The CUBIC FOOT AS A NATIONAL LOG-SCALING STANDARD

by

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Missoula Montana

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INDEX

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INTRODUCTION

That board-foot log rules inadequately serve their purpose in determining the quantitative contents of logs has been recognized to a greater or lesser extent ever since the first rule came into being over a centry ago. Whoever invented the second rule probably did so because the first was in disrepute or was not widely accepted. But providing a log rule which would be widely used proved to be no easy task. Apparently there were many diverging opinions pertaining to log rules, for in succeeding years forty or fifty more were devised, old ones were remodeled, and hybrid rules were constructed by combining the best or worst features of existing rules. Since the number of rules and their inconsistencies led to endless confusion, many were discarded and passed into oblivion. Not more than a dozen are still in wide commercial use. Using these has now become a custom, albeit often a bad one.

Undoubtedly most makers of board-foot log rules intended them to show with a reasonable degree of accuracy the number of board feet of lumber that could be obtained from logs of different sizes. These estimates were called "board feet log scale." Though the similarity in name creates an impression that board feet log scale and board feet of lumber are identical, actually there are decided differences.

A board foot of lumber is a piece 1 foot wide, 1 foot long, and 1 inch thick. Equal in volume to one twelfth of a cubic foot, it makes an exceedingly convenient unit for measuring the volume of boards. Lumbermen have used this standard for years and found it satisfactory. It should not be inferred from anything said herein that a new standard is advocated for measuring lumber.

Unlike a board foot of lumber, however, the board foot log scale is an ambiguous unit of no certain size. Sawmill men have learned that the board-foot scale of a run of logs is apt to be merely a rough criterion of the yield of lumber. There is usually some disparity between the log scale and the lumber tally, the amount depending on the size of the logs, the log rule used, who saws the logs and how, and various other factors. If the yield of lumber exceeds the log scale, the excess is called overrun. If a shortage occurs, it is called underrun. The amount of the overrun or underrun cannot be foretold unless similar logs have been sawed in the same mill.

Many manufactories which produce products other than lumber (pulp,veneer,etc.) have also learned from experience that the board foot log scale is ambiguous. They find that the relationship between a log's size (cubic volume) and its

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1/ This Paper was originally published January 31, 1940 as an unnumbered mimeographed release of the Northern Rocky Mountain Forest and Range Experiment Station

board foot scale is so variable that the board foot log scale becomes a meaningless standard in their industry. There seems to be no answer to the question: How large is a board foot log scale? Then too, the number of log rules in use furnishes further confusion because different rules show different board-foot contents for the same logs.

The discussion which follows proposes that log volumes should be measured in cubic feet. Before this standardization can be accomplished, it must have the approval of men who are concerned with log buying and selling. Their consent must be freely given or the plan cannot become effective. The writer hopes they will study in a fair, impartial manner the viewpoint presented herein. Needless to say, this viewpoint is the writer's own and not necessarily that of his associates.

CONSTRUCTION OF BOARD-FOOT LOG RULES

Log rules are usually constructed from diagrams or from a mathematical formula. In addition, they are occasionally constructed from lumber tallies or by modifying existing rules.

Diagram Rules

Rules of this type are based on diagrams drawn to scale, which show the volume of boards that can be obtained from logs of different diameters after allowing for waste. The Scribner is one of these diagram rules. Constructed in 1846, it is a relic of old-fashioned sawmill practices and, though still in use, is becoming out of date. Many improvements have been made in sawmills since 1846, and as might be expected high overruns are now

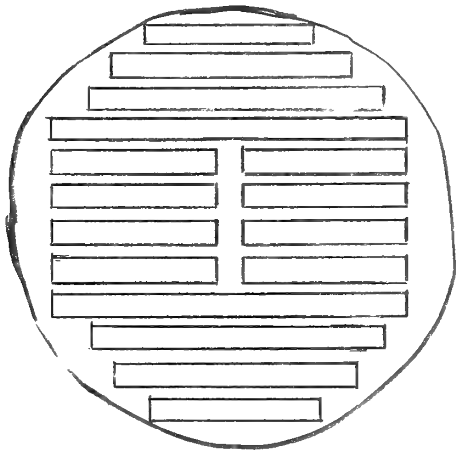


Figure 1. Diagram method of log-rule construction.

obtained, particularly from small logs. The Scribner Decimal C rule, a variation and extension of the original Scribner, is used by the United States Forest Service. It is not more accurate than the original rule.

