurate determination of the volume of logs of various lengths and diameters, and the amount of manufactured lumber possible to produce from such logs. There are many log rules in use throughout the United States, some more accurate than others.

The following discussion has been prepared by Mr. H. E. McKenzie, Forest Engineer with this department, and was suggested by the result of a mill scale study (to be issued as a separate publication) in which the statute rule of California, the Spaulding Log Rule, was found to show a marked discrepancy between the log scale and the amount of lumber sawed out. This discrepancy led to the further investigation embracing all of the log rules in use in the United States, with the view of determining what rule, if any, is universally applicable or to devise such a rule.

G. M. HOMANS,  
State Forester.

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## DISCUSSION OF LOG RULES

### INTRODUCTION

**I**T is customary among the lumbermen of this country, when buying or selling logs, to base their calculations upon the value of the lumber the logs will produce when sawed rather than upon the total volume. The by-products, such as slabs, sawdust, and loss by normal crook, which accompany the manufacture of lumber from logs of various sizes, are therefore ignored in the valuation, and tables have been compiled which aim to show the volume of lumber in units, known as board feet (1"x 12"x 12"), after the elimination of by-products has been made. Such tables are called "log rules."

It is the object of this publication to discuss many of the different log rules now in use, to show the principles upon which they are based, and wherein they are defective; to introduce a new log rule, based upon mathematical principles, and designed to be flexible to the varying conditions, both in milling operations and in the character of the timber to be sawed. Also, to show relations, where they exist, between any two rules or any number of rules, such that a transformation from one rule to another can be accomplished, and to reduce the various rules, wherever possible, to a definite form, in order that comparisons by formulæ may be easily made, and the allowance for slabs, sawdust, etc., by each rule readily ascertained.

## CONSTRUCTION AND UNDERLYING PRINCIPLES OF LOG RULES.

### LOG RULES IN GENERAL.

About forty-five log rules have been devised within the last seventy-five years for the measurement of sawed lumber from logs of different sizes, and the values shown by these different rules cover an enormous range. It is safe to say that 90 per cent of them are so constructed that at best they are of value only under the conditions of the locality where they were first employed, and there is no means whereby they can be intelligently corrected for other conditions. Such is the case with all log rules based upon diagrams showing the amount of lumber in logs after allowances have been made for slabs, saw-kerf, etc. Such is the case with all log rules obtained by correcting these rules or combining them for others. Also rules resulting from actual experience at saw-mills have the same objections. They bear the prints of local conditions and, due to the method whereby they came into existence, they can never be anything more than local, and can only be applied to milling conditions similar to those existing at the mills where they were first constructed.

The only logical way of constructing a log rule which will be flexible and which will adjust itself to universal conditions, is to so construct it that the underlying, fundamental principles are so segregated as to make them independent of one another, and to have them so worked together as to give the aggregate result of all factors, which will be in all cases proportional and equal to the volume of the manufactured product. There are several distinct principles underlying the measurement of lumber which logs of different sizes will produce, which cannot be overlooked in any rule that is destined to become a correct universal measure. Such a rule must embody the principle that the slabs which cover the material, or part of the log which is to become the finished product, should be allowed for by making the allowance proportional to the barked area of the log. The slabs are the covering, as it were, which necessarily has to be removed in order to get to the part of the log that produces lumber, and they should not be, and are not, cut any thicker from large logs than from small ones. The best material contained in the log usually lies nearest to the bark, and it is greatly to the advantage of the millman not to waste any of his best grades.

Several log rules in most common use today do not embody the above principle. The Spaulding Log Rule, which is the statute rule of California, does not adhere to it. The Scribner Rule, which is the official rule of the Forest Service, U. S. Department of Agriculture, and of several states, does not take it into consideration, and instead of having the volume of slabs proportional to the barked area of the logs, they have them proportional to the total volume, as will be shown further on.

It would not be any more absurd if one tried to figure the number of board feet necessary to side up a house by figuring the volume of the house instead of its lateral surface. A definite per cent cannot be given as indicating the relation of slabs to trees of different volume, any more than a definite per cent can be given as indicating the relation of all lateral surface to the volume of houses of different dimen-

sions. The Spaulding, Scribner and all other log rules with a waste allowance for slabs varying directly as the volume of the log are mathematically incorrect, since there is no reason for cutting any thicker slabs from large logs than from small ones.

Another principle underlying the measurement of lumber contained in logs of different diameters and lengths is the relation of the allowance for sawdust to the size of the log. Since the waste allowance which should be allotted to slabs should be proportional to the barked area, it can be met by reducing the diameter of all sized logs a constant amount, and the remaining volume can then be considered as lumber plus sawdust. It is very evident that the sawdust allowance depends upon the dimensions of the lumber to be sawed and upon the width of the saw used. It is also evident that, for any specific width of saw-kerf and dimensions of lumber to be sawed, the allowance for sawdust should be a definite per cent of the total volume of all logs, not including slabs. A sawdust factor which fulfills these conditions is as follows:

$$\frac{k(w + t + k)}{(w + k)(t + k)}$$

Where  $k$  = width of saw, in inches.

$w$  = average width of lumber to be manufactured, in inches.

$t$  = average thickness, in inches.

This factor shows what fractional part of the log minus allowance for slabs should be allowed for sawdust.

$$\left[ 1 - \frac{k(w + t + k)}{(w + k)(t + k)} \right]$$

represents the fractional part of the log after slab allowance is made, which becomes lumber.

Log rules which ignore these principles can not be any more than local rules, applying to conditions existing at very few mills.

There are several other considerations to be taken into account in constructing a log rule, which are not of such vital importance as the two principles cited above. They are allowances for taper, shrinkage, normal crook and excessive taper in small logs. All of these factors depend largely upon the character of the timber, and should be adjusted accordingly for the different species, and for the same species growing under different conditions.

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### THE THREE RULES MOST COMMONLY USED.

#### *The Spaulding Log Rule.*

The Spaulding Log Rule is the statute rule of California, having been adopted by an act of the legislature in 1878. It is constructed from diagrams, and the following comments upon it were published by its author:

“Each sized log has been scaled so as to make all that can be practically sawed out of it, if economically sawed. Each log to be measured at the top of small end, inside of the bark, and if not round, to be measured two ways—at right angles—and the average

taken for the diameter. Where there are any known defects, the amount to be deducted should be agreed upon by the buyer and the seller, and no fractions of an inch to be taken into the measurement.

“In the foregoing table I have varied the size of the slab in proportion to the size of the log, and have arranged it more particularly for large logs by taking them in sections of twelve feet and carrying the table up to 96” in diameter. As there has never been any in use for scaling over 44”, it has been my purpose to furnish a table for the measuring of logs that can be implicitly relied upon for correctness by both the buyer and the seller; and to do so, I have spared no pains to render it perfect.”

This rule has been very carefully prepared, and all values given are very consistent with the principles upon which it is constructed. These principles are clearly shown in the graphic analysis made of the rule in Fig. 1. They are as follows: (a) The sawdust allowance varies

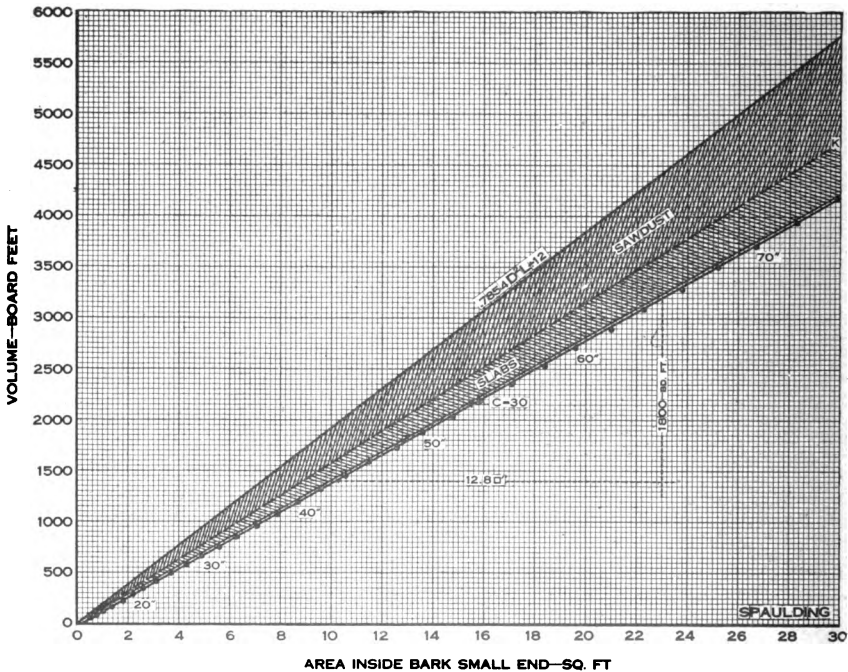
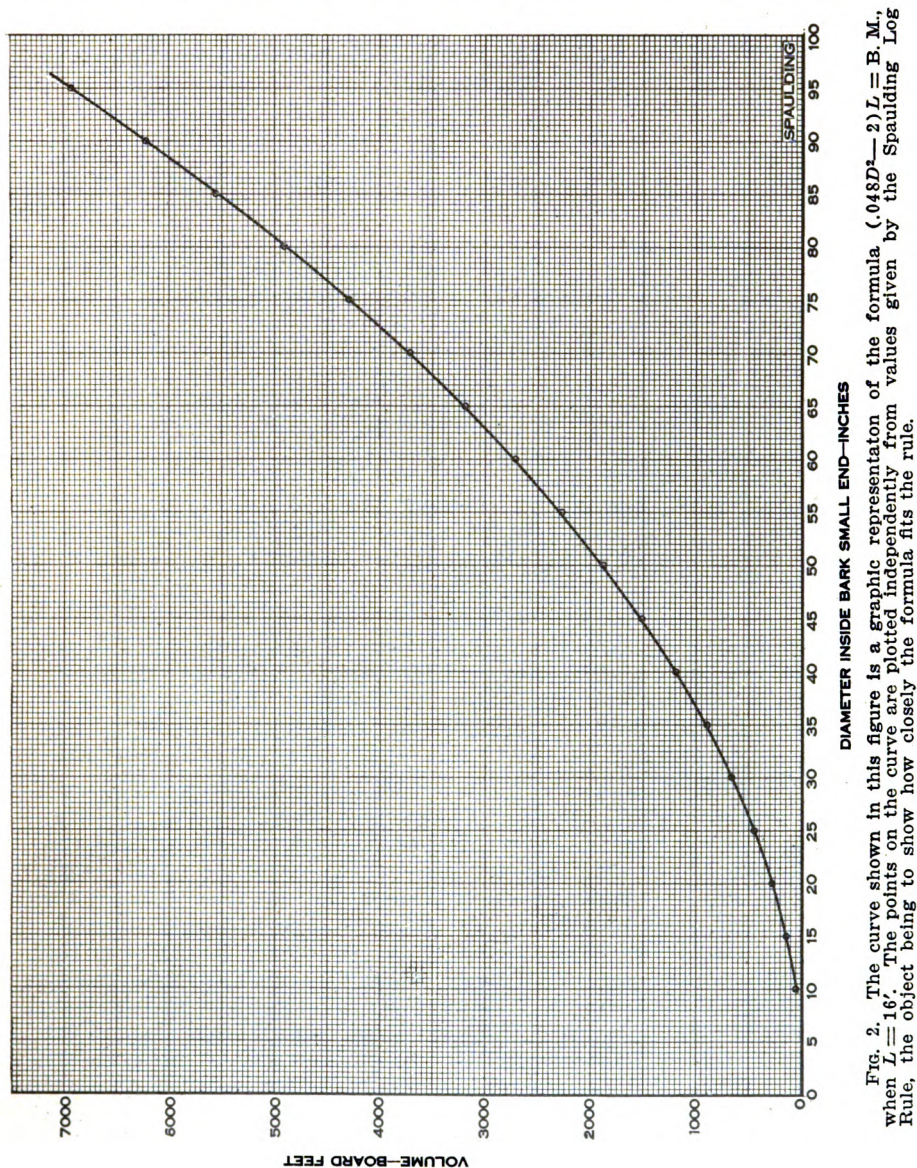


FIG. 1. A graphic analysis of the Spaulding Log Rule, based upon area in square feet inside bark at small end of logs. This diagram shows the following: (a) Top curve total contents in board feet of logs of different diameters 16' long with no allowance made for taper. (b) Curve "k," volume in board feet remaining after 18% of the total volume has been allowed for sawdust (this allowance is about right for 3/4" saw-kerf). (c) Curve passing through origin and drawn parallel to bottom curve. (d) Bottom curve located by plotting volumes in board feet for 16' logs of even inches in diameter inside bark, as given by the Spaulding Log Rule. The formula indicated by this analysis is as follows:  $(.048D^2 - 2)L = B. M. = \text{volume in board feet.}$

directly with the volume. (b) Slab allowance varies directly as the volume plus a constant. (c) No allowance made for taper. (d) No allowance made for normal crook. (e) Total waste allowance remains constant, regardless of the width of saw-kerf.

The big disadvantage of such a rule lies in the fact that it is not flexible to conditions existing at mills in different localities where it

might be used, or to the character of the timber sawed. It is unaffected by taper, normal crook, width of saw-kerf and excessive taper in small logs, and such corrections can not be properly made due to the diagram



method used in first constructing the rule. Fig. 1 indicates the following formula:  $(.048D^2 - 2)L = B. M. =$  volume in board feet, which very closely fits this rule as shown in Fig. 2.

Small logs will invariably over-run this scale, due to the constant "2" shown by the formula. Intermediate logs will hold up the scale, fall below, or go above, largely depending upon the width of saw-kerf and

the average dimensions of the lumber sawed. Large logs will generally run higher than the intermediate sizes, due to the fact that the slab allowance varies directly with the volume plus a constant. The following deduction shows the total waste allowance of the Spaulding Log Rule expressed in per cent of the rule:

$$(.048D^2 - 2)L = \text{B. M.} = \text{total sawed out as shown by Spaulding Log Rule.}$$

$$\frac{.7854D^2}{12} L = \text{total contents} = .0655D^2 L$$

$$.0655D^2 L - (.048D^2 - 2)L = \text{waste} = [(.0655 - .048)D^2 + 2]L \\ = (.0175D^2 + 2)L.$$

$$100 \frac{(.0175D^2 + 2)L}{(.048D^2 - 2)L} = \% \text{ waste based on total sawed out as shown by Spaulding Log Rule.} \\ = 100 \frac{.0175D^2 + 2}{.048D^2 - 2}.$$

When  $D = 10''$ , the waste allowance based on the total sawed out as shown by the Spaulding Log Rule = 134%.

When  $D = 20''$ , the waste allowance = 52.2%.

When  $D = 30''$ , the waste allowance = 43.1%.

When  $D = 40''$ , the waste allowance = 40.1%.

When  $D =$  diameter in inches of very large logs, waste allowance = 36.5%.

### *The Scribner Log Rule.*

The Scribner Log Rule is the oldest rule in general use, and is the statute rule of Idaho, Minnesota, Oregon, Wisconsin and West Virginia. Also, it is the official rule adopted by the Federal Forest Service.

It was constructed from diagrams the same as the Spaulding Log Rule, and the following description was published by its author in 1846:

“This table has been computed from accurately drawn diagrams for each and every diameter of logs from twelve inches to forty-four, and the exact width of each board taken after being squared by taking off the wane edge and the contents reckoned up for every log, so that it is mathematically certain that the true contents are here given, and both buyer and seller of logs will unhesitatingly adopt these tables as the standard for all future contracts in the purchase of saw logs where strict honesty between party and party is taken into account. In these revised computations I have allowed a thicker slab to be taken from the larger class of logs than in the former edition, which accounts for the discrepancy between the results given in these tables and those in former editions.

“The diameter is supposed to be taken at the small end, inside the bark, and in sections of 15', and the fractions of an inch not taken into the measurement. This mode of measurement, which is customary, gives the buyer the advantage of the swell of the log, the gain by sawing into scantling, or large timber, and the fractional part of an inch in the diameter. Still it must be remembered that logs are never straight and that oftentimes there are concealed defects which must be taken as an offset for the gain above mentioned. It has been my desire to furnish those who deal

in lumber of any kind with a set of tables that can implicitly be relied upon for correctness by both buyer and seller, and to do so I have spared no pains nor expense to render them perfect; and it is to be hoped that hereafter these will be preferred to the palpably erroneous tables which have hitherto been in use. If there is any truth in mathematics or dependence to be placed in the estimates given in diagrams, there cannot remain a particle of doubt of the accuracy of the results here given."