Formula Rules

Formula rules are based on a mathematical statement which gives the board-foot contents after making allowance for waste and other elements influencing lumber yields. One of the poorest rules of this type is the Doyle. Though the Doyle is used extensively, it is reputed to be one of the most inconsistent rules ever devised.

One of the better rules which is based on a formula is the International. Embodied in it are allowances for log taper, saw kerf, slabs, edgings, and lumber shrinkage. There is no doubt that the International is better adapted to accurate work than most of the other log rules now in existence. Unfortunately it is seldom used commercially except in the New England States, where it recently found favor. In most sawmills, logs measured with the International will under-run the scale. There is a tendency for small logs to give overruns.

Those who wish to learn more about log rules and their construction will find considerable information in various textbooks on forest mensuration. Table 1 is also of assistance as it makes comparisons among a few of the best known log rules.

THE NEED FOR A COMMON STANDARD

The timber industry, one of the largest in the nation with billions of dollars in investments, needs a common standard for figuring log volumes and for buying and selling timber. Log rules have flourished for a century but no standard has so far been evolved. It is probably true that this is the fault of the board foot log scale. It is so ambiguous and so indefinite that it fails to meet the requirements for a standard which can be used in common by sawmills, pulp mills, and other users of timber. Changing from one log rule to another seems to be merely a matter of jumping from the frying pan into the fire, or back again.

The United States has many units of measure, among which are units of weight (ounce, gram, pound, ton), units of length (foot, mile, centimeter), and units of volume (cubic foot, gallon, board foot of lumber), to mention only a few. The board foot log scale differs from all these standards in three important respects:

1. There are as many definitions of a board foot log scale as there are log rules and log sizes.

2. No single log rule has ever been nationally accepted as a common standard.

3. Log rules which are accepted as standards in limited areas are replaced from time to time by other log rules.

The basic assumption that a board foot log scale is approximately equal to a board foot of lumber creates innumerable difficulties and results in a multiplicity of log rules. Log rules are used today that did not exist 50 years ago. Rules, old and new, fall into disrepute and are replaced

Table 1.- Comparison of Log Rules

Top Diameter of Log inside Bark	Volumes of 16-foot logs for various log rules, expressed in board feet and in percentage of the International Log Rule volumes												
	International 1/4-inch kerf	Scribner Decimal C		Spaulding		Doyle		Holland or Maine		Blodgett or New Hampshire		Humphrey or Vermont	
Inches	Bd. ft.	Bd. ft.	Per-Cent	Bd. ft.	Per-Cent	Bd. ft.	Per-Cent	Bd. ft.	Per-Cent	Bd. ft.	Per-cent	Bd. ft.	Per-Cent
6	20	20	100	..	..	4	20	20	100	26	130	24	120
7	30	30	100	..	..	9	30	31	103	35	117	32	107
8	40	30	75	..	..	16	40	44	110	43	108	43	108
9	50	40	80	..	..	25	50	52	104	54	108	53	106
10	65	60	92	50	77	36	55	68	105	66	102	67	103
11	80	70	88	63	79	49	61	83	104	78	98	80	100
12	95	80	84	77	81	64	67	105	111	92	97	96	101
13	115	100	87	94	82	81	70	120	104	106	92	112	97
14	135	110	81	114	84	100	74	142	105	123	91	131	97
15	160	140	88	137	86	121	76	161	101	139	87	149	93
16	180	160	89	161	89	144	80	179	99	157	87	171	95
17	205	180	88	188	92	169	82	205	100	176	86	192	94
18	230	210	91	216	94	196	85	232	101	197	86	216	94
19	260	240	92	245	94	225	87	271	104	217	83	240	92
20	290	280	97	276	95	256	88	302	104	240	83	267	92
21	320	300	94	308	96	289	90	336	105	262	82	293	92
22	355	330	93	341	96	324	91	363	102	287	81	323	91
23	390	380	97	376	96	361	93	401	103	313	80	352	90
24	425	400	94	412	97	400	94	439	103	339	80	384	90
25	460	460	100	449	98	441	96	477	104	367	80	416	90
26	500	500	100	488	98	484	97	507	101	397	79	451	90
27	540	550	102	528	98	529	98	546	101	426	79	485	90
28	585	580	99	569	97	576	98	614	105	457	78	523	89
29	630	610	97	612	97	625	99	657	104	489	78	560	89
30	675	660	98	656	97	676	100	706	105	514	76	600	89
31	720	710	99	701	97	728	101	755	105	557	77	640	89
32	770	740	96	748	97	784	102	792	103	592	77	683	89
33	820	780	95	796	97	841	103	848	103	628	77	725	88
34	875	800	91	845	97	900	103	900	103	666	76	771	88
35	925	880	95	897	97	961	104	949	103	704	76	816	88
36	980	920	94	950	97	1024	104	1026	105	744	76	864	88
37	1040	1030	99	1006	97	1089	105	1089	105	785	75	912	88
38	1095	1070	98	1064	97	1156	106	1135	104	827	76	963	88
39	1155	1120	97	1124	97	1225	106	1209	105	870	75	1013	88
40	1220	1200	98	1185	97	1296	106	1261	103	914	75	1067	87

1/ Adapted from "Converting Factors and Tables of Equivalents Used in Forestry," U.S. Dept. Agri. Misc. Publ. No. 225

by others which are sometimes better but often worse. Though lumber is measured in a standard way by the board foot, there is no common standard for measuring log volumes and never has been.

There seems to be little possibility of constructing a board-foot log rule which will estimate the lumber tally reasonably accurately in every sawmill. In devising such a universal rule it becomes necessary to make numerous assumptions regarding factors that influence lumber yields. Among these factors are the following:

1. Products cut (inch boards versus timbers)
2. Saw kerf (thick saws versus thin)
3. Workmen (skilled employees versus unskilled)
4. Machinery (good machines and well-fitted saws versus poor equipment)
5. Utilization (close utilization versus wasteful methods)
6. Remanufacturing (heavy footage losses in seasoning yard and planing mill versus light losses)

Whatever assumptions are made will not be universally applicable. Each sawmill differs from its neighbor. Some have low standards of utilization and others high. Lumber yields vary accordingly.

IS A UNIVERSAL LOG RULE PRACTICABLE?

Is it practical to recommend as a universal standard a board-foot log rule, comparable to the International, which embraces such high standards of utilization that only the nearly perfect sawmills could achieve the lumber yields it forecasts?

It is probably true that such a high-standard rule would be viewed with much apprehension. Many log buyers derive a sense of well-being from purchasing a thousand feet of logs, measured with their regular scale stick, and obtaining therefrom 1,200 feet of lumber. These same buyers would less willingly purchase 1,300 feet of logs scaled by this high-standard rule and derive therefrom only 1,200 feet of lumber even though the cubic volume of the logs and their cash value are the same in each transaction. Overrun has long been considered "velvet" and a bonus for good manufacturing practice, even though it is generally known that a mill would need to be intolerably obsolete and archaic to avoid obtaining an overrun if the customary scale rules are used.

Furthermore, this so-called high-standard rule would have the same disadvantages which now attend the use of prevailing board-foot log rules. It would not eliminate the disparity between log scale and lumber tally

because the yield of lumber would still depend on who sawed the logs and how. It would not eliminate the perennial disputes on overrun except by substituting disputes on underrun. It would not be fair to log haulers who are concerned with the cubical contents (weight) they carry. It would not be applicable to the use of industries such as pulp mills which are concerned with the amount of wood in a log and not the volume of inch boards a sawmill might obtain. It would not be as fair as a cubic-foot rule to employees who are paid on a "per thousand" piecework basis. It would not be equally accurate for all species because some are utilized more closely than others, even in the same sawmill. It would not eliminate the pressure brought upon scalers, in iniquitous ways or otherwise, to scale toward a certain overrun. It would not be suitable for scientific purposes. In addition, it probably would not be consistent for all sizes of logs but, like the present-day rules, show different overruns or underruns for different log sizes. Also, it probably would not be of permanent value but become obsolete just as other log rules have become so. Such obsolescence is caused mainly by (1) changes in machinery or manufacturing practice and (2) changes in utilization which are brought about as business conditions change from good to bad, from bad to worse, or vice versa.