This log rule gives practically the same results as does the Spaulding. It is not as carefully prepared, however, since the values given are not as consistent with the underlying principles of the rule. A graphic

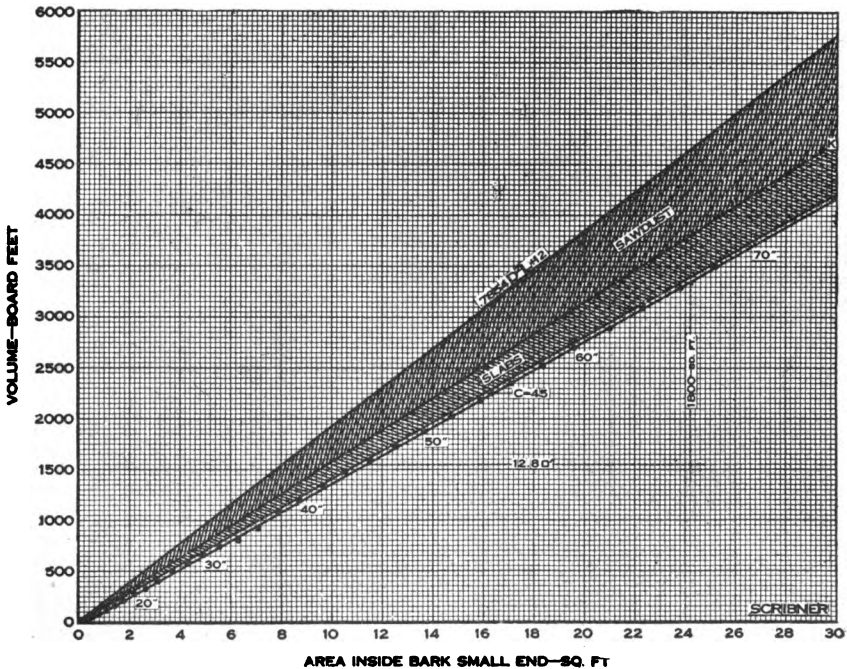


Fig. 3. A graphic analysis of the Scribner Log Rule, based upon area in square feet inside bark at small end of logs. This diagram shows the following: (a) Top curve, total contents in board feet of logs of different diameters 16' long, with no allowance made for taper. (b) Curve "k," volume in board feet remaining after 18% of the total volume has been allowed for sawdust (this allowance is about right for  $\frac{1}{4}$ " saw-kerf). (c) Curve passing through origin and drawn parallel to bottom curve. (d) Bottom curve located by plotting volume in board feet for 16' logs of even inches in diameter inside bark as given by the Scribner Log Rule. The formula indicated by this analysis is as follows:  $(.048D^2 - 3)L = B. M. =$  volume in board feet. This formula is almost identical with the one obtained for the Spaulding Log Rule. It does not apply, however, to diameters below 14" or above 75". No formula can be written for the Scribner Log Rule that will fit all values given, due to the inconsistency of the individual values of the rule.

analysis of it is given in Fig. 3, which shows the fundamental principles upon which it is based, and which are the same as for the Spaulding rule. The formula indicated by the analysis shown in Fig. 3 is  $(.048D^2 - 3)L = B. M. =$  volume in board feet, which is practically the same as for the Spaulding Log Rule, the only difference being in the constant "3". Fig. 4 shows how closely this formula fits the rule.

Small logs will invariably overrun this scale, and to a slightly greater extent than for the Spaulding Log Rule, since the constant shown by the formula is "3" instead of "2". Intermediate logs will hold up the

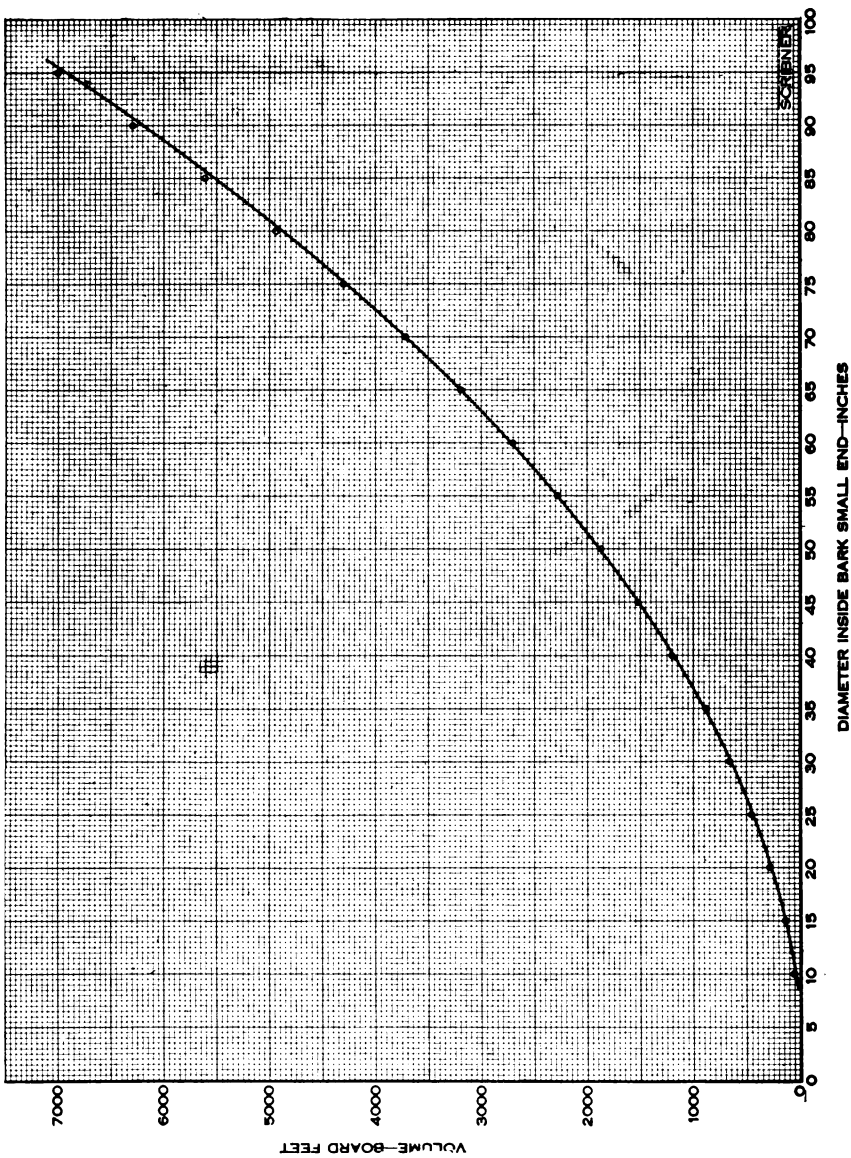


FIG. 4. The curve shown in this figure is a graphical representation of the formula  $(.048D^2 - 3)L = B. M.$  when  $L = 16'$ . The points on the curve are plotted independently from values given by the Scribner Log Rule, the object being to show how closely the formula fits the rule. (It does not apply to diameters below 14" or above 75".)

scale, fall below or go above, largely depending upon the width of the saw-kerf and the average dimensions of the lumber sawed. Large logs will run higher than the intermediate sizes, due to the fact that the slab allowance is directly proportional to the volume plus a constant. The following deduction shows the total waste allowance of the Scribner rule expressed in per cent of total sawed out, as shown by the rule:

$(.048D^2 - 3)L = B. M. =$  Total sawed out as shown by the Scribner Log Rule.

$$\frac{.7854D^2}{12} L = \text{total contents} = .0655D^2L$$

$$.0655D^2L - (.048D^2 - 3)L = \text{waste} = [(.0655 - .048)D^2 + 3]L \\ = (.0175D^2 + 3)L$$

$$100 \frac{(.0175D^2 + 3)L}{(.018D^2 - 3)L} = \% \text{ waste based on total sawed out as shown} \\ \text{by Scribner Log Rule.} \\ = 100 \frac{.0175D^2 + 3}{.048D^2 - 3}$$

When  $D = 10''$ , the waste allowance based on the total sawed out as shown by the Scribner Log Rule = (Formula does not apply below  $14''$ ).

When  $D = 20''$ , the waste allowance = 61.8%.

When  $D = 30''$ , the waste allowance = 46.7%.

When  $D = 40''$ , the waste allowance = 42.0%.

When  $D =$  diameter in inches for very large logs, waste allowance = 36.5%.

#### *The Doyle Log Rule.*

The Doyle Log Rule is used throughout the entire country and is the statute rule of Florida, Louisiana and Arkansas. It is constructed

from the formula  $\left(\frac{D-4}{4}\right)^2 L = B. M.$ , which is stated as follows:

Deduct  $4''$  from the diameter of the log as an allowance for slabs; square one quarter of the remainder and multiply the result by the length of the log in feet. No mention is made in this rule of a sawdust allowance. If four inches from the diameter of the small end is the slab allowance, the sawdust allowance must be the difference between the solid contents in board feet remaining after the slab allowance has been made and the contents shown by the rule. The determination of sawdust allowance follows:

$$\left(\frac{D-4}{4}\right)^2 L = B. M. = \text{volume in board feet, as shown by the} \\ \text{Doyle rule, of log } D \text{ inches in diameter at small end} \\ \text{inside bark and } L \text{ feet long.}$$

$$\frac{.7854 (D-4)^2}{12} L = \text{volume in board feet of log } D \text{ inches in diame-} \\ \text{ter inside bark at small end } L \text{ feet long with} \\ \text{waste allowance for slabs but none for sawdust.}$$

$$\frac{.7854 (D-4)^2}{12} L - \left(\frac{D-4}{4}\right)^2 L = \text{sawdust allowance for log } D \\ \text{inches in diameter and } L \text{ feet long.}$$

$$\frac{.7854 (D-4)^2}{12} L - \left(\frac{D-4}{4}\right)^2 L \\ \frac{.7854 (D-4)^2}{12} L \times 100 = \text{sawdust allowance for} \\ \text{log } D \text{ inches in diameter and} \\ \text{ } L \text{ feet long expressed in per} \\ \text{cent of volume in board feet left} \\ \text{after slab allowance has been} \\ \text{made} \\ = \frac{.295}{.0655} = 4.5\%$$

Therefore, the sawdust allowance for the Doyle Log Rule = 4.5% of the total volume left after 4" has been deducted from the diameter as an allowance for slabs. This sawdust allowance is correct in principle, since it is a definite per cent of the total volume after slabs have been accounted for. It is, however, entirely too small. The thinnest modern band saws take away at least 10% of the volume of the lumber sawed unless the product be large timbers, and the allowance of 4.5% is not one-half as large as it should be for even one of these saws. The

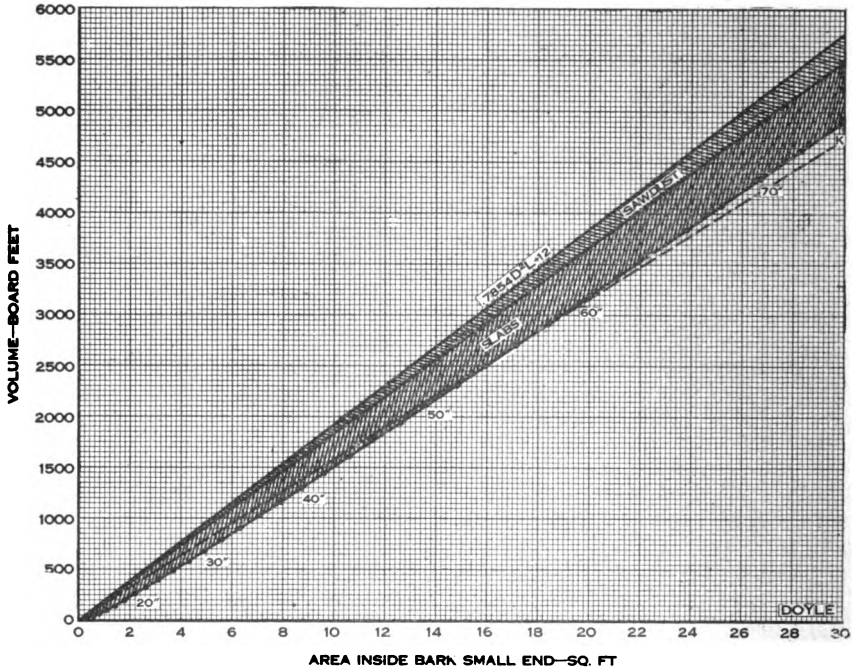


FIG. 5. A graphic analysis of the Doyle Log Rule, based upon area in square feet inside bark at small end of logs. This diagram shows the following: (a) Top curve, total contents in board feet of logs of different diameters 16' long with no allowance made for taper. (b) Next lower curve, volume in board feet remaining after an allowance of 4.5% has been made for sawdust. (4.5% of the total volume of logs, after slab allowance has been made, is the only portion of the waste allowance of the Doyle Log Rule that varies directly as the volume. Therefore, it is the only part of the formula that varies directly as the amount of sawdust.) (c) Curve "k," values for volume in board feet after an allowance of 18% for sawdust has been made. This curve intersects the log rule at about 56", showing, that, at this point and above, the waste allowance which should cover slabs and sawdust is not sufficient to even cover the sawdust. The Doyle Log Rule, however, is correct in principle, but its values are very poorly chosen.

principle upon which the Doyle Log Rule is based is correct, however, since the slab allowance is proportional to the barked area and the sawdust allowance is proportional to the total volume left after the allowance for slabs has been made. But the allowance for slabs is absurdly large and that for sawdust is absurdly low. In short, the principle of the rule is correct, but the values are very poorly chosen. Fig. 5 shows a graphic analysis of the rule.

A log rule was used long before the Doyle rule came into existence, which gave the same results, and was stated as follows: Deduct 4" from the diameter for slabs, then, squaring the remainder, subtract one-fourth

for saw-kerf and the balance will be the contents of the log 12' long, from which the others may be obtained by proportion. It would appear from this that a generous allowance for sawdust had been made, but as a matter of fact the apparent sawdust allowance is a part of the allowance already made for slabs. This is clearly illustrated in figures 6 and 7, when the above rule is applied. (Deduct 4" from the diameter for slabs and in Figures 6 and 7 we have  $D - 4 = AB$ . Then, squaring the remainder  $(D - 4)$ , we have  $(D - 4)^2 = ABCD$ . Subtract  $\frac{1}{4}$

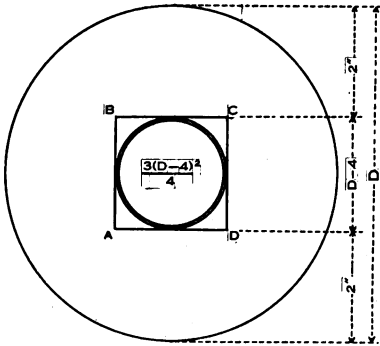


FIG. 6. The Doyle Log Rule as applied to a 6" log.

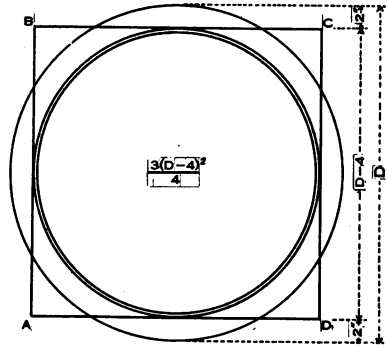


FIG. 7. The Doyle Log Rule as applied to a 30" log.

for saw-kerf, giving  $\frac{3}{4}(D - 4)^2$ , which is the inside circle. The inscribed circle outside of this is equal to  $.7854(D - 4)^2$ . It is apparent from this that  $.7854(D - 4)^2 - \frac{3}{4}(D - 4)^2$  is the only true portion of the diagram which could represent sawdust.) This rule amounts to the same thing as the Doyle Log Rule, but in statement is misleading and ambiguous.

The sawdust allowance as shown by Figures 6 and 7 in per cent of total contents after slab allowance has been made is as follows:

$$\frac{.7854(D - 4)^2 - \frac{3}{4}(D - 4)^2}{.7854(D - 4)^2} \times 100 =$$

$$\frac{.0354(D - 4)^2}{.7854(D - 4)^2} \times 100 = \frac{3.54}{.7854} = 4.5\%$$

which is the same as shown by the Doyle Log Rule formula.

The following deduction will show the total waste allowance of the Doyle Log Rule for logs of different sizes expressed in per cent of total sawed out, as indicated by the rule:

$$\left(\frac{D-4}{4}\right)^2 L = B.M. = \text{volume in board feet of log } D \text{ inches in diameter at small end inside bark and } L \text{ feet long.}$$

$$\frac{.7854 D^2}{12} L = \text{total volume in board feet contained in log } D \text{ inches in diameter and } L \text{ feet long. (No allowance for taper.)}$$

$$\frac{.7854 D^2}{12} L - \left(\frac{D-4}{4}\right)^2 L = \text{total waste allowance.}$$

$$\frac{\frac{.7854 D^2}{12} L - \left(\frac{D-4}{4}\right)^2 L}{\left(\frac{D-4}{4}\right)^2 L} \times 100 = \text{total waste allowance for log } D \text{ inches in diameter and } L \text{ feet long expressed in per cent of used volume.}$$

$$= \frac{.003 D^2 + .5 D - 1}{.0625 D^2 - .5 D + 1} \times 100.$$

When  $D = 10''$ , the waste allowance based on the total sawed out as shown by the Doyle Log Rule = 191%.

When  $D = 20''$ , the waste allowance = 63.8%.

When  $D = 30''$ , the waste allowance = 39.5%.

When  $D = 40''$ , the waste allowance = 29.4%.

When  $D = 50''$ , the waste allowance = 23.8%.

This waste allowance is obviously too high for small logs and too low for large ones. This is due to the fact that the slab allowance is too generous and the sawdust allowance too small. Small logs will invariably over-run the scale; intermediate logs will usually scale about right, since the large slab allowance makes up the shortage for sawdust; large logs will invariably under-run the scale, because the combined slab and sawdust allowance is too small for waste, though the actual slab allowance is too large for slabs alone.

#### *The McKenzie Log Rule.*

The McKenzie Log Rule is based on mathematical principles and is designed to cover all conditions encountered in the manufacture of lumber from logs of various diameters and lengths. All factors influencing the total volume sawed out have been taken into consideration and treated separately, thus making the rule flexible to the varying conditions, both in milling operations and in the character of the timber.

The following factors which affect the mill output from logs of different sizes have been included:

- (a) Slabs.
- (b) Normal crook.
- (c) Saw-kerf.
- (d) Average dimensions of lumber sawed.
- (e) Taper.
- (f) Excessive taper in small logs.

The mathematical principles underlying the rule are as follows:

(a) The slab allowance is a function of the barked area and varies directly with it.

(b) Normal crook is also a function of the barked area, and varies directly with it the same as slabs.

(c) The sawdust allowance is a function of saw-kerf and average dimensions sawed at mill, and for any given saw-kerf and average dimensions the sawdust allowance should vary directly as the volume minus the slabs.

(d) Taper allowance equal to  $e''$  in  $f'$ . ( $f$  not to exceed  $16'$ .)

(e) Excessive taper in small logs offset by a constant.

Let  $D$  = diameter in inches inside bark at small end.