REASONS FOR CUBIC-FOOT LOG SCALING

Many difficulties which attend the use of log rules in log scaling are susceptible of elimination by the adoption of a unit of measure such as the cubic foot. The logic of measuring a commodity such as wood in terms of its actual volume by the use of a unit which has the same size today as tomorrow, for a small log as a large, and the same size in Montana as in Maine or California, can scarcely be disputed. Logs would be sold on the basis of the wood contained therein, and whether they are made into inch boards, mine timbers, ties, shingles, excelsior, pulp chips, or cord wood is the prerogative of the purchaser. No assumptions as to certain products nor as to the intensity of manufacture need be made in cubic-foot scaling.

Because the cubic foot is a simple, clearly defined unit of measure which everyone understands and which has the same size at all times and at all places, it is universally applicable to measuring logs of all sizes and species, logs in transit, logs in the market, or logs in any stage of handling, as well as standing trees. Converting cubic feet of logs to other classes of products (board feet of lumber, units of pulp chips, etc.) usually involves less conjecture than is the case in converting board feet log scale to these products. That the cubic foot measures the amount of wood in a log is, of course, indisputable. This makes it peculiarly adapted to industries which use wood in one form or another but do not produce lumber.

In using the cubic foot there need be no assumptions as to products to be manufactured nor as to the intensity of utilization. What can be fairer? Why should it be assumed, as is done by board-foot log rules, that 1-inch boards are the final product and that they will be manufactured in accordance with practices which were often obsolete at the time of the Spanish-American War? It is probably true that over three-fourths of the lumber sold in the United States is thicker or thinner than 1-inch. There probably

are not a half dozen sawmills which produce 1-inch boards entirely, and none of them produce these boards in accordance with standards prescribed by leading log rules.

An Advantage to Scalers

It is probably true that when scalers use board-foot rules they are thinking of the intensity of utilization and of lumber as the final product. But if business conditions change from good to bad, there are changes in utilization because low-grade material in a log becomes unprofitable to handle.

It is probably true that scalers will be more at peace with the world if they scale logs in cubic feet. This system makes no assumption as to what products will be manufactured nor as to the intensity of utilization. The scaler can divorce himself from the job he creates in his subconscious mind of judging what the standard of utilization ought to be in different manufactories. He can direct his attention to measuring diameters and lengths correctly and making logical deductions for defect. This is his job, nothing more.

In a recent article[1], Henri Roy of the Forest Service, Province of Quebec, declared that use of the cubic foot encourages scalers to do a better job of log measuring. He says:

> "The cubic method of measurement which we have adopted in Quebec, requires that the total mass of wood be tallied and reported separately from the amount to be subtracted for defects .... The scaler is directed in such a way that he is no longer a judge of what the commercial standards of utilization ought to be; he has definite instructions to follow, enacted by official authorities and he must follow them. The result has been that the scaler now submits much closer tallies or, in other words, that the range of variation between different scales of the same log of wood is less, if scaled either a repeated number of times by the same scaler or by many scalers...."

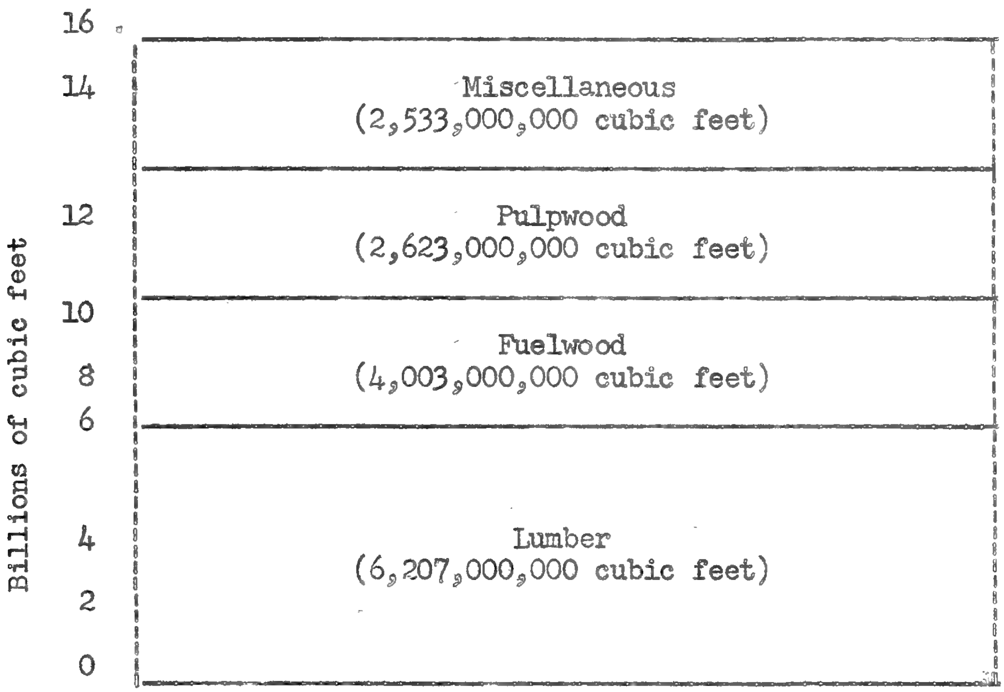
An Advantage to Manufacturers

The board-foot log rules are not as universally useful to the lumbering industry as is commonly supposed. Even the board foot of lumber is not used in all transactions. One large lumbering operation in Montana sells about one-third of its products on a piece basis, and converts from a piece to a board-foot basis chiefly for bookkeeping purposes. There are many smaller mills in Montana and elsewhere which sell their products (ties, round and sawed mining timbers) on a piece basis entirely and never convert from a piece to a log-scale basis or even to lumber tally.

1/ Roy, Henri
1938. Log Scaling in Quebec. Journal of Forestry, vol. 36, no. 10, pp. 969-975.

Though lumber is still the most important product of the forest, it should not be forgotten that over one-half of the timber consumed in the United States is utilized for products other than lumber. Among these products are pulp, plywood, veneer, shingles, cooperage, fuelwood, excelsior, charcoal, and wood distillates. Some of these uses are growing by leaps and bounds. It is estimated that the pulp and paper industry used 1,215,000,000 cubic feet of wood in 1930 (roughly, the equivalent of 6-3/4 billion board feet) and will use twice that quantity by 1950.

Board-foot log rules are of little value to many wood-using industries. Pulp manufacturers, for example, are concerned with the actual amount of wood rather than a hypothetical yield of 1-inch lumber, because they use the entire volume in making chips or groundwood pulp. Log rules are poor indicators of cubical contents because they presuppose that lumber is the final product and that its manufacture entails considerable waste



Source of data: Senate Doc. No. 12, 73rd Congress

Figure 2. Prospective timber requirements.

in the form of sawdust, slabs, and edgings. Pulp manufacturers need a unit of measure which tells them how much wood there is in a log. Board-foot log rules do not do this. Cubic measure does.

Figure 3 illustrates the relationships between the Scribner Decimal C log rule and the cubical contents of logs. The figure shows the number of cubic feet per thousand board feet for 16-foot logs of different diameters. Small logs contain much more wood per thousand feet than large logs.