Let  $L$  = length of log in feet.

Let  $k$  = width of saw-kerf, in inches.

Let  $w$  = average width of lumber sawed, in inches.

Let  $t$  = average thickness of lumber sawed, in inches.

Let  $C$  = constant.

Let  $a$  = constant.

then  $(D - a)$  = diameter of log after an allowance for slabs and normal crook has been made. (Since slabs and normal crook both vary the same, they can be accounted for by the same constant,  $a$ .)

$$\frac{\pi (D - a)^2}{4} = \text{area in square inches of small end of log after the slab and normal crook allowance has been made.}$$

$$\frac{\pi (D - a)^2 L}{4} = \text{volume in units of } 1'' \times 1'' \times 12'' \text{ contained in log } L \text{ feet long and } D \text{ inches in diameter after the slab and normal crook allowance has been made. (Taper allowance to be made later.)}$$

$$\frac{\pi (D - a)^2 L}{4 \times 12} = \text{volume in units of } 1'' \times 12'' \times 12'' \text{ or board feet in log } L \text{ feet long and } D \text{ inches in diameter after slab and normal crook allowance has been made.}$$

No allowance has, as yet, been made for sawdust. This allowance depends upon the width of saw-kerf and the average dimensions of

lumber to be sawed. The saw-kerf from one side and edge of an average board bears the same ratio to that board as the total sawdust from all boards does to the total volume after slab allowance has been made. This is true of all volume becoming sawdust, excepting saw-kerf amounting to  $2k(D - a)$ , which should be considered as part of the slabs since it varies directly as the barked area, and is the sawdust formed in cutting the slabs.

$$k(w + t + k) \frac{L}{12} = \text{volume of wood forming sawdust from each average board.}$$

$$(w + k)(t + k) \frac{L}{12} = \text{volume of sawdust plus volume of average board.}$$

$$\frac{k(w + t + k) \frac{L}{12}}{(w + k)(t + k) \frac{L}{12}} = \frac{k(w + t + k)}{(w + k)(t + k)} = \text{fractional part of wood, necessary to make average board, becoming sawdust.}$$

This ratio of sawdust to average board plus sawdust holds for volume of logs minus allowance for slabs.

$$\left[ 1 - \frac{k(w + t + k)}{(w + k)(t + k)} \right] = \text{fractional part of log, after slab allowance is made, which becomes lumber.}$$

$$\text{Therefore, } \left[ 1 - \frac{k(w + t + k)}{(w + k)(t + k)} \right] \pi \frac{(D - a)^2}{48} \cdot L = \text{volume in}$$

board feet of lumber of average dimensions from log  $D$  inches in diameter at small end inside the bark and  $L$  feet long, when saw-kerf is  $k$  inches wide.

A constant  $C =$  to a few board feet, when added to this formula has a compensating effect for the excessive taper in small logs. Since most small logs sawed are the top logs from medium or large sized trees, they have an excessive taper which can not be accounted for by a uniform taper allowance applied to the whole tree. Therefore, this constant, which in all cases will be very small (not exceeding 10 board feet) is applied and its effect on large logs is negligible, but on small ones it will play an important part in eliminating an accumulative error in total sawed out at the mill.

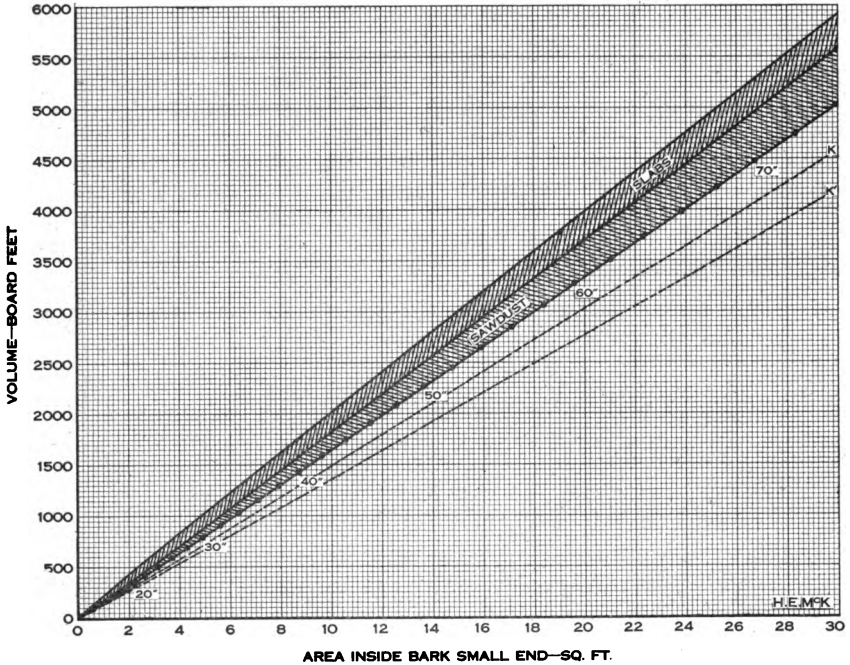


FIG. 8. A graphic analysis of the McKenzie Log Rule, based upon area in square feet inside bark at small end of logs. This diagram shows the following: (a) Top curve, total contents in board feet of logs of different diameters 16' long with taper allowance of 1" in 8'. (b) Next lower curve, volume in board feet remaining after an allowance for slabs has been made. (c) The log rule curve for 1" saw-kerf, showing volume in board feet after an allowance for slabs and sawdust has been made. (The allowance for slabs in this rule varies directly as the "barked" area, and that for sawdust directly as the volume minus slab allowance.) (d) Curve "k," position that the log rule curve takes when the saw-kerf is 1/2" instead of 1". (e) Curve "k" shows position of the log rule curve for a 3/4" saw-kerf. The formula for this rule is as follows:

$$\left[ 1 - \frac{k(w+t+k)}{(w+k)(t+k)} \right] \frac{\pi(D-a)^2}{48} L + C = \text{B.M.}$$

$k$  = width of saw-kerf, in inches.  
 $w$  = average width of lumber, sawed, in inches.  
 $t$  = average thickness of lumber sawed, in inches.  
 $\pi$  = 3.1416.

$D$  = average diameter inside bark, small end, in inches.  
 $a$  = constant.  
 $L$  = length of log, in feet.  
 $C$  = constant included to compensate for excessive taper in small logs.

The formula is:

(not making any allowance for shrinkage and surfacing; the complete formula with this allowance made is shown on page 52.):

$$\left[ 1 - \frac{k(w+t+k)}{(w+k)(t+k)} \right] \frac{\pi(D-a)^2}{48} L + C = \text{B.M.}$$

with a taper allowance of  $e''$  in  $f'$  to be applied when compiling a table. The section used should not be taken over 16' long: 8' is better.

*Its Application.*

The above formula when applied to conditions existing at the Red River Lumber Company's mill in Lassen County, California, gave results shown in the following table. The value of  $a$  determined at this mill is extremely small, due to the fact that slabs were cut very thin and edgings were graded as moulding stock, also to the fact that short lengths were cut from logs where taper was great enough to permit it. The formula was first applied to 16' logs, thus getting the taper in 16' included with the slabs. Volumes in board feet of logs of other lengths were then figured with a taper allowance of 1" in 8'.

TABLE 1. The McKenzie Log Rule, based upon the following formula:

$$\left[ 1 - \frac{k(w+t+k)}{(w+k)(t+k)} \right] \frac{\pi(D-a)^2}{48} L + C = \text{B.M.}$$

Where  $k$  = saw-kerf =  $\frac{1}{8}$ ".

Where  $k$  = average width of lumber = 12".

Where  $t$  = average thickness of lumber =  $\frac{5}{4}$ ".

Where  $D$  = average diameter of log inside bark, small end, in inches.

Where  $a$  = 1".

Where  $L$  = length of log in feet.

Where  $C$  = 2 = constant allowed for excessive taper occurring in small logs.

Where B. M. = volume in board feet.

Where  $\pi$  = 3.1416.

With these values substituted, the formula becomes  $.942(D-1)^2 + 2 = \text{B. M.}$  for 16' logs.

Table based upon 16' logs. Taper allowance of 1" in 8' made for other lengths.



TABLE I—Continued.

Length in feet		DIAMETER IN INCHES													Length in feet																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
		17	18	19	20	21	22	23	24	25	26	27	28	29																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
BOARD FEET															8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
8	114	129	144	162	180	199	219	240	261	283	307	336	369	403	438	473	509	544	582	621	663	707	752	798	845	893	941	990	1039	1088	1137	1186	1235	1284	1333	1382	1431	1480	1529	1578	1627	1676	1725	1774	1823	1872	1921	1970	2019	2068	2117	2166	2215	2264	2313	2362	2411	2460	2509	2558	2607	2656	2705	2754	2803	2852	2901	2950	3000	3049	3098	3147	3196	3245	3294	3343	3392	3441	3490	3539	3588	3637	3686	3735	3784	3833	3882	3931	3980	4029	4078	4127	4176	4225	4274	4323	4372	4421	4470	4519	4568	4617	4666	4715	4764	4813	4862	4911	4960	5009	5058	5107	5156	5205	5254	5303	5352	5401	5450	5499	5548	5597	5646	5695	5744	5793	5842	5891	5940	5989	6038	6087	6136	6185	6234	6283	6332	6381	6430	6479	6528	6577	6626	6675	6724	6773	6822	6871	6920	6969	7018	7067	7116	7165	7214	7263	7312	7361	7410	7459	7508	7557	7606	7655	7704	7753	7802	7851	7900	7949	7998	8047	8096	8145	8194	8243	8292	8341	8390	8439	8488	8537	8586	8635	8684	8733	8782	8831	8880	8929	8978	9027	9076	9125	9174	9223	9272	9321	9370	9419	9468	9517	9566	9615	9664	9713	9762	9811	9860	9909	9958	10047	10096	10145	10194	10243	10292	10341	10390	10439	10488	10537	10586	10635	10684	10733	10782	10831	10880	10929	10978	11027	11076	11125	11174	11223	11272	11321	11370	11419	11468	11517	11566	11615	11664	11713	11762	11811	11860	11909	11958	12007	12056	12105	12154	12203	12252	12301	12350	12399	12448	12497	12546	12595	12644	12693	12742	12791	12840	12889	12938	12987	13036	13085	13134	13183	13232	13281	13330	13379	13428	13477	13526	13575	13624	13673	13722	13771	13820	13869	13918	13967	14016	14065	14114	14163	14212	14261	14310	14359	14408	14457	14506	14555	14604	14653	14702	14751	14800	14849	14898	14947	14996	15045	15094	15143	15192	15241	15290	15339	15388	15437	15486	15535	15584	15633	15682	15731	15780	15829	15878	15927	15976	16025	16074	16123	16172	16221	16270	16319	16368	16417	16466	16515	16564	16613	16662	16711	16760	16809	16858	16907	16956	17005	17054	17103	17152	17201	17250	17299	17348	17397	17446	17495	17544	17593	17642	17691	17740	17789	17838	17887	17936	17985	18034	18083	18132	18181	18230	18279	18328	18377	18426	18475	18524	18573	18622	18671	18720	18769	18818	18867	18916	18965	19014	19063	19112	19161	19210	19259	19308	19357	19406	19455	19504	19553	19602	19651	19700	19749	19798	19847	19896	19945	19994	20043	20092	20141	20190	20239	20288	20337	20386	20435	20484	20533	20582	20631	20680	20729	20778	20827	20876	20925	20974	21023	21072	21121	21170	21219	21268	21317	21366	21415	21464	21513	21562	21611	21660	21709	21758	21807	21856	21905	21954	22003	22052	22101	22150	22199	22248	22297	22346	22395	22444	22493	22542	22591	22640	22689	22738	22787	22836	22885	22934	22983	23032	23081	23130	23179	23228	23277	23326	23375	23424	23473	23522	23571	23620	23669	23718	23767	23816	23865	23914	23963	24012	24061	24110	24159	24208	24257	24306	24355	24404	24453	24502	24551	24600	24649	24698	24747	24796	24845	24894	24943	24992	25041	25090	25139	25188	25237	25286	25335	25384	25433	25482	25531	25580	25629	25678	25727	25776	25825	25874	25923	25972	26021	26070	26119	26168	26217	26266	26315	26364	26413	26462	26511	26560	26609	26658	26707	26756	26805	26854	26903	26952	27001	27050	27099	27148	27197	27246	27295	27344	27393	27442	27491	27540	27589	27638	27687	27736	27785	27834	27883	27932	27981	28030	28079	28128	28177	28226	28275	28324	28373	28422	28471	28520	28569	28618	28667	28716	28765	28814	28863	28912	28961	29010	29059	29108	29157	29206	29255	29304	29353	29402	29451	29500	29549	29598	29647	29696	29745	29794	29843	29892	29941	29990	30039	30088	30137	30186	30235	30284	30333	30382	30431	30480	30529	30578	30627	30676	30725	30774	30823	30872	30921	30970	31019	31068	31117	31166	31215	31264	31313	31362	31411	31460	31509	31558	31607	31656	31705	31754	31803	31852	31901	31950	31999	32048	32097	32146	32195	32244	32293	32342	32391	32440	32489	32538	32587	32636	32685	32734	32783	32832	32881	32930	32979	33028	33077	33126	33175	33224	33273	33322	33371	33420	33469	33518	33567	33616	33665	33714	33763	33812	33861	33910	33959	34008	34057	34106	34155	34204	34253	34302	34351	34400	34449	34498	34547	34596	34645	34694	34743	34792	34841	34890	34939	34988	35037	35086	35135	35184	35233	35282	35331	35380	35429	35478	35527	35576	35625	35674	35723	35772	35821	35870	35919	35968	36017	36066	36115	36164	36213	36262	36311	36360	36409	36458	36507	36556	36605	36654	36703	36752	36801	36850	36899	36948	36997	37046	37095	37144	37193	37242	37291	37340	37389	37438	37487	37536	37585	37634	37683	37732	37781	37830	37879	37928	37977	38026	38075	38124	38173	38222	38271	38320	38369	38418	38467	38516	38565	38614	38663	38712	38761	38810	38859	38908	38957	39006	39055	39104	39153	39202	39251	39300	39349	39398	39447	39496	39545	39594	39643	39692	39741	39790	39839	39888	39937	39986	40035	40084	40133	40182	40231	40280	40329	40378	40427	40476	40525	40574	40623	40672	40721	40770	40819	40868	40917	40966	41015	41064	41113	41162	41211	41260	41309	41358	41407	41456	41505	41554	41603	41652	41701	41750	41799	41848	41897	41946	41995	42044	42093	42142	42191	42240	42289	42338	42387	42436	42485	42534	42583	42632	42681	42730	42779	42828	42877	42926	42975	43024	43073	43122	43171	43220	43269	43318	43367	43416	43465	43514	43563	43612	43661	43710	43759	43808	43857	43906	43955	44004	44053	44102	44151	44200	44249	44298	44347	44396	44445	44494	44543	44592	44641	44690	44739	44788	44837	44886	44935	44984	45033	45082	45131	45180	45229	45278	45327	45376	45425	45474	45523	45572	45621	45670	45719	45768	45817	45866	45915	45964	46013	46062	46111	46160	46209	46258	46307	46356	46405	46454	46503	46552	46601	46650	46699	46748	46797	46846	46895	46944	46993	47042	47091	47140	47189	47238	47287	47336	47385	47434	47483	47532	47581	47630	47679	47728	47777	47826	47875	47924	47973	48022	48071	48120	48169	48218	48267	48316	48365	48414	48463	48512	48561	48610	48659	48708	48757	48806	48855	48904	48953	49002	49051	49100	49149	49198	49247	49296	49345	49394	49443	49492	49541	49590	49639	49688	49737	49786	49835	49884	49933	49982	50031	50080	50129	50178	50227	50276	50325	50374	50423	50472	50521	50570	50619	50668	50717	50766	50815	50864	50913	50962	51011	51060	51109	51158	51207	51256	51305	51354	51403	51452	51501	51550	51599	51648	51697	51746	51795	51844	51893	51942	51991	52040	52089	52138	52187	52236	52285	52334	52383	52432	52481	52530	52579	52628	52677	52726	52775	52824	52873	52922	52971	53020	53069	53118	53167	53216	53265	53314	53363	53412	53461	53510	53559	53608	53657	53706	53755	53804	53853	53902	53951	53999	54048	54097	54146	54195	54244	54293	54342	54391	54440	54489	54538	54587	54636	54685	54734	54783	54832	54881	54930	54979	55028	55077	55126	55175	55224	55273	55322	55371	55420	55469	55518	55567	55616	55665	55714	55763	55812	55861	55910	55959	56008	56057	56106	56155	56204	56253	56302	56351	56400	56449	56498	56547	56596	56645	56694	56743	56792	56841	56890	56939	56988	57037	57086	57135	57184	57233	57282	57331	57380	57429	57478	57527	57576	57625	57674	57723	57772	57821	57870	57919	57968	58017	58066	58115	58164	58213	58262	58311	58360	58409	58458	58507	58556	58605	58654	58703	58752	58801

TABLE I—Continued.

Length		DIAMETER IN INCHES												Length feet										
		30	31	32	33	34	35	36	37	38	39	40	41		42									
in		BOARD FEET												feet										
8	9	10	11	12	13	14	15	16	17	18	19	20	21		22	23	24	25	26	27	28	29	30	31
383	410	438	469	496	528	561	594	627	664	698	734	774	808	848	888	928	968	1008	1048	1088	1128	1168	1208	1248
434	465	497	531	564	598	635	672	710	752	790	831	876	916	960	1000	1040	1080	1120	1160	1200	1240	1280	1320	1360
486	520	555	594	636	688	740	795	855	915	980	1045	1115	1185	1260	1335	1415	1495	1575	1655	1735	1815	1895	1975	2055
537	574	614	656	696	739	783	829	876	928	973	1024	1076	1128	1185	1245	1305	1365	1425	1485	1545	1605	1665	1725	1785
588	629	673	718	762	808	858	908	969	1015	1065	1120	1176	1236	1295	1355	1415	1475	1535	1595	1655	1715	1775	1835	1895
639	684	721	781	828	879	932	986	1040	1100	1155	1215	1280	1340	1400	1460	1520	1580	1640	1700	1760	1820	1880	1940	2000
690	739	790	843	894	949	1005	1065	1125	1185	1250	1315	1380	1440	1500	1560	1620	1680	1740	1800	1860	1920	1980	2040	2100
742	792	848	905	960	1020	1080	1140	1210	1275	1340	1410	1485	1560	1630	1700	1770	1840	1910	1980	2050	2120	2190	2260	2330
793	848	907	968	1025	1090	1155	1220	1290	1360	1430	1505	1585	1660	1735	1810	1885	1960	2035	2110	2185	2260	2335	2410	2485
848	907	969	1035	1096	1165	1235	1305	1375	1455	1530	1610	1690	1770	1850	1930	2010	2090	2170	2250	2330	2410	2490	2570	2650
903	965	1030	1100	1165	1235	1310	1385	1465	1545	1625	1710	1800	1890	1980	2070	2160	2250	2340	2430	2520	2610	2700	2790	2880
957	1025	1095	1165	1235	1310	1390	1470	1550	1635	1720	1810	1905	1995	2090	2180	2270	2360	2450	2540	2630	2720	2810	2900	2990
1010	1085	1155	1230	1305	1385	1470	1550	1640	1730	1820	1915	2010	2105	2200	2295	2390	2485	2580	2675	2770	2865	2960	3055	3150
1065	1140	1220	1300	1375	1460	1545	1635	1725	1820	1915	2015	2110	2210	2305	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300
1120	1200	1290	1365	1450	1535	1625	1720	1810	1910	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400
1175	1260	1345	1430	1520	1610	1705	1800	1900	2005	2110	2220	2330	2440	2550	2660	2770	2880	2990	3100	3210	3320	3430	3540	3650
1230	1320	1405	1495	1590	1685	1780	1885	1985	2095	2205	2320	2435	2550	2665	2780	2895	3010	3125	3240	3355	3470	3585	3700	3815
1290	1380	1470	1565	1660	1760	1865	1970	2080	2190	2305	2425	2545	2665	2785	2905	3025	3145	3265	3385	3505	3625	3745	3865	3985
1350	1440	1535	1635	1735	1840	1950	2060	2170	2285	2410	2530	2650	2770	2890	3010	3130	3250	3370	3490	3610	3730	3850	3970	4090
1405	1505	1605	1705	1810	1920	2030	2145	2260	2385	2510	2640	2770	2900	3030	3160	3290	3420	3550	3680	3810	3940	4070	4200	4330
1465	1565	1670	1776	1885	1995	2115	2230	2355	2480	2610	2740	2870	3000	3130	3260	3390	3520	3650	3780	3910	4040	4170	4300	4430
1525	1630	1735	1845	1960	2075	2195	2320	2445	2580	2715	2850	2985	3120	3255	3390	3525	3660	3795	3930	4065	4200	4335	4470	4605
1585	1690	1800	1915	2030	2155	2280	2405	2535	2670	2805	2940	3075	3210	3345	3480	3615	3750	3885	4020	4155	4290	4425	4560	4695
1640	1750	1865	1990	2105	2230	2365	2495	2630	2770	2910	3050	3190	3330	3470	3610	3750	3890	4030	4170	4310	4450	4590	4730	4870
1700	1815	1935	2055	2180	2310	2445	2580	2720	2870	3015	3160	3305	3450	3595	3740	3885	4030	4175	4320	4465	4610	4755	4900	5045

TABLE I—Continued.

Length in feet		DIAMETER IN INCHES													Length in feet																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
		43	44	45	46	47	48	49	50	51	52	53	54	55																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
8	812	852	890	932	976	1020	1065	1110	1156	1200	1250	1300	1345	1380	1410	1465	1520	1575	1630	1685	1740	1795	1850	1905	1960	2015	2070	2125	2180	2235	2290	2345	2400	2455	2510	2565	2620	2675	2730	2785	2840	2895	2950	3005	3060	3115	3170	3225	3280	3335	3390	3445	3500	3555	3610	3665	3720	3775	3830	3885	3940	3995	4050	4105	4160	4215	4270	4325	4380	4435	4490	4545	4600	4655	4710	4765	4820	4875	4930	4985	5040	5095	5150	5205	5260	5315	5370	5425	5480	5535	5590	5645	5700	5755	5810	5865	5920	5975	6030	6085	6140	6195	6250	6305	6360	6415	6470	6525	6580	6635	6690	6745	6800	6855	6910	6965	7020	7075	7130	7185	7240	7295	7350	7405	7460	7515	7570	7625	7680	7735	7790	7845	7900	7955	8010	8065	8120	8175	8230	8285	8340	8395	8450	8505	8560	8615	8670	8725	8780	8835	8890	8945	9000	9055	9110	9165	9220	9275	9330	9385	9440	9495	9550	9605	9660	9715	9770	9825	9880	9935	9990	10045	10100	10155	10210	10265	10320	10375	10430	10485	10540	10595	10650	10705	10760	10815	10870	10925	10980	11035	11090	11145	11200	11255	11310	11365	11420	11475	11530	11585	11640	11695	11750	11805	11860	11915	11970	12025	12080	12135	12190	12245	12300	12355	12410	12465	12520	12575	12630	12685	12740	12795	12850	12905	12960	13015	13070	13125	13180	13235	13290	13345	13400	13455	13510	13565	13620	13675	13730	13785	13840	13895	13950	14005	14060	14115	14170	14225	14280	14335	14390	14445	14500	14555	14610	14665	14720	14775	14830	14885	14940	14995	15050	15105	15160	15215	15270	15325	15380	15435	15490	15545	15600	15655	15710	15765	15820	15875	15930	15985	16040	16095	16150	16205	16260	16315	16370	16425	16480	16535	16590	16645	16700	16755	16810	16865	16920	16975	17030	17085	17140	17195	17250	17305	17360	17415	17470	17525	17580	17635	17690	17745	17800	17855	17910	17965	18020	18075	18130	18185	18240	18295	18350	18405	18460	18515	18570	18625	18680	18735	18790	18845	18900	18955	19010	19065	19120	19175	19230	19285	19340	19395	19450	19505	19560	19615	19670	19725	19780	19835	19890	19945	20000	20055	20110	20165	20220	20275	20330	20385	20440	20495	20550	20605	20660	20715	20770	20825	20880	20935	20990	21045	21100	21155	21210	21265	21320	21375	21430	21485	21540	21595	21650	21705	21760	21815	21870	21925	21980	22035	22090	22145	22200	22255	22310	22365	22420	22475	22530	22585	22640	22695	22750	22805	22860	22915	22970	23025	23080	23135	23190	23245	23300	23355	23410	23465	23520	23575	23630	23685	23740	23795	23850	23905	23960	24015	24070	24125	24180	24235	24290	24345	24400	24455	24510	24565	24620	24675	24730	24785	24840	24895	24950	25005	25060	25115	25170	25225	25280	25335	25390	25445	25500	25555	25610	25665	25720	25775	25830	25885	25940	25995	26050	26105	26160	26215	26270	26325	26380	26435	26490	26545	26600	26655	26710	26765	26820	26875	26930	26985	27040	27095	27150	27205	27260	27315	27370	27425	27480	27535	27590	27645	27700	27755	27810	27865	27920	27975	28030	28085	28140	28195	28250	28305	28360	28415	28470	28525	28580	28635	28690	28745	28800	28855	28910	28965	29020	29075	29130	29185	29240	29295	29350	29405	29460	29515	29570	29625	29680	29735	29790	29845	29900	29955	30010	30065	30120	30175	30230	30285	30340	30395	30450	30505	30560	30615	30670	30725	30780	30835	30890	30945	31000	31055	31110	31165	31220	31275	31330	31385	31440	31495	31550	31605	31660	31715	31770	31825	31880	31935	31990	32045	32100	32155	32210	32265	32320	32375	32430	32485	32540	32595	32650	32705	32760	32815	32870	32925	32980	33035	33090	33145	33200	33255	33310	33365	33420	33475	33530	33585	33640	33695	33750	33805	33860	33915	33970	34025	34080	34135	34190	34245	34300	34355	34410	34465	34520	34575	34630	34685	34740	34795	34850	34905	34960	35015	35070	35125	35180	35235	35290	35345	35400	35455	35510	35565	35620	35675	35730	35785	35840	35895	35950	36005	36060	36115	36170	36225	36280	36335	36390	36445	36500	36555	36610	36665	36720	36775	36830	36885	36940	36995	37050	37105	37160	37215	37270	37325	37380	37435	37490	37545	37600	37655	37710	37765	37820	37875	37930	37985	38040	38095	38150	38205	38260	38315	38370	38425	38480	38535	38590	38645	38700	38755	38810	38865	38920	38975	39030	39085	39140	39195	39250	39305	39360	39415	39470	39525	39580	39635	39690	39745	39800	39855	39910	39965	40020	40075	40130	40185	40240	40295	40350	40405	40460	40515	40570	40625	40680	40735	40790	40845	40900	40955	41010	41065	41120	41175	41230	41285	41340	41395	41450	41505	41560	41615	41670	41725	41780	41835	41890	41945	42000	42055	42110	42165	42220	42275	42330	42385	42440	42495	42550	42605	42660	42715	42770	42825	42880	42935	42990	43045	43100	43155	43210	43265	43320	43375	43430	43485	43540	43595	43650	43705	43760	43815	43870	43925	43980	44035	44090	44145	44200	44255	44310	44365	44420	44475	44530	44585	44640	44695	44750	44805	44860	44915	44970	45025	45080	45135	45190	45245	45300	45355	45410	45465	45520	45575	45630	45685	45740	45795	45850	45905	45960	46015	46070	46125	46180	46235	46290	46345	46400	46455	46510	46565	46620	46675	46730	46785	46840	46895	46950	47005	47060	47115	47170	47225	47280	47335	47390	47445	47500	47555	47610	47665	47720	47775	47830	47885	47940	47995	48050	48105	48160	48215	48270	48325	48380	48435	48490	48545	48600	48655	48710	48765	48820	48875	48930	48985	49040	49095	49150	49205	49260	49315	49370	49425	49480	49535	49590	49645	49700	49755	49810	49865	49920	49975	50030	50085	50140	50195	50250	50305	50360	50415	50470	50525	50580	50635	50690	50745	50800	50855	50910	50965	51020	51075	51130	51185	51240	51295	51350	51405	51460	51515	51570	51625	51680	51735	51790	51845	51900	51955	52010	52065	52120	52175	52230	52285	52340	52395	52450	52505	52560	52615	52670	52725	52780	52835	52890	52945	53000	53055	53110	53165	53220	53275	53330	53385	53440	53495	53550	53605	53660	53715	53770	53825	53880	53935	53990	54045	54100	54155	54210	54265	54320	54375	54430	54485	54540	54595	54650	54705	54760	54815	54870	54925	54980	55035	55090	55145	55200	55255	55310	55365	55420	55475	55530	55585	55640	55695	55750	55805	55860	55915	55970	56025	56080	56135	56190	56245	56300	56355	56410	56465	56520	56575	56630	56685	56740	56795	56850	56905	56960	57015	57070	57125	57180	57235	57290	57345	57400	57455	57510	57565	57620	57675	57730	57785	57840	57895	57950	58005	58060	58115	58170	58225	58280	58335	58390	58445	58500	58555	58610	58665	58720	58775	58830	58885	58940	58995	59050	59105	59160	59215	59270	59325	59380	59435	59490	59545	59600	59655	59710	59765	59820	59875	59930	59985	60040	60095	60150	60205	60260	60315	60370	60425	60480	60535	60590	60645	60700	60755	60810	60865	60920	60975	61030	61085	61140	61195	61250	61305	61360	61415	61470	61525	61580	61

TABLE I--Continued.

Length in feet		DIAMETER IN INCHES													Length in feet	
		56	57	58	59	60	61	62	63	64	65	66	67	68		
8	1400	1450	1505	1560	1615	1665	1725	1780	1840	1900	1960	2020	2080	2140		
9	1580	1640	1700	1760	1820	1880	1945	2010	2075	2145	2210	2280	2350	2420		
10	1760	1825	1895	1960	2030	2100	2170	2240	2315	2390	2465	2540	2620	2700		
11	1945	2015	2090	2165	2240	2315	2390	2470	2550	2635	2715	2800	2885	2970		
12	2125	2200	2285	2365	2445	2525	2615	2700	2790	2880	2970	3060	3150	3240		
13	2305	2390	2475	2570	2655	2745	2840	2930	3030	3125	3220	3320	3420	3520		
14	2485	2580	2675	2770	2865	2960	3060	3160	3265	3370	3475	3580	3690	3800		
15	2670	2765	2865	2975	3075	3175	3285	3390	3500	3615	3730	3840	3960	4080		
16	2850	2950	3060	3170	3280	3390	3500	3620	3735	3855	3975	4100	4220	4350		
17	3035	3145	3265	3380	3495	3615	3730	3860	3980	4110	4235	4370	4500	4640		
18	3225	3340	3465	3585	3710	3835	3960	4095	4225	4360	4495	4640	4775	4920		
19	3415	3535	3665	3795	3930	4060	4190	4335	4470	4615	4755	4905	5060	5210		
20	3600	3730	3870	4010	4145	4290	4430	4570	4715	4865	5015	5175	5325	5480		
21	3790	3925	4070	4210	4360	4505	4650	4810	4960	5120	5275	5445	5600	5770		
22	3975	4120	4275	4420	4575	4730	4890	5045	5205	5370	5535	5710	5880	6060		
23	4165	4315	4475	4630	4790	4950	5110	5280	5450	5625	5795	5980	6150	6340		
24	4355	4510	4675	4835	5005	5170	5340	5520	5695	5875	6065	6245	6430	6620		
25	4545	4710	4885	5060	5230	5400	5580	5765	5950	6135	6325	6520	6715	6910		
26	4740	4915	5095	5280	5465	5650	5840	6030	6225	6420	6620	6820	7020	7220		
27	4935	5115	5300	5490	5675	5860	6055	6255	6455	6655	6860	7075	7285	7500		
28	5130	5315	5510	5705	5895	6090	6290	6500	6705	6915	7130	7350	7570	7800		
29	5325	5520	5715	5915	6120	6320	6530	6745	6960	7175	7395	7625	7855	8090		
30	5520	5720	5915	6130	6345	6560	6785	6995	7210	7435	7665	7900	8140	8380		
31	5715	5925	6125	6345	6565	6780	7005	7235	7465	7695	7935	8180	8425	8670		
32	5910	6120	6345	6560	6785	7010	7240	7480	7715	7960	8200	8455	8705	8960		

TABLE I—Continued.

Length in feet		DIAMETER IN INCHES												Length in feet	
		69	70	71	72	73	74	75	76	77	78	79	80		
8	2145	2210	2290	2340	2405	2475	2540	2610	2685	2755	2825	2900	2970	8	2970
9	2420	2495	2515	2640	2705	2795	2865	2945	3030	3110	3185	3270	3355	9	3355
10	2695	2780	2865	2940	3025	3115	3205	3285	3375	3460	3550	3645	3735	10	3735
11	2975	3065	3155	3245	3335	3430	3520	3620	3720	3815	3910	4015	4115	11	4115
12	3250	3350	3450	3545	3645	3745	3845	3955	4065	4165	4275	4385	4500	12	4500
13	3525	3630	3740	3845	3965	4065	4170	4290	4410	4520	4636	4755	4880	13	4880
14	3800	3915	4035	4145	4265	4385	4500	4620	4755	4875	5000	5130	5260	14	5260
15	4075	4200	4325	4445	4570	4700	4825	4960	5100	5225	5360	5500	5640	15	5640
16	4350	4480	4610	4745	4880	5020	5150	5290	5440	5580	5720	5870	6020	16	6020
17	4625	4775	4915	5055	5200	5350	5490	5635	5795	5945	6090	6255	6415	17	6415
18	4920	5065	5215	5365	5520	5675	5825	5980	6150	6305	6465	6635	6805	18	6805
19	5205	5360	5515	5675	5835	6000	6160	6325	6500	6670	6835	7015	7195	19	7195
20	5490	5650	5815	5985	6150	6325	6495	6670	6855	7030	7205	7400	7585	20	7585
21	5775	5945	6115	6295	6470	6655	6830	7010	7205	7395	7575	7790	7975	21	7975
22	6060	6235	6415	6605	6790	6980	7165	7355	7560	7755	7950	8160	8370	22	8370
23	6345	6525	6715	6910	7105	7305	7500	7700	7910	8115	8320	8540	8755	23	8755
24	6630	6820	7020	7225	7425	7635	7840	8045	8265	8480	8690	8925	9150	24	9150
25	6925	7125	7330	7540	7750	7970	8190	8400	8625	8855	9075	9315	9560	25	9560
26	7215	7425	7640	7860	8075	8305	8525	8755	8990	9225	9455	9705	9960	26	9960
27	7510	7725	7950	8180	8400	8640	8870	9105	9350	9595	9835	10100	10380	27	10380
28	7800	8025	8260	8495	8730	8975	9215	9460	9715	9970	10220	10480	10750	28	10750
29	8095	8325	8570	8815	9055	9310	9560	9810	10100	10350	10600	10900	11150	29	11150
30	8385	8630	8880	9130	9380	9645	9905	10150	10450	10700	11000	11250	11560	30	11560
31	8680	8940	9190	9450	9710	9965	10250	10500	10800	11100	11350	11650	11950	31	11950
32	8965	9280	9495	9770	10060	10360	10660	10980	11150	11454	11750	12050	12355	32	12355

TABLE I—Continued.