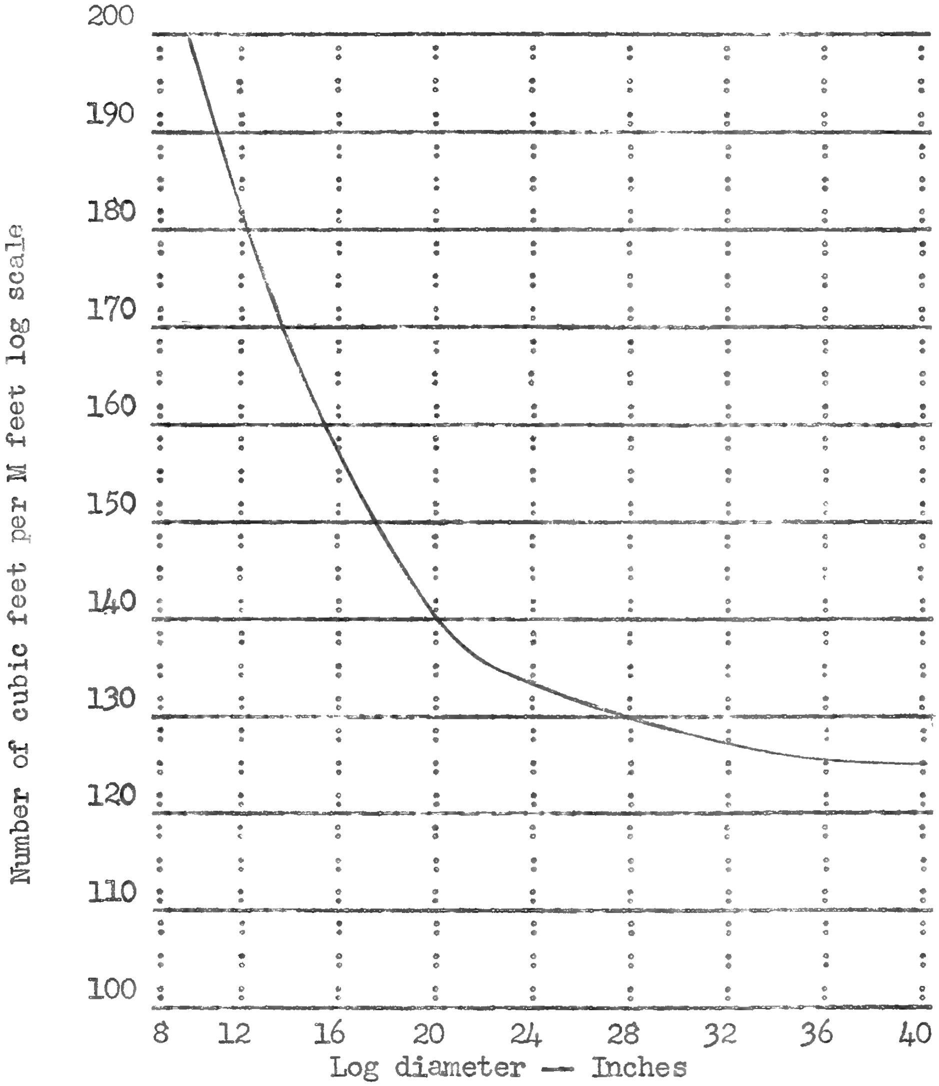


Figure 3. Relation of cubic volume to board feet log scale, by log diameter, based on Scribner Decimal C rule.

The large number of cubic feet per thousand board feet in small logs constitutes one of the worst defects of log rules and militates against the use of young forests. The incongruity is so neatly hidden that its existence is seldom recognized and compensated for by a higher price per thousand feet. Then too, a shrewd buyer may assume that the extra wood is part of the overrun bonus to which he should be entitled. The practical effect of the inconsistency, however, is that independent loggers leave small trees and logs in the woods because their board-foot scale is so low that they furnish no profit. A large waste of small timber results where stumpage is cheap and clear cutting is practiced.

An Advantage to Log Haulers

Reasons for adopting the cubic foot extend into businesses associated with the timber industry. Those who haul logs (steamship lines, railroads, motor truckers) will probably agree that cubical content provides a better base for rates than a thousand board feet log scale. There is precedent in this respect. Many steamship lines on the Pacific Coast have successfully used the Brereton rule for several years in determining the contents of log cargos. The Brereton rule, printed in "The Practical Lumberman" (see the bibliography on the last page), is essentially a cubic-foot rule.