Length in feet	DIAMETER IN INCHES														Length in feet
	BOARD FEET														
	82	83	84	85	86	87	88	89	90	91	92	93	94		
8	3060	3130	3205	3285	3365	3445	3525	3605	3690	3775	3855	3940	4030	8	
9	3445	3530	3615	3705	3795	3885	3975	4070	4160	4255	4350	4445	4545	9	
10	3835	3930	4025	4125	4225	4325	4425	4530	4630	4735	4845	4950	5060	10	
11	4225	4330	4435	4545	4655	4765	4880	4995	5105	5220	5335	5455	5570	11	
12	4615	4730	4850	4965	5085	5205	5325	5450	5575	5700	5830	5965	6090	12	
13	5010	5135	5260	5390	5515	5650	5775	5910	6050	6185	6325	6460	6600	13	
14	5400	5535	5670	5810	5950	6085	6230	6370	6520	6665	6815	6965	7120	14	
15	5790	5935	6080	6230	6375	6530	6680	6835	6990	7150	7305	7470	7630	15	
16	6180	6335	6490	6650	6810	6965	7130	7295	7460	7630	7800	7970	8145	16	
17	6580	6745	6910	7080	7250	7420	7590	7765	7945	8125	8305	8485	8670	17	
18	6980	7155	7330	7510	7690	7870	8055	8235	8425	8615	8810	9000	9200	18	
19	7380	7565	7755	7940	8130	8320	8515	8710	8910	9110	9310	9515	9725	19	
20	7785	7975	8170	8370	8570	8770	8975	9180	9390	9600	9815	10050	10250	20	
21	8190	8385	8585	8805	9015	9220	9435	9650	9870	10100	10300	10530	10800	21	
22	8590	8800	9015	9235	9455	9675	9900	10100	10330	10600	10850	11050	11300	22	
23	8995	9210	9435	9665	9895	10120	10350	10600	10850	11100	11300	11530	11850	23	
24	9385	9620	9855	10100	10350	10620	10890	11050	11300	11600	11850	12100	12350	24	
25	9735	10050	10360	10650	10950	11250	11550	11850	12150	12450	12800	13000	13200	25	
26	10090	10450	10760	10950	11250	11550	11900	12200	12500	12800	13250	13450	13600	26	
27	10600	10960	11150	11450	11700	11950	12300	12500	12800	13100	13550	13850	13950	27	
28	11050	11390	11600	11850	12150	12400	12700	13000	13300	13600	13900	14200	14500	28	
29	11450	11700	12000	12300	12600	12900	13200	13500	13800	14100	14400	14700	15050	29	
30	11850	12150	12450	12750	13050	13350	13650	13950	14300	14600	14900	15250	15550	30	
31	12250	12550	12850	13200	13500	13800	14100	14450	14800	15100	15450	15750	16100	31	
32	12650	13000	13300	13600	13950	14250	14600	14950	15300	15600	15950	16300	16650	32	

TABLE 1—Continued.

Length in feet		DIAMETER IN INCHES														Length in feet																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
		95	96	97	98	99	100	101	102	103	104	105	106	107																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
8	4115	4205	4305	4480	4570	4665	4755	4855	4950	5045	5145	5240	5340	5440	5540	5640	5740	5840	5940	6040	6140	6240	6340	6440	6540	6640	6740	6840	6940	7040	7140	7240	7340	7440	7540	7640	7740	7840	7940	8040	8140	8240	8340	8440	8540	8640	8740	8840	8940	9040	9140	9240	9340	9440	9540	9640	9740	9840	9940	10040	10140	10240	10340	10440	10540	10640	10740	10840	10940	11040	11140	11240	11340	11440	11540	11640	11740	11840	11940	12040	12140	12240	12340	12440	12540	12640	12740	12840	12940	13040	13140	13240	13340	13440	13540	13640	13740	13840	13940	14040	14140	14240	14340	14440	14540	14640	14740	14840	14940	15040	15140	15240	15340	15440	15540	15640	15740	15840	15940	16040	16140	16240	16340	16440	16540	16640	16740	16840	16940	17040	17140	17240	17340	17440	17540	17640	17740	17840	17940	18040	18140	18240	18340	18440	18540	18640	18740	18840	18940	19040	19140	19240	19340	19440	19540	19640	19740	19840	19940	20040	20140	20240	20340	20440	20540	20640	20740	20840	20940	21040	21140	21240	21340	21440	21540	21640	21740	21840	21940	22040	22140	22240	22340	22440	22540	22640	22740	22840	22940	23040	23140	23240	23340	23440	23540	23640	23740	23840	23940	24040	24140	24240	24340	24440	24540	24640	24740	24840	24940	25040	25140	25240	25340	25440	25540	25640	25740	25840	25940	26040	26140	26240	26340	26440	26540	26640	26740	26840	26940	27040	27140	27240	27340	27440	27540	27640	27740	27840	27940	28040	28140	28240	28340	28440	28540	28640	28740	28840	28940	29040	29140	29240	29340	29440	29540	29640	29740	29840	29940	30040	30140	30240	30340	30440	30540	30640	30740	30840	30940	31040	31140	31240	31340	31440	31540	31640	31740	31840	31940	32040	32140	32240	32340	32440	32540	32640	32740	32840	32940	33040	33140	33240	33340	33440	33540	33640	33740	33840	33940	34040	34140	34240	34340	34440	34540	34640	34740	34840	34940	35040	35140	35240	35340	35440	35540	35640	35740	35840	35940	36040	36140	36240	36340	36440	36540	36640	36740	36840	36940	37040	37140	37240	37340	37440	37540	37640	37740	37840	37940	38040	38140	38240	38340	38440	38540	38640	38740	38840	38940	39040	39140	39240	39340	39440	39540	39640	39740	39840	39940	40040	40140	40240	40340	40440	40540	40640	40740	40840	40940	41040	41140	41240	41340	41440	41540	41640	41740	41840	41940	42040	42140	42240	42340	42440	42540	42640	42740	42840	42940	43040	43140	43240	43340	43440	43540	43640	43740	43840	43940	44040	44140	44240	44340	44440	44540	44640	44740	44840	44940	45040	45140	45240	45340	45440	45540	45640	45740	45840	45940	46040	46140	46240	46340	46440	46540	46640	46740	46840	46940	47040	47140	47240	47340	47440	47540	47640	47740	47840	47940	48040	48140	48240	48340	48440	48540	48640	48740	48840	48940	49040	49140	49240	49340	49440	49540	49640	49740	49840	49940	50040	50140	50240	50340	50440	50540	50640	50740	50840	50940	51040	51140	51240	51340	51440	51540	51640	51740	51840	51940	52040	52140	52240	52340	52440	52540	52640	52740	52840	52940	53040	53140	53240	53340	53440	53540	53640	53740	53840	53940	54040	54140	54240	54340	54440	54540	54640	54740	54840	54940	55040	55140	55240	55340	55440	55540	55640	55740	55840	55940	56040	56140	56240	56340	56440	56540	56640	56740	56840	56940	57040	57140	57240	57340	57440	57540	57640	57740	57840	57940	58040	58140	58240	58340	58440	58540	58640	58740	58840	58940	59040	59140	59240	59340	59440	59540	59640	59740	59840	59940	60040	60140	60240	60340	60440	60540	60640	60740	60840	60940	61040	61140	61240	61340	61440	61540	61640	61740	61840	61940	62040	62140	62240	62340	62440	62540	62640	62740	62840	62940	63040	63140	63240	63340	63440	63540	63640	63740	63840	63940	64040	64140	64240	64340	64440	64540	64640	64740	64840	64940	65040	65140	65240	65340	65440	65540	65640	65740	65840	65940	66040	66140	66240	66340	66440	66540	66640	66740	66840	66940	67040	67140	67240	67340	67440	67540	67640	67740	67840	67940	68040	68140	68240	68340	68440	68540	68640	68740	68840	68940	69040	69140	69240	69340	69440	69540	69640	69740	69840	69940	70040	70140	70240	70340	70440	70540	70640	70740	70840	70940	71040	71140	71240	71340	71440	71540	71640	71740	71840	71940	72040	72140	72240	72340	72440	72540	72640	72740	72840	72940	73040	73140	73240	73340	73440	73540	73640	73740	73840	73940	74040	74140	74240	74340	74440	74540	74640	74740	74840	74940	75040	75140	75240	75340	75440	75540	75640	75740	75840	75940	76040	76140	76240	76340	76440	76540	76640	76740	76840	76940	77040	77140	77240	77340	77440	77540	77640	77740	77840	77940	78040	78140	78240	78340	78440	78540	78640	78740	78840	78940	79040	79140	79240	79340	79440	79540	79640	79740	79840	79940	80040	80140	80240	80340	80440	80540	80640	80740	80840	80940	81040	81140	81240	81340	81440	81540	81640	81740	81840	81940	82040	82140	82240	82340	82440	82540	82640	82740	82840	82940	83040	83140	83240	83340	83440	83540	83640	83740	83840	83940	84040	84140	84240	84340	84440	84540	84640	84740	84840	84940	85040	85140	85240	85340	85440	85540	85640	85740	85840	85940	86040	86140	86240	86340	86440	86540	86640	86740	86840	86940	87040	87140	87240	87340	87440	87540	87640	87740	87840	87940	88040	88140	88240	88340	88440	88540	88640	88740	88840	88940	89040	89140	89240	89340	89440	89540	89640	89740	89840	89940	90040	90140	90240	90340	90440	90540	90640	90740	90840	90940	91040	91140	91240	91340	91440	91540	91640	91740	91840	91940	92040	92140	92240	92340	92440	92540	92640	92740	92840	92940	93040	93140	93240	93340	93440	93540	93640	93740	93840	93940	94040	94140	94240	94340	94440	94540	94640	94740	94840	94940	95040	95140	95240	95340	95440	95540	95640	95740	95840	95940	96040	96140	96240	96340	96440	96540	96640	96740	96840	96940	97040	97140	97240	97340	97440	97540	97640	97740	97840	97940	98040	98140	98240	98340	98440	98540	98640	98740	98840	98940	99040	99140	99240	99340	99440	99540	99640	99740	99840	99940	100040

TABLE I—Continued.

Length in feet		DIAMETER IN INCHES														Length in feet												
		108	109	110	111	112	113	114	115	116	117	118	119	120														
8	5345	5445	5545	5650	5750	5860	5965	6070	6175	6285	6395	6505	6615	8	6615	6505	6395	6285	6175	6070	5965	5860	5750	5650	5545	5445	5345	
9	6025	6140	6250	6370	6485	6605	6700	6840	6930	7080	7150	7300	7460	9	7460	7300	7205	7080	6930	6840	6700	6605	6485	6370	6250	6140	6025	
10	6705	6830	6955	7080	7215	7350	7500	7615	7745	7890	8025	8160	8300	10	8300	8160	8025	7890	7745	7615	7500	7350	7215	7080	6955	6830	6705	
11	7385	7520	7660	7810	7945	8095	8250	8385	8530	8675	8835	8985	9140	11	9140	8985	8835	8675	8530	8385	8250	8095	8025	7890	7745	7660	7520	7385
12	8065	8220	8370	8525	8680	8840	9000	9155	9320	9480	9645	9815	9980	12	9980	9815	9645	9480	9320	9155	9000	8840	8680	8525	8370	8220	8065	
13	8745	8910	9075	9250	9415	9585	9750	9930	10100	10250	10450	10645	10800	13	10800	10645	10450	10250	10100	9930	9750	9585	9415	9250	9075	8910	8745	
14	9425	9600	9780	9970	10150	10350	10540	10700	10900	11050	11250	11450	11650	14	11650	11450	11250	11050	10900	10700	10540	10350	10150	9970	9780	9600	9425	
15	10100	10300	10500	10700	10900	11100	11300	11500	11650	11850	12000	12200	12500	15	12500	12200	12000	11850	11650	11500	11300	11100	10900	10700	10500	10300	10100	
16	10800	11000	11200	11400	11600	11800	12050	12250	12450	12700	12900	13100	13350	16	13350	13100	12900	12700	12450	12250	12050	11800	11600	11400	11200	11000	10800	
17	11500	11700	11900	12150	12350	12600	12800	12950	13250	13500	13700	13950	14200	17	14200	13950	13700	13500	13250	12950	12800	12600	12350	12150	11900	11700	11500	
18	12150	12400	12650	12850	13100	13350	13560	13800	14050	14300	14500	14800	15060	18	15060	14800	14500	14300	14050	13800	13560	13350	13100	12850	12650	12400	12150	
19	12850	13100	13350	13600	13860	14000	14350	14600	14850	15100	15350	15600	15900	19	15900	15600	15350	15100	14850	14600	14350	14000	13860	13600	13350	13100	12850	
20	13550	13800	14050	14350	14600	14850	15150	15400	15650	15950	16200	16500	16750	20	16750	16500	16200	15950	15650	15400	15150	14850	14600	14350	14050	13800	13550	
21	14250	14500	14800	15050	15350	15650	16000	16150	16450	16750	17000	17300	17600	21	17600	17300	17000	16750	16450	16150	15850	15650	15350	15050	14800	14500	14250	
22	14950	15250	15500	15900	16100	16350	16650	16950	17250	17550	17850	18150	18450	22	18450	18150	17850	17550	17250	16950	16650	16350	16100	15900	15500	15250	14950	
23	15650	15900	16250	16550	16850	17100	17450	17750	18050	18350	18650	19000	19300	23	19300	19000	18650	18350	18050	17750	17450	17100	16850	16550	16250	15900	15650	
24	16350	16650	16950	17250	17550	17900	18200	18550	18850	19200	19500	19850	20200	24	20200	19850	19500	19200	18850	18550	18200	17900	17550	17250	16950	16650	16350	
25	17050	17350	17650	18000	18350	18650	19000	19350	19650	20000	20300	20700	21050	25	21050	20700	20300	20000	19650	19350	19000	18650	18350	18000	17650	17350	17050	
26	17750	18050	18400	18750	19100	19400	19800	20150	20500	20850	21200	21550	21950	26	21950	21550	21200	20850	20500	20150	19800	19400	19100	18750	18400	18050	17750	
27	18450	18800	19150	19500	19850	20200	20550	20900	21300	21650	22000	22400	22800	27	22800	22400	22000	21650	21300	20900	20550	20200	19850	19500	19150	18800	18450	
28	19150	19600	19950	20250	20600	21000	21350	21700	22100	22500	22850	23250	23650	28	23650	23250	22850	22500	22100	21700	21350	21000	20600	20250	19950	19600	19150	
29	19850	20250	20600	21000	21350	21750	22150	22500	22900	23300	23700	24100	24500	29	24500	24100	23700	23300	22900	22500	22150	21750	21350	21000	20600	20250	19850	
30	20550	20950	21350	21750	22100	22500	22900	23300	23750	24150	24550	24950	25400	30	25400	24950	24550	24150	23750	23300	22900	22500	22100	21750	21350	20950	20550	
31	21250	21650	22050	22500	22900	23300	23700	24100	24550	24950	25400	25850	26250	31	26250	25850	25400	24950	24550	24100	23700	23300	22900	22500	22050	21650	21250	
32	22000	22400	22800	23300	23650	24050	24500	24900	25350	25800	26250	26700	27150	32	27150	26700	26250	25800	25350	24900	24500	24050	23650	23300	22800	22400	22000	

BOARD FEET.

### A COMPARISON OF THREE DIFFERENT TYPES OF LOG RULES.

There are three distinct types of log rules now in general use. They are as follows: (a) Rules with a waste allowance varying directly as the barked area of the log and the volume of the log after the barked area allowance is made. (b) Rules with a waste allowance varying directly as the total volume of the log alone. (c) Rules with a waste allowance varying directly as the total volume of the log plus a constant.

When  $D$  = diameter at small end inside bark in inches.

When  $L$  = length of log in feet.

When  $a$  = constant (in inches).

When  $\pi$  = 3.1416.

When  $c$  = constant with limits of 0 and 1.

When B. M. = volume in board feet of manufactured product,  
the three types may be expressed by these formulæ:

$$(a) \quad (1 - c) \frac{\pi (D - a)^2}{4 \times 12} L = \text{B.M.}$$

$$(b) \quad (1 - c) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$$

$$(c) \quad \left[ (1 - c) \frac{\pi D^2}{4 \times 12} - b \right] L = \text{B.M.}$$

NOTE: The above formulæ are special cases of

$$\left[ (1 - c) \frac{\pi (D - a)^2}{4 \times 12} - b \right] L = \text{B.M.}$$

In formula (a) the constant  $b$  equals zero, and the constant  $a$  has a positive value. Therefore, the curve  $(1 - c) \frac{\pi D^2}{4 \times 12} L$  has been moved in a horizontal direction  $a$  units to the right of the origin.

In (b),  $a=0$ , and  $b=0$ , or the curve maintains its normal position.

In (c),  $a=0$ , and  $b$  has a positive value, or the curve has been moved in a vertical direction  $b$  units.

None of the log rules analyzed had values for both  $a$  and  $b$  such that one of them could not be easily eliminated. The Universal Log Rule, for instance, reduces to the following formula:

$$\left[ (1 - .20) \frac{\pi (D - 1.591)^2}{4 \times 12} - .1325 \right] L = \text{B.M.}$$

The constant  $b=.1325$  is so small that its effect upon the log rule is negligible.  $(1 - .20) \frac{\pi (D - 1.6)^2}{4 \times 12} L = \text{B.M.}$  gives values for this rule within 2 board feet, and is the formula listed below.

The following is a comparison of log rules which may be expressed in the form:

$$(1 - c) \frac{\pi (D - a)^2}{4 \times 12} L = \text{B.M.}$$

NOTE: The constant  $c$  is the fractional part of the log becoming sawdust after an allowance of  $a$  inches from the diameter has been made for slabs. It can be expressed in per cent by multiplying by 100, or moving the decimal point two places to the right.  $(1 - c)$  in like manner is the fractional part allowed for the manufactured product.

Champlain:

$$(1 - .20) \frac{\pi (D - .8)^2}{4 \times 12} L = \text{B.M.}$$

Boughman Rotary Saw: (Original values slightly erratic)

$$(1 - .19) \frac{\pi (D - .87)^2}{4 \times 12} L = \text{B.M.}$$

Boughman Band Saw: (Original values slightly erratic)

$$(1 - .10) \frac{\pi (D - 1)^2}{4 \times 12} L = \text{B.M.}$$

Wilson: (Original values slightly erratic)

$$(1 - .193) \frac{\pi (D - 1)^2}{4 \times 12} L = \text{B.M.}$$

Carey: (Original values slightly erratic)

$$(1 - .193) \frac{\pi (D - 1)^2}{4 \times 12} L = \text{B.M.}$$

Baxter:

$$(1 - .338) \frac{\pi (D - 1)^2}{4 \times 12} L = \text{B.M.}$$

Click: (Original values slightly erratic)

$$(1 - .236) \frac{\pi (D - 1.25)^2}{4 \times 12} L = \text{B.M.}$$

British Columbia:

$$(1 - .273) \frac{\pi (D - 1.5)^2}{4 \times 12} L = \text{B.M.}$$

Universal:

$$(1 - .20) \frac{\pi (D - 1.6)^2}{4 \times 12} L = \text{B.M.}$$

International:

$$(1 - .16) \frac{\pi (D - 1.62)^2}{4 \times 12} L = \text{B.M.}$$

(Applied to 4' sections with taper allowance of 1" in 8', and constructed for  $\frac{1}{8}$ " saw-kerf.)

Preston:

$$(1 - .20) \frac{\pi (D - 1.75)^2}{4 \times 12} L = \text{B.M.} \quad (\text{Small logs})$$

$$(1 - .20) \frac{\pi (D - 1.5)^2}{4 \times 12} L = \text{B.M.} \quad (\text{Large logs})$$

Doyle:

$$(1 - .045) \frac{\pi (D - 4)^2}{4 \times 12} L = \text{B.M.}$$

McKenzie:

$$\left[ 1 - \frac{k(w + t + k)}{(w + k)(t + k)} \right] \frac{\pi (D - a)^2}{4 \times 12} L + C = \text{B.M.}$$

Where  $k$  = saw-kerf in inches.

Where  $t$  = average thickness of lumber sawed, in inches.

Where  $w$  = average width of lumber sawed, in inches.

Where  $a$  = constant.

Where  $C$  = constant included to compensate for excessive taper in small logs.

To be applied to 8' sections with taper allowance of  $e''$  in  $f'$ .

It will be observed that of the above rules the Doyle and the Baxter are the two extremes. The Doyle rule has an enormous slab allowance with extremely small allowance for sawdust, (4.5%); where the Baxter rule has a small slab allowance and a very large allowance for sawdust, (33.8%).

Log rules of this form are correct in principle, and can be adapted to conditions existing at different mills, and to the character of the timber in different localities. The sawdust allowance, however, should not be fixed, but should depend upon the width of saw-kerf and the average dimensions of the lumber. The slab allowance should also be flexible, and should be determined by the timber to be sawed. Allowances for taper, excessive taper in small logs, shrinkage, etc., can be applied when making up a table based upon

$$(1 - c) \frac{\pi (D - a)^2}{4 \times 12} L = \text{B.M.}$$

This type of log rule can be represented diagrammatically by drawing concentric circles of diameters  $D$  and  $(D - a)$  respectively. The difference between the two rings will represent slab allowance. Draw a sector of the small circle with angle equal to  $c \times 360^\circ$ . This will represent the sawdust allowance.

The following is a comparison of log rules which may be expressed in the form:

$$(1 - c) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$$

Constantine:

$$(1 - 0) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$$

Saco River: (Original values slightly erratic)

$$(1 - .276) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$$

Derby: (Original values slightly erratic)

$$(1 - .279) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$$

Square of Three-quarters:

$$(1 - .283) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$$

Partridge: (Original values slightly erratic)

$$(1 - .312) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$$

Vermont:

$$(1 - .363) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$$

NOTE: This rule gives the solid contents in board feet of the largest square timber contained in a log  $D''$  in diameter inside bark at small end, and when divided by 12, becomes the formula for the Inscribed Square Rule, which actually gives the cubic contents of the largest square timber that can be sawed from a log of known length and diameter.

Stillwell: (Original values erratic)

$$(1 - .368) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$$

Ake:

$$(1 - .376) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$$

Square of Two-Thirds:

$$(1 - .435) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$$

NOTE: This formula, when divided by 12, is supposed to give, but does not give, the number of cubic feet of square timber that can be sawed from a log  $D''$  in diameter at middle point inside bark. After the division by 12 is made, it is called the Two-Thirds Rule.

Orange River:

$$(1 - .491) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$$

Cumberland River:

$$(1 - .548) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$$

It is obvious that the Constantine rule has no allowance for either slabs or sawdust, and that all log rules which can be expressed in this form have a total waste allowance which is directly proportional to the total volume of the log, (taper not taken into consideration). The two extremes are the Constantine and the Cumberland River. The former with no allowance for waste whatever and the latter with an allowance of 54.8%.

There can not exist for different sized logs a constant ratio between volume sawed out at mill and volume in board feet as shown by a log rule of the above form. The principle is incorrect.

$(1 - c) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$  can be represented diagrammatically by

drawing a circle diameter  $D$  and then a sector of that circle with angle at center equal to  $c \times 360^\circ$ . The area of the sector will represent the total waste allowance and the remaining area the lumber product.

The following is a comparison of log rules which may be expressed in the form:

$$\left[ (1 - c) \frac{\pi D^2}{4 \times 12} - b \right] L = \text{B.M.}$$

Bangor: (Original values slightly erratic)

$$\left[ (1 - .258) \frac{\pi D^2}{4 \times 12} - .5 \right] L = \text{B.M.}$$

Boynton: (Original values erratic)

$$\left[ (1 - .350) \frac{\pi D^2}{4 \times 12} - .67 \right] L = \text{B.M.}$$

Parsons: (Original values erratic)

$$\left[ (1 - .246) \frac{\pi D^2}{4 \times 12} - 1 \right] L = \text{B.M.}$$

Warner: (Original values erratic)

$$\left[ (1 - .466) \frac{\pi D^2}{4 \times 12} - 1 \right] L = \text{B.M.}$$

Spaulding: (Original values slightly erratic)

$$\left[ (1 - .266) \frac{\pi D^2}{4 \times 12} - 2 \right] L = \text{B.M.}$$

Hannah: (Original values very erratic)

$$\left[ (1 - .266) \frac{\pi D^2}{4 \times 12} - 2 \right] L = \text{B.M.}$$

Applies approximately to logs from 12" to 42" in diameter.  
This rule is very poorly constructed.

Wilcox: (Original values erratic)

$$\left[ (1 - .340) \frac{\pi D^2}{4 \times 12} - 2 \right] L = \text{B.M.}$$

Finch and Apgar: (Original values very erratic)

$$\left[ (1 - .280) \frac{\pi D^2}{4 \times 12} - 2.5 \right] L = \text{B.M.}$$

Ropp:

$$\left[ (1 - .236) \frac{\pi D^2}{4 \times 12} - 3 \right] L = \text{B.M.}$$

Scribner: (Original values very erratic)

$$\left[ (1 - .266) \frac{\pi D^2}{4 \times 12} - 3 \right] L = \text{B.M.}$$

Applies approximately to logs from 14" to 75", inclusive, in diameter. This rule is very poorly constructed.

Favorite: (Original values erratic)

$$\left[ (1 - .285) \frac{\pi D^2}{4 \times 12} - 3 \right] L = \text{B.M.}$$

Maine: (Original values slightly erratic)

$$\left[ (1 - .222) \frac{\pi D^2}{4 \times 12} - .67 \right] L = \text{B.M.}$$

(For small logs, 6" to 15", inclusive.)

$$\left[ (1 - .222) \frac{\pi D^2}{4 \times 12} - 2 \right] L = \text{B.M.}$$

(For logs 16" to 48", inclusive.)

Herring: (Original values slightly erratic)

$$\left[ (1 - .392) \frac{\pi D^2}{4 \times 12} - 1 \right] L = \text{B.M.}$$

(Small logs up to 30".)

$$\left[ (1 - .313) \frac{\pi D^2}{4 \times 12} - 5.5 \right] L = \text{B.M.}$$

(For logs from 30" to 42", inclusive.)

Dusenbury: (Original values slightly erratic)

Practically the same as the Herring Log Rule.

Rules of this form will usually give a large per cent of mill overrun for small logs, due to the presence of the constant *b*. Intermediate logs will run below, hold up the scale or overrun, all depending upon

the value of  $c$  in the rule used and the width of the saw-kerf. The effect of the constant  $b$  becomes small for intermediate sized logs, and is practically negligible for large ones. Large logs will run higher in per cent of mill overrun than the intermediate, since the slab allowance in this type of log rule increases directly as the volume of the log plus a constant. The principle is incorrect.

$\left[ (1 - c) \frac{\pi D^2}{4 \times 12} - b \right] L = \text{B.M.}$  can be represented diagrammatically

by drawing two concentric circles, the larger one with diameter  $D$  and the smaller one with diameter sufficient to allow for  $b$  board feet; then drawing a sector forming an angle of  $c \times 360^\circ$  at the center. The area of the sector and the small circle will represent the waste allowance for slabs, sawdust, etc., while the remaining area will be the lumber product.

**MISCELLANEOUS LOG RULES.**

The Chapin, Northwestern, White and Ballou log rules have no definite underlying principles.

The Drew and the Forty-five were found to be of the form

$$\left[1 - (c - eD)\right] \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$$

Where  $c$  = constant less than 1 and greater than 0.

Where  $e$  = constant much smaller than  $c$  and greater than 0.

Their formulæ are as follows:

The Forty-five rule:

$$\left[1 - (.496 - .00763 D)\right] \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$$

The Drew Rule:

$$\left[1 - (.450 - .003 D)\right] \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$$

In these rules the allowance for total wastage when expressed in per cent of the total contents of the log, taper not considered, decreases uniformly as the diameter increases. When  $eD = c$ , there is no allowance for wastage whatever. The Forty-five Log Rule allows for no wastage in logs 65" in diameter and shows more volume for logs over 65" than they actually contain. The Drew rule also shows a uniformly decreasing per cent of wastage, and for logs 150" in diameter the waste allowance becomes zero. The principle of these rules is absolutely incorrect.

**LOG RULES BASED ON STANDARDS.**

Any log rule, constructed to show volume in board feet of lumber contained in logs of various lengths and diameters, which is based upon definite principles, may be reduced to what is called a standard log rule. The only difference between the ordinary log rule and its unlimited number of standards is in the unit of measure. A log of any specified dimensions may be chosen as the unit of measure, and so long as the underlying principles of both the standard and the rule expressing values in board feet are the same, there will always exist a definite relation between them and the one may be expressed in terms of the other by multiplying by a constant.

When  $d$  = Diameter in inches of the standard log and  
 $l$  = Length in feet of the standard log,

log rules of the form  $(1-c) \frac{\pi (D-a)^2}{4 \times 12} L = \text{B.M.}$

become  $\frac{(D-a)^2 L}{(d-a)^2 l} = V$ , in standards.

Log rules of the form  $(1-c) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$

become  $\frac{D^2 L}{d^2 l} = V$ , in standards.

Log rules of the form  $\left[ (1-c) \frac{\pi D^2}{4 \times 12} - b \right] L = \text{B.M.}$

become  $\frac{(D^2 - s) L}{(d^2 - s) l} = V$ , in standards.

All standard log rules now in use are based upon  $\frac{D^2 L}{d^2 l} = \text{Vol.}$ , in standards. Therefore, any one of them may be reduced to the form  $(1-c) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$ , since  $\frac{D^2 L}{d^2 l} \times \text{Const.} = (1-c) \frac{\pi D^2}{4 \times 12} L$ . Furthermore, it is evident that all standard rules of the same form bear a constant relation the one to the other, and any number of units of a certain standard rule may be reduced to units of any other standard of the same form by multiplying by the proper constant. For example, the Nineteen Inch Standard Rule,  $\left( \frac{D^2 L}{19^2 \times 13} = V, \text{ in standards} \right)$ , may be applied to a large number of logs of different sizes, and the aggregate scale of these logs then given in 19" standards, may be reduced to Blodgett, cube standards, etc., or to any of the following log rules expressing results in board feet: Constantine, Saco River, Derby,

Square of Three-quarters, Partridge, Vermont, Stillwell, Ake, Square of Two-thirds, Orange River, or Cumberland River, by multiplying the aggregate by the proper constant. The result in every case will be precisely the same as though the logs were scaled separately by each of the rules. If, however, it is desired to reduce the aggregate scale of these logs now expressed in standards or in board feet, as the case may be, to board feet as shown by the Doyle Log Rule, for instance, the problem is impossible. There is no way of making the reduction. The logs will have to be scaled in accordance with the principles of the Doyle Log Rule in order to get such results. If only a single log were in question instead of a number of different sizes, it would be very easy to make such a reduction, but since there is no common ratio existing between the Doyle Log Rule (also other rules of that form) and the Nineteen Inch Standard (and others of its form) for logs of all sizes, the reduction can not be applied to more than one log or set of logs of equal diameters.

It is folly to compare results obtained by two logs rules of different forms as applied to logs of various sizes. It is evident that a comparison of the formulæ of such rules would reveal a great deal more. Values shown by log rules of different forms are not comparable, since their underlying principles are different. Any comparison made of such values only lead to confusion and really do more harm than good.

The following will illustrate how the Nineteen Inch Standard Rule may be reduced to other standards and also to any log rule giving values in board feet which is of the same form :

Given: The Nineteen Inch Standard Rule  $\frac{D^2 L}{19^2 \times 13} = V$ , in 19" standards, and given: The Blodgett rule  $\frac{D^2}{16^2} L = V$ , in Blodgett standards, to find the common reducing factor  $c$ :

$$\begin{aligned} \frac{D^2 L}{19^2 \times 13} \times c &= \frac{D^2 L}{16^2} \\ \frac{c}{19^2 \times 13} &= \frac{1}{16^2} \\ c &= \frac{19^2 \times 13}{16^2} = 18.33 \end{aligned}$$

Therefore, if a log or any number of logs of different sizes have been scaled by the Nineteen Inch Standard Rule, the results may be expressed in Blodgett standards by multiplying by 18.33, which is the number of Blodgett standards contained in a Nineteen Inch standard. The ratio holds constant regardless of the size of the logs.

In like manner, the reducing factors for all other standard rules may be obtained.

Given: The Nineteen Inch Standard Rule  $\frac{D^2 L}{19^2 \times 13} = V$ , in standards, and the Vermont rule  $(1 - .363) \frac{\pi D^2}{4 \times 12} L = \text{B.M. in board feet}$ .

To find how many board feet as shown by the Vermont rule are equivalent to a standard of the Nineteen Inch rule:

$$(1 - .363) \frac{\pi 19^2}{48} \times 13 = 195.5$$

Therefore, 195.5 board feet as shown by the Vermont rule equals one standard of the Nineteen Inch Standard Rule. This relation holds for all sized logs. In like manner, reducing factors for the Constantine, Saco River, Derby, Square of Three-quarters, Partridge, Stillwell, Ake, Square of Two-thirds, Orange River and Cumberland River rules may be obtained. All rules of the above form have definite reducing factors which apply to all logs, regardless of size, and to any aggregate scale representing any number of logs.

Given: The Nineteen Inch Standard Rule  $\frac{D^2 L}{19^2 \times 13} = V$ , in standards, to find a log rule equivalent to it when one standard = 200 board feet:

$$(1 - c) \frac{\pi 19^2}{4 \times 12} \times 13 = 200$$

$$1 - c = \frac{200 \times 48}{\pi \times 19^2 \times 13} = .650$$

$$c = .350$$

Therefore:  $(1 - .350) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$  is an equivalent rule for the

Nineteen Inch Standard when a standard unit is equal to 200 board feet. In like manner equivalent rules for other standard rules may be obtained when the value of the unit is given in board feet.

For instance, the Blodgett rule allows 10 board feet for the equivalent of one standard, and the resulting rule which is equivalent to the Blodgett under these conditions is

$$(1 - .405) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$$

$(1 - .423) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$  is the equivalent for the cube rule when its standard unit = 12 board feet.

It must be borne in mind that log rules of the form

$$(1 - c) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$$

are very poor rules for measuring the number of board feet of lumber that can be sawed from logs of different sizes, and that the three distinct types of rules discussed under the heading "A Comparison of Three Different Types of Log Rules" can have no common reducing factor for

logs of different sizes, since the underlying principles are not the same.

In the case of the standard rule based upon  $\frac{D^2 L}{d^2 l} = V$ ,  $V$  is directly proportional to the square of the diameter of the log and also directly proportional to its length, whereas a log rule based upon correct principles has the volume in board feet vary directly as the diameter minus a constant squared, and directly as the length, with a taper correction applied to at least 8' sections.

Standard log rules based upon  $\frac{D^2 L}{d^2 l} = V$  are, however, excellent rules

where a measurement proportional to the total contents of the log is desired. Such measures are applicable to logs which are to be made into pulp or whenever the total contents of the log is to be used. These rules do not take taper into consideration. They can be reduced to cubic feet by multiplying by a constant.

**THE TRANSFORMATION OF VOLUME TABLES BASED UPON A  
GIVEN LOG RULE TO VOLUME TABLES BASED  
UPON OTHER RULES.**

Volume tables constructed to show the number of board feet contained in trees of different merchantable lengths and diameters breasthigh, and based upon a log rule of the form

$$(1 - c) \frac{\pi (D - a)^2}{4 \times 12} L = \text{B.M.}$$

can be transformed to tables based upon other rules of the same form where the value of the constant  $a$  is the same. If the value of  $a$  is different in the rule to which the values are to be reduced, there is no way of accomplishing the transformation. For example, tables based upon the Baxter rule can be transformed to tables based upon the Boughman Band Saw rule by dividing each value in the former table by  $(1 - .338)$  and multiplying by  $(1 - .10)$ . But tables based upon the Baxter rule cannot be transformed to ones based upon the Doyle rule, or on any other rule of that form where  $a$  is not the same as in the Baxter rule, or to forms where  $a$  does not enter, unless the average diameter of all portions of the bole is known thus making it possible to find the value of  $D$  for all logs in the tree.

Volume tables based upon rules of the form  $(1 - c) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$

and also upon the form  $\left[ (1 - c) \frac{\pi D^2}{4 \times 12} - b \right] L = \text{B.M.}$  can be easily

transformed from the one to the other. For example, a volume table based upon the Spaulding Log Rule, showing the average volume in board feet of trees of different diameters breasthigh and merchantable lengths can be transformed to a table based upon the Ropp rule by adding twice the average merchantable length shown in the table to each average value, and then dividing by  $(1 - .266)$  and multiplying by  $(1 - .236)$  and subtracting from each value thus obtained three times the merchantable length. The resulting table will then be based upon the Ropp rule, and the values therein will be the same as though the Ropp rule had been used for scaling the individual logs instead of the Spaulding rule. In like manner, any volume table based upon a log rule

of the form  $\left[ (1 - c) \frac{\pi D^2}{4 \times 12} - b \right] L = \text{B.M.}$ , can be transformed to a volume table based upon any other log rule of that form.

Again, a volume table based upon a log rule of the above form can be transformed to a volume table based upon any log rule of the form

$(1 - c) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$  by adding to each value in the table  $b \times$  the

merchantable length, and then dividing by  $(1 - c)$  of the log rule upon which it is based and multiplying by the value of  $(1 - c)$  of the log rule to which the transformation is to be made. For example: A volume table based upon the Spaulding Log Rule showing average volume in board

feet of trees of different diameters breasthigh and merchantable lengths can be transformed to a table based upon the Vermont rule by adding twice the average merchantable length to each of the values shown in the table, and then dividing the values thus obtained by  $(1 - .266)$  and multiplying by  $(1 - .363)$ . The resulting table will then be based upon the Vermont rule. Should it be desirable to further transform the table to values in cubic feet of the Inscribed Square rule, divide all values by 12. This last reduction will show the volume in cubic feet of the square timbers that can be sawed from trees of different merchantable lengths and diameters breasthigh.

The total number of cubic feet inside bark contained in logs of trees measured for the original volume table based on the Spaulding Log Rule can be obtained by adding twice the average merchantable length to each value in the table and then dividing by  $(1 - .266)$  and dividing by 12. This reduction gives the volume in cubic feet of the total logs in each tree, without the taper of the various logs originally measured being taken into consideration.

To recapitulate: All volume tables based upon

$$(1 - c) \frac{\pi (D - a)^2}{4 \times 12} L = \text{B.M.}$$

can be reduced to any other table based upon the same form of log rule where the constant  $a$  is the same as in the rule originally used in compiling the table.

All volume tables based upon rules of the form

$$(1 - c) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}, \text{ or } \left[ (1 - c) \frac{\pi D^2}{4 \times 12} - b \right] L = \text{B.M.}$$

can be reduced or transformed to volume tables based upon any log rule of either of these forms, and in all cases the resulting tables will be the same as though the individual rules had been applied to the original data.

Any volume table based upon one of the following rules can be transformed to a volume table based upon any of the other rules here given: Constantine, Saco River, Derby, Square of Three-fourths, Partridge, Vermont, Inscribed Square (which is the Vermont rule divided by 12), Sillwell, Ake, Square of Two-thirds, Two-thirds rule (which is the Square of Two-thirds Rule divided by twelve), Orange River, Cumberland River, Bangor, Boynton, Parsons, Warner, Spaulding, Wilcox, Ropp, Favorite, Nineteen Inch Standard, New Hampshire (or Blodgett), the Cube Rule, Twenty-two Inch Standard, Twenty-four Inch Standard, Seventeen Inch Rule.

NOTE: The Hannah, Finch and Apgar, and Scribner rules have been omitted in the above list since their original values appear too erratic to be included. The Maine, Herring and Dusenbury also have been omitted, since each of these rules have separate formulæ for small and large logs.

In like manner any volume table based upon

$$(1 - c) \frac{\pi (D - a)^2}{4 \times 12} L = \text{B.M.}$$

can be transformed to other volume tables of the same form, provided the constant  $a$  is the same in rules under consideration.

The following tables illustrate how the transformations described above may be made:

TABLE 2. Average volume in board feet, as shown by the Spaulding Log Rule, contained in merchantable portion of immature western yellow pine trees of different merchantable lengths and diameters breast high.

TABLE 2.

Diameter breast-high in inches	Merchantable length (feet)							Diameter inside bark top log, inches	Height of stump, feet	Basis, number of trees
	70	80	90	100	110	120	130			
	Volume, based on the Spaulding Rule (bd. ft.)									
20	300	380	465	550	-----	-----	-----	6.6	1.2	11
21	325	405	495	580	-----	-----	-----	6.7	1.2	
22	350	435	530	630	730	-----	-----	6.7	1.2	39
23	380	475	570	680	780	-----	-----	6.8	1.2	
24	415	510	620	730	840	-----	-----	6.9	1.3	67
25	450	560	670	785	905	-----	-----	7.0	1.3	
26	490	605	725	845	975	1100	-----	7.1	1.3	92
27	-----	655	780	915	1050	1180	-----	7.1	1.3	
28	-----	710	845	980	1130	1270	1415	7.2	1.3	100
29	-----	-----	910	1060	1210	1365	1520	7.3	1.3	
30	-----	-----	980	1140	1300	1460	1630	7.4	1.3	65
31	-----	-----	-----	1225	1395	1565	1750	7.5	1.3	
32	-----	-----	-----	1310	1490	1675	1870	7.6	1.4	57
33	-----	-----	-----	1400	1585	1790	1990	7.7	1.4	
34	-----	-----	-----	1495	1695	1900	2125	7.8	1.3	29
35	-----	-----	-----	-----	1800	2020	2255	7.9	1.3	
36	-----	-----	-----	-----	1910	2140	2400	8.0	1.4	27
37	-----	-----	-----	-----	-----	2265	2550	8.2	1.4	
38	-----	-----	-----	-----	-----	2395	2700	8.5	1.5	7
39	-----	-----	-----	-----	-----	2525	2850	9.0	1.5	
40	-----	-----	-----	-----	-----	2660	3005	9.6	1.5	8
Total number of trees-----										502

This table is based upon the original measurements of 502 trees.

TABLE 3. (A transformation of Table 2.) Average volume in board feet, as shown by the Ropp Log Rule, contained in merchantable portion of immature western yellow pine trees of different merchantable lengths and diameters breasthigh.

TABLE 3.

Diameter breast-high in inches	Merchantable length (feet)						Diameter inside bark top log, inches	Height of stump, feet	Basis, number of trees	
	70	80	90	100	110	120				130
	Volume, based on the Ropp Log Rule (bd. ft.)									
20	245	322	402	481	-----	-----	-----	6.6	1.2	11
21	274	348	433	512	-----	-----	-----	6.7	1.2	
22	300	390	469	564	659	-----	-----	6.7	1.2	39
23	331	421	511	616	710	-----	-----	6.8	1.2	
24	368	456	568	688	772	-----	-----	6.9	1.3	67
25	404	509	615	725	841	-----	-----	7.0	1.3	
26	446	556	672	787	913	1036	-----	7.1	1.3	92
27	-----	608	730	861	992	1118	-----	7.1	1.3	
28	-----	666	796	929	1076	1211	1353	7.2	1.3	100
29	-----	-----	874	1011	1159	1310	1463	7.3	1.3	
30	-----	-----	968	1045	1252	1410	1578	7.4	1.3	65
31	-----	-----	-----	1182	1350	1520	1702	7.5	1.3	
32	-----	-----	-----	1271	1450	1632	1829	7.6	1.4	57
33	-----	-----	-----	1335	1550	1745	1952	7.7	1.4	
34	-----	-----	-----	1464	1663	1868	2094	7.8	1.3	29
35	-----	-----	-----	-----	1771	1995	2230	7.9	1.3	
36	-----	-----	-----	-----	1890	2120	2378	8.0	1.4	27
37	-----	-----	-----	-----	-----	2248	2535	8.2	1.4	
38	-----	-----	-----	-----	-----	2390	2690	8.5	1.5	7
39	-----	-----	-----	-----	-----	2520	2850	9.0	1.5	
40	-----	-----	-----	-----	-----	2630	3010	9.6	1.5	8
Total number of trees.....									502	

This table was obtained by transforming the values in Table 2, based on the Spaulding Log Rule, to values shown here based upon the Ropp rule. The transformation was made in accordance with the underlying principles of both rules, and was accomplished as follows: To each value shown in Table 2 twice the merchantable length indicated at top of table was added. The new values thus obtained were divided by  $(1 - .266)$  and multiplied by  $(1 - .236)$ , and three times the merchantable length subtracted. The resulting table is based upon the Ropp rule, and does not include any logs under 10" in diameter, since logs below this size have been automatically discarded by the Ropp rule formula, which gives small negative results for logs under 8" and small positive results for logs between 8" and 10". The negatives below 8" and the positives between an 8" and 10" will about neutralize, thus giving a table which does not include logs below 10" in diameter.

TABLE 4. (A transformation of Table 2.) Average values in board feet, as shown by the Vermont Log Rule, contained in merchantable portion of immature western yellow pine trees of different merchantable lengths and diameters breasthigh.

TABLE 4.

Diameter breast-high in inches	Merchantable length (feet)						Diameter inside bark top log, inches	Height of stump, feet	Basis, number of trees	
	70	80	90	100	110	120				130
	Volume, based on the Vermont Rule (bd. ft.)									
20	382	469	560	651	-----	-----	-----	6.6	1.2	11
21	404	491	587	677	-----	-----	-----	6.7	1.2	
22	426	517	617	721	825	-----	-----	6.7	1.2	39
23	452	552	652	764	868	-----	-----	6.8	1.2	
24	482	582	685	807	922	-----	-----	6.9	1.3	67
25	512	625	738	855	977	-----	-----	7.0	1.3	
26	547	665	786	908	1039	1164	-----	7.1	1.3	92
27	-----	708	834	969	1103	1232	-----	7.1	1.3	
28	-----	755	890	1025	1172	1311	1454	7.2	1.3	100
29	-----	-----	954	1094	1242	1395	1548	7.3	1.3	
30	-----	-----	1008	1163	1320	1478	1641	7.4	1.3	65
31	-----	-----	-----	1238	1403	1568	1746	7.5	1.3	
32	-----	-----	-----	1312	1496	1663	1850	7.6	1.4	57
33	-----	-----	-----	1390	1568	1754	1954	7.7	1.4	
34	-----	-----	-----	1471	1668	1850	2072	7.8	1.3	29
35	-----	-----	-----	-----	1754	1962	2182	7.9	1.3	
36	-----	-----	-----	-----	1850	2068	2310	8.0	1.4	27
37	-----	-----	-----	-----	-----	2175	2440	8.2	1.4	
38	-----	-----	-----	-----	-----	2287	2572	8.5	1.5	7
39	-----	-----	-----	-----	-----	2400	2705	9.0	1.5	
40	-----	-----	-----	-----	-----	2520	2835	9.6	1.5	8
Total number of trees.....									502	

This table was obtained by transforming the values in Table 2, based upon the Spaulding Log Rule, to values shown here based upon the Vermont Rule. The transformation was made in the following manner: To each value shown in Table 2, twice the merchantable length indicated at top of table was added to each of the values. Each of the new values thus obtained was divided by  $(1 - .266)$  and multiplied by  $(1 - .363)$ . The resulting values form the above table, and include all logs contained in the merchantable lengths. This table is the same as would have been obtained had the results been based directly upon the woods measurements.

TABLE 5. (A transformation of Table 2.) Average values in cubic feet as shown by the Inscribed Square Log Rule contained in the largest square timbers that can be sawed from the merchantable portion of immature western yellow pine trees of different merchantable lengths and diameters breasthigh.

TABLE 5.

Diameter breast-high in inches	Merchantable length (feet)							Diameter inside bark top log, inches	Height of stump, feet	Basis, number of trees
	70	80	90	100	110	120	130			
	Volume, based on the Inscribed Square Rule (cu. ft.)									
20	31.8	39.1	46.7	54.3	-----	-----	-----	6.6	1.2	11
21	33.7	40.9	48.8	56.4	-----	-----	-----	6.7	1.2	
22	35.5	43.1	51.4	60.0	68.7	-----	-----	6.7	1.2	89
23	37.6	46.0	54.3	63.6	72.3	-----	-----	6.8	1.2	
24	40.2	48.5	57.9	67.4	76.8	-----	-----	6.9	1.3	67
25	42.7	52.1	61.5	71.3	81.4	-----	-----	7.0	1.3	
26	45.6	55.4	65.5	75.7	86.5	97.0	-----	7.1	1.3	92
27	-----	59.0	69.5	80.7	92.0	102.7	-----	7.1	1.3	
28	-----	62.9	74.2	85.5	97.7	109.3	121.1	7.2	1.3	100
29	-----	-----	79.4	91.2	108.6	116.2	128.8	7.3	1.3	
30	-----	-----	84.0	97.0	110.0	123.0	136.8	7.4	1.3	65
31	-----	-----	-----	103.2	117.0	130.7	145.4	7.5	1.3	
32	-----	-----	-----	109.3	123.8	138.7	154.0	7.6	1.4	57
33	-----	-----	-----	115.8	130.7	146.1	162.8	7.7	1.4	
34	-----	-----	-----	122.6	138.7	155.0	172.5	7.8	1.3	29
35	-----	-----	-----	-----	146.2	163.5	182.0	7.9	1.3	
36	-----	-----	-----	-----	154.2	172.3	192.5	8.0	1.4	27
37	-----	-----	-----	-----	-----	181.2	203.2	8.2	1.4	
38	-----	-----	-----	-----	-----	190.8	214.0	8.5	1.5	7
39	-----	-----	-----	-----	-----	200.0	225.3	9.0	1.5	
40	-----	-----	-----	-----	-----	210.0	236.0	9.6	1.5	8
Total number of trees-----										502

Values in this table are indirectly based upon the measurements necessary for a compilation of Table 2. They were obtained by dividing values shown in Table 4 by the constant 12.

**THE TRANSFORMATION OF THE SCALE OF A NUMBER OF LOGS IN THE AGGREGATE, BASED UPON A GIVEN LOG RULE, TO THE SCALE OF THE SAME LOGS IN THE AGGREGATE, BASED UPON ANOTHER LOG RULE.**

The total volume of a number of logs of various sizes as shown by a log rule of the form  $(1-c) \frac{\pi (D-a)^2}{4 \times 12} L = \text{B.M.}$  can be transformed

to the volume as would be shown by another log rule of that form where the constant  $a$  is the same. For example: Should it be required to know the total volume in board feet of a trainload of logs of various sizes as would be shown by the Boughman Band Saw Rule when the aggregate scale based upon the Baxter Rule is known to be 320,000 board feet, the following steps are necessary: Divide 320,000 by  $(1-c)$  of the Baxter rule, which is  $(1-.338)$ , and multiply by  $(1-c)$  of the Boughman Band Saw Rule, which is  $(1-.10)$ . The result thus obtained which will be 435,000 is the same as would have been obtained had the Bowman rule been used for the original scale. Such transformations can not be made where the constant  $a$  in the two rules in question are not the same. Had the trainload of logs been scaled by a rule of the

form  $(1-c) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$  it would not be possible to make such a

transformation, but it would be possible to transform the total scale to a new total based upon another rule of the same form. For example: If a trainload of logs should scale 300,000 board feet by the Square of Three-quarters rule, and it should be required to find the aggregate scale according to the Inscribed Square rule, the following procedure is all that is necessary: Divide 300,000 by  $(1-.283)$  and multiply by  $(1-.363)$  and then divide by 12. The final result, 32,000 cubic feet, is exactly the same as would have been obtained had the Inscribed Square rule been used for the original scale. In like manner, a transformation could have been made to a number of other rules of similar form.

Had the trainload of logs been originally scaled by a log rule of the

form  $\left[ (1-c) \frac{D^2}{4 \times 12} - b \right] L = \text{B.M.}$ , such as the Spaulding rule, a trans-

formation to another rule of that form where  $b$  is the same could be accomplished by dividing by  $(1-c)$  of the formula used and multiplying by  $(1-c)$  of the formula to which the transformation is to be made. But, in cases where the value of the constant  $b$  is different in the log rules in question, no reduction can be made, unless the sum of the length of all the logs in the trainload be known. If the sum of all log lengths is known, it would then be possible to transform the total scale

to other total scales based upon  $\left[ (1-c) \frac{\pi D^2}{4 \times 12} - b \right] L = \text{B.M.}$  or

$(1-c) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$  whether the constant  $b$  is the same or different in the rules in question. Had the trainload of logs been

originally scaled by the Spaulding Log Rule, or any other rule of similar form, where  $b$  has a value greater than 0, the transformation of the total scale to a total based on a log rule of the form

$(1-c) \frac{\pi D^2}{4 \times 12} L = \text{B.M.}$  would be impossible unless the sum of the

lengths of all logs in the trainload be known. Suppose, for example, the aggregate scale of a trainload of logs was 250,000 board feet by the Spaulding Log Rule, and the sum of all log lengths in the load was 12,000 linear feet, and it was required to know the total scale when based upon the Square of Two-thirds rule, the following operations are all that would be necessary: Add to 250,000 twice the sum of all log lengths, which would be 24,000, divide by  $(1 - .266)$  and multiply by  $(1 - .435)$ . The resulting aggregate scale of the trainload of logs based on the Square of Two-thirds rule would then be 211,000 board feet, which is the same as would have been obtained had the Square of Two-thirds rule been originally applied.

**SUMMARY.**

No log rule will give an accurate measure of the lumber content of logs of various sizes that fails to properly combine all the factors encountered in converting logs into lumber. These factors are the same for all species under all milling conditions. The value of the factors alone increases or decreases according to the species and method of sawing, but the number of factors remain constant. As a result of failing to recognize the factors that must be combined in devising a properly constructed log rule, by failing to employ all of them, or by combining them improperly, there is no accurate log rule in use applicable to variable milling conditions. Any log rule capable of becoming a standard measure and susceptible of correction for certain variable factors must recognize a slab allowance proportional to the barked area of the log, and a sawdust allowance expressed as a definite per cent of the total volume of all logs, not including slabs. The per cent for sawdust is dependent upon the width of the saw-kerf and average dimensions of lumber to be sawed. Other factors to be taken into account are taper, shrinkage, normal crook and excessive taper in small logs, but these are of less importance than the two cited above.

The following log rules are constructed with a total wastage allowance proportional to the total volume of the log, regardless of size—taper not considered:

Constantine, Saco River, Derby, Square of Three-quarters, Partridge, Vermont, Stillwell, Ake, Square of Two-thirds, Orange River, Cumberland River. These rules are incorrect in principle, therefore no correction is possible.

Another group of rules is derived by substituting a waste allowance proportional to total volume, plus a constant for logs of different sizes—taper not considered. It would seem as though some effort had been made to correct the inaccuracy of the preceding group by adding a constant to compensate for waste occasioned by sawing logs of different sizes. The underlying principles of these rules are incorrect, however, and consequently their values cannot be properly adjusted. Such rules are the following:

Bangor, Boynton, Parsons, Warner, Spaulding, Hannah, Wilcox, Finch and Apgar, Ropp, Scribner, Favorite, Maine, Herring, Dusenbury.

Log rules with slab allowance varying directly as the barked area of logs of different sizes and with sawdust allowance directly as the volume after the slab allowance has been made are correct in principle, but are not necessarily correct measures. Rules of this type are as follows:

Champlain, Boughman's Rotary Saw, Boughman's Band Saw, Wilson, Carey, Baxter, Click, British Columbia, Universal, International, Preston, Doyle, McKenzie.

Of the preceding rules the Champlain, Universal, International and McKenzie are the only ones that are at all flexible to milling conditions and character of timber to be sawed. The Champlain and the Universal are the same, with the exception of the slab allowance, which in the case of the Universal is twice as great as for the Champlain. The saw-

dust allowance for both rules is made by allowing  $\left(100 - \frac{100}{1+k}\right)$  per cent of the volume of the log (taper not included) for sawdust. This

factor is correct for a gang saw with saws  $k''$  thick and  $1''$  apart, but does not apply to any other milling conditions. Taper is not taken into consideration by either of these rules. Both rules have a fixed slab allowance, and the sawdust factor is affected by saw-kerf alone.

The International Log Rule also has a fixed slab allowance, and the sawdust allowance is unaffected by the dimensions of the lumber to be sawed. The value of this factor has been worked out for different gauge saws, and is the same regardless of dimensions of the manufactured product. The rule has a fixed taper allowance of  $\frac{1}{2}''$  in  $4'$ , and tables compiled in accordance with the rule are based upon  $4'$  sections.

Since the analysis proved that no log rule now in use is universally applicable, a rule has been prepared and designated the McKenzie rule, which may be made to apply accurately to any set of conditions and at all times be susceptible to proper corrections made necessary by modifications of local methods employed.

This rule, with no allowance made for shrinkage and surfacing, is shown on page 19, and for convenience may be written:

$$\left[ 1 - \frac{(w+k)(t+k) - wt}{(w+k)(t+k)} \right] \frac{\pi(D-a)^2}{4 \times 12} L + C = \text{B.M.}$$

With an allowance for shrinkage and surfacing included, the rule complete becomes:

$$\left[ 1 - \frac{(w+c+k)(t+b+k) - wt}{(w+c+k)(t+b+k)} \right] \frac{\pi(D-a)^2}{4 \times 12} L + C = \text{B.M.}$$

Where  $b$  and  $c$  in inches, represent these allowances in thickness and width, respectively.

## APPENDIX.

**How to Adjust the McKenzie Log Rule to Conditions Existing at Any Mill.**

This can best be shown by assuming a set of conditions and then reducing the rule from its general form to a special form in accordance with whatever the limitations imposed may be. For example, assume the following:

Mill output for period of three months:

150,000	bd. ft. of	1" × 3"	cut	1 1/16" × 3 1/8"
120,000	bd. ft. of	1" × 4"	cut	1 1/16" × 4 1/8"
180,000	bd. ft. of	1" × 6"	cut	1 1/16" × 6 1/8"
225,000	bd. ft. of	1" × 8"	cut	1 1/16" × 8 1/8"
700,000	bd. ft. of	1" × 12"	cut	1 1/16" × 12 1/4"
550,000	bd. ft. of	1" × 14"	cut	1 1/16" × 14 1/4"
300,000	bd. ft. of	1" × 16"	cut	1 1/16" × 16 1/4"
270,000	bd. ft. of	1" × 18"	cut	1 1/16" × 18 1/4"
180,000	bd. ft. of	6/4" × 8"	cut	1 9/16" × 8 1/8"
275,000	bd. ft. of	6/4" × 10"	cut	1 9/16" × 10 1/8"
500,000	bd. ft. of	6/4" × 12"	cut	1 9/16" × 12 1/4"
300,000	bd. ft. of	6/4" × 14"	cut	1 9/16" × 14 1/4"
275,000	bd. ft. of	6/4" × 16"	cut	1 9/16" × 16 1/4"
240,000	bd. ft. of	6/4" × 18"	cut	1 9/16" × 18 1/4"
600,000	bd. ft. of	2" × 4"	cut	2 1/8" × 4 1/8"
450,000	bd. ft. of	2" × 6"	cut	2 1/8" × 6 1/8"
225,000	bd. ft. of	2" × 8"	cut	2 1/8" × 8 1/8"
175,000	bd. ft. of	2" × 10"	cut	2 1/8" × 10 1/8"
200,000	bd. ft. of	2" × 12"	cut	2 1/8" × 12 1/4"
210,000	bd. ft. of	3" × 3"	cut	3 1/8" × 3 1/8"
270,000	bd. ft. of	3" × 6"	cut	3 1/8" × 6 1/8"
250,000	bd. ft. of	3" × 12"	cut	3 1/8" × 12 1/4"
300,000	bd. ft. of	4" × 4"	cut	4 1/8" × 4 1/8"
150,000	bd. ft. of	4" × 6"	cut	4 1/8" × 6 1/8"
375,000	bd. ft. of	5" × 8"	cut	5 1/8" × 8 1/8"
180,000	bd. ft. of	6" × 6"	cut	6 3/16" × 6 3/16"
120,000	bd. ft. of	6" × 8"	cut	6 3/16" × 8 3/16"
275,000	bd. ft. of	7" × 9"	cut	7 3/16" × 9 3/16"
250,000	bd. ft. of	8" × 8"	cut	8 1/4" × 8 1/4"
200,000	bd. ft. of	8" × 12"	cut	8 1/4" × 12 1/4"
375,000	bd. ft. of	8" × 16"	cut	8 1/4" × 16 1/4"
190,000	bd. ft. of	12" × 12"	cut	12 1/4" × 12 1/4"

Width of saw kerf = 1/8"

Average taper (not including butt logs or top logs)

= approx. 1/2" in 8'

Average thickness of slabs and edgings at small end of logs = 5/8"

To determine a special form of

$$\left[ 1 - \frac{(w + c + k)(t + b + k) - wt}{(w + c + k)(t + b + k)} \right] \frac{\pi(D - a)^2}{4 \times 12} L + C = \text{B.M.}$$

which will conform to the above milling conditions and character of timber.

(a) The determination of the average value of

$$\left[ 1 - \frac{(w + c + k)(t + b + k) - wt}{(w + c + k)(t + b + k)} \right] \quad (A)$$

For 1" x 3" lumber cut 1 1/16" x 3 1/8"

$w = 3, \quad c = 1/8 = .125, \quad k = 1/8 = .125$

$t = 1, \quad b = 1/16 = .0625$

$(w + c + k) = 3 + .125 + .125 = 3.25$

$(t + b + k) = 1 + .062 + .125 = 1.187$

$(w + c + k)(t + b + k) = 3.25 \times 1.187 = 3.86$

$wt = 1 \times 3 = 3$

Then (A) =  $1 - \frac{3.86 - 3}{3.86} = 1 - .223 = .777$

Therefore 150,000 bd. ft. represents 77.7% of the original material, or 22.3% has been forfeited to sawdust, shrinkage and surfacing in manufacturing 1" x 3" lumber, cut 1 1/16" x 3 1/8" when saw kerf = 1/8"

$\frac{150,000}{.777} = 193,000 =$  the volume in bd. ft. of material actually used in producing 150,000 bd. ft. of 1" x 3" lumber (not including slabs and edgings).

With simliar determinations made for all other dimensions of lumber cut, we have:

150,000 bd. ft. of	1" x 3" cut	1 1/16" x 3 1/8"	requiring 193,000 bd. ft. of solid material.
120,000 bd. ft. of	1" x 4" cut	1 1/16" x 4 1/8"	requiring 151,000 bd. ft. of solid material.
180,000 bd. ft. of	1" x 6" cut	1 1/16" x 6 1/8"	requiring 222,000 bd. ft. of solid material.
225,000 bd. ft. of	1" x 8" cut	1 1/16" x 8 1/8"	requiring 276,000 bd. ft. of solid material.
700,000 bd. ft. of	1" x 12" cut	1 1/16" x 12 1/4"	requiring 857,000 bd. ft. of solid material.
550,000 bd. ft. of	1" x 14" cut	1 1/16" x 14 1/4"	requiring 672,000 bd. ft. of solid material.
300,000 bd. ft. of	1" x 16" cut	1 1/16" x 16 1/4"	requiring 364,000 bd. ft. of solid material.
270,000 bd. ft. of	1" x 18" cut	1 1/16" x 18 1/4"	requiring 327,000 bd. ft. of solid material.
180,000 bd. ft. of	6/4" x 8" cut	1 9/16" x 8 1/8"	requiring 209,000 bd. ft. of solid material.
275,000 bd. ft. of	6/4" x 10" cut	1 9/16" x 10 1/8"	requiring 317,000 bd. ft. of solid material.
500,000 bd. ft. of	6/4" x 12" cut	1 9/16" x 12 1/4"	requiring 579,000 bd. ft. of solid material.
300,000 bd. ft. of	6/4" x 14" cut	1 9/16" x 14 1/4"	requiring 346,000 bd. ft. of solid material.
275,000 bd. ft. of	6/4" x 16" cut	1 9/16" x 16 1/4"	requiring 316,000 bd. ft. of solid material.
240,000 bd. ft. of	6/4" x 18" cut	1 9/16" x 18 1/4"	requiring 275,000 bd. ft. of solid material.
600,000 bd. ft. of	2" x 4" cut	2 1/8" x 4 1/8"	requiring 718,000 bd. ft. of solid material.
450,000 bd. ft. of	2" x 6" cut	2 1/8" x 6 1/8"	requiring 529,000 bd. ft. of solid material.
225,000 bd. ft. of	2" x 8" cut	2 1/8" x 8 1/8"	requiring 261,000 bd. ft. of solid material.
175,000 bd. ft. of	2" x 10" cut	2 1/8" x 10 1/8"	requiring 202,000 bd. ft. of solid material.
200,000 bd. ft. of	2" x 12" cut	2 1/8" x 12 1/4"	requiring 232,000 bd. ft. of solid material.
210,000 bd. ft. of	3" x 3" cut	3 1/8" x 3 1/8"	requiring 246,000 bd. ft. of solid material.
270,000 bd. ft. of	3" x 6" cut	3 1/8" x 6 1/8"	requiring 304,000 bd. ft. of solid material.
250,000 bd. ft. of	3" x 12" cut	3 1/8" x 12 1/4"	requiring 279,000 bd. ft. of solid material.
300,000 bd. ft. of	4" x 4" cut	4 1/8" x 4 1/8"	requiring 340,000 bd. ft. of solid material.
150,000 bd. ft. of	4" x 6" cut	4 1/8" x 6 1/8"	requiring 166,000 bd. ft. of solid material.
375,000 bd. ft. of	5" x 8" cut	5 1/8" x 8 1/8"	requiring 405,000 bd. ft. of solid material.
180,000 bd. ft. of	6" x 6" cut	6 3/16" x 6 3/16"	requiring 199,000 bd. ft. of solid material.
120,000 bd. ft. of	6" x 8" cut	6 3/16" x 8 3/16"	requiring 131,000 bd. ft. of solid material.
275,000 bd. ft. of	7" x 9" cut	7 3/16" x 9 3/16"	requiring 297,000 bd. ft. of solid material.
250,000 bd. ft. of	8" x 8" cut	8 1/4" x 8 1/4"	requiring 277,000 bd. ft. of solid material.
200,000 bd. ft. of	8" x 12" cut	8 1/4" x 12 1/4"	requiring 216,000 bd. ft. of solid material.
375,000 bd. ft. of	8" x 16" cut	8 1/4" x 16 1/4"	requiring 402,000 bd. ft. of solid material.
190,000 bd. ft. of	12" x 12" cut	12 1/4" x 12 1/4"	requiring 202,000 bd. ft. of solid material.

9,060,000 bd. ft. is manufactured from.....10,510,000 bd. ft. of solid material, not including the wastage necessary for slabs and edgings.

10,510,000 — 9,060,000 = 1,450,000 bd. ft. required for sawdust, shrinkage and surfacing.

$\frac{1,450,000}{10,510,000} = .138 =$  fractional part of the logs, after slab allowance has been made, which becomes waste.

$(1 - .138) =$  fractional part becoming lumber.

Therefore the average value of (A) becomes  $(1 - .138)$  for the above milling conditions.

(b) The determination of slab allowance or surface wastage:

This allowance is provided for in the formula by the constant "a", which represents twice the average thickness of the slabs and edgings coming from the small end of logs, regardless of their length. The value of "a" can be closely estimated at any mill by watching the logs being sawed into lumber. If the character of the timber being sawed is such that a waste allowance, additional to that made for slabs and edgings is necessary, to correct for losses due to crook, such an allowance should be made by increasing the value of the factor "a" to a sufficient amount to offset losses caused by such defects.

For the milling conditions under consideration here, the value of "a" is assumed to be  $5/8'' \times 2$ , or 1.25. Substituting this value and the average value of (A), already determined, in the general formula, we have the following special form:

$$(1 - .223) \frac{\pi (D - 1.25)^2}{4 \times 12} L + C = \text{B.M.}$$

for logs L feet long with no allowance made for taper.

For 8' sections this form becomes:

$$(1 - .223) \frac{\pi (D - 1.25)^2}{6} + C$$

or

$$.407 (D - 1.25)^2 + C = \text{B.M.}$$

The constant C is included in the formula to counteract excessive taper in small logs, and its value should never be over 10 board feet. It can be definitely determined for a certain class of timber, by first ascertaining the mill overrun for small logs when  $C = 0$ , and then making the value of C great enough to correct for the overrun. Large logs will be affected a negligible amount by the addition of this small quantity.

With  $C = 3$  board feet, we have for the final reduction of the general rule:

$$.407 (D - 1.25)^2 + 3 = \text{B.M.}$$

to be applied to 8' sections with a taper of  $1/2''$  in each 8'.

A volume table based on the above rule with a taper allowance of  $1/2''$  in 8' should be compiled as follows:

Length in feet	DIAMETER IN INCHES									
	6	7	8	9	10	11	12	13	14	15
	BOARD FEET									
8	12	16	22	28	34	42	50	59	69	80
9	14	18	25							
10	16	21	28							
11	17	23	31							
12	19	26	34							
13	21	28	38							
14	22	30	41							
15	24	33	44							
16	26	35	47	59	72	98	104	123	144	
17	28	38	50							
18	30	41	54							
19	32	43	57							
20	34	46	61							
21	36	49	64							
22	38	51	68							
23	40	54	71							
24	42	57	75	93	114	148	163	192	224	

Values for 8' sections of different diameters are first determined directly from the formula. Then 16' logs are considered as being made up of two 8' sections, the one being one-half inch in diameter greater than the other; 24' logs as three 8' sections, one of them being the measured diameter at small end of log, another one, one-half inch greater than this, and the third, one inch greater. Thus, 26 board feet, which is the volume given in the above table for a log 16' long and 6'' in diameter, was obtained by adding 12 board feet, which is the volume given for an 8' section of same diameter, and 14 board feet obtained by averaging twelve and sixteen. (The average of 12 and 16 board feet gives volume for 8' section, six and one-half inches in diameter.) The volume of the 24' log of six inches in diameter shown in the table was obtained by adding 26 and 16. Twenty-six board feet being the volume of the first two 8' sections contained in the log and sixteen board feet being the volume of the third or largest section. Other values may be obtained in a similar manner.

If the taper allowance were 1'' in 8' instead of  $1/2''$  in 8', a 16' log 6'' in diameter at the small end would scale the same as two 8' sections; the one 6'' in diameter and the other 7''. A 24' log 20'' in diameter would, in like manner, scale the same as three 8' sections; the first 20'', the second 21'' and the third 22'' in diameter. If this log were 22' long instead of 24' the scale would then be equal to that of the first two sections plus three-quarters of the third. By similar computations, all values composing a complete volume table for logs of different diameters and lengths can be compiled.

Log rules determined as explained in this Appendix apply to average conditions existing at the mills where they are made and are average rules which do not measure the fluctuations encountered in individual logs.