Railroad rates for logs are occasionally on a carload basis though usually on a thousand-feet-log-scale basis. In either case the rate per carload or per thousand feet depends primarily on weight. Railroads haul tonnage. If it is worth 30 cents a ton to haul logs between two points, and a thousand feet of logs as ascertained by tests averages four tons in weight, the rate becomes $1.20 per thousand board feet. Though the rate books quote figures on a per-thousand-feet basis, somewhere among the calculations is the fact that logs average so much weight per thousand board feet and it is worth so much per ton to haul them.

Cubic volume is not a perfect criterion of weight, quite true. In many species, small logs contain high percentages of the heavy sapwood. Also, butt logs are often heavier than average. Though these variations occur, the basic fact exists that cubic volume is a better expression of weight than board-foot volumes.

As was shown previously (figure 3), small logs contain more wood per thousand board feet and, of course, they weigh more. Since they weigh more they are hauled to market cheaper because, as mentioned previously, the rate is determined on the basis of weight and then converted to thousand board feet log scale.

An Advantage to Employees

In many places, the job of making trees into logs is on a piece-work basis, the earnings of employees depending on their output. Though different systems are in effect, it is common practice to pay a flat rate per thousand feet log scale for logs produced. Tests show that if outputs were measured in cubic feet, the results would be more equitable to employee and employer alike.

Table 2 gives a comparison of earnings in different sizes of Idaho white pine timber, with the volumes in the table computed on both a board-foot log scale and a cubic-foot basis. When average earnings equal 100, the range in earnings on a board-foot log scale basis is from 55 for small timber to 116 for large, or a spread of 61 units. On a cubic-foot basis the range is from 63 to 110, or a spread of only 47 units, which is 23 percent less than the board-foot basis.

Table 2. Relative earnings of woods sawyers
(Average earnings = 100 percent)

Diameter breast high class	Scribner Decimal C rule gross scale basis	Cubic feet, gross volume basis
Inches	Percent	Percent
10-13	55	63
14-16	75	84
17-20	92	98
21-24	105	105
25 & up	116	110
Wt. average	100	100

An Advantage to Scientists

Where exactness is required, as in scientific work, volumes computed by using board-foot log rules give very uncertain answers. Then too, if results must be expressed in terms of a number of log rules, computations must be repeated, which adds to the work.

The uncertainty of answers obtained by using board-foot log rules can best be illustrated by an example. The example chosen for illustration deals with the growth of a tree which contains one 16-foot log whose diameter was 6 inches in 1900 and 9 inches in 1930, the rate of growth being 1 inch per decade, as shown in table 3. Volumes for this tree on a board foot (Scribner Decimal C) basis and on a cubic-foot basis are also shown, as well as the percent of increase in volume, by decades.

Table 3. Tree growth by decades, expressed in board feet log scale and cubic feet.

Year	1900	1910	1920	1930
Diameter, top end of log - inches	6	7	8	9
Volume, Scribner Decimal C rule - board feet	20	30	30	40
Volume - cubic feet	4.0	5.3	6.7	8.3

Percent increase in volume by decades, board-foot basis: 1900-1910, 50 percent; 1910-1920, 0 percent; 1920-1930, 33 percent.

Percent increase in volume by decades, cubic-foot basis; 1900-1910, 32 percent; 1910-1920, 26 percent; 1920-1930, 24 percent.

Evidently the percent increase in volume on a cubic-foot basis is much more meaningful than the increase shown by the board-foot basis. According to the board-foot basis, the tree grew by leaps and bounds during the first decade, then stopped growing for one decade, and in the next decade again leaped ahead. Actually, the rate of volume growth was decreasing each decade as the cubic-foot basis shows.

It might also be mentioned, in passing, that since the Scribner rule, as well as many others, gives high overruns for small logs it naturally follows that small logs are so badly underscaled that they cannot be handled profitably. The end result is poor utilization of top logs in large trees. The use of young timber is also penalized, and though this may be fortunate in some cases, it is unfortunate in others. As time goes on and the supplies of virgin timber wane, more and more dependence must be placed on young forests.

CONVERTING CUBIC FEET TO OTHER UNITS OF MEASURE

Log volumes in cubic feet can be converted to the unit of measure appropriate to each manufacturing plant with often less uncertainty and difficulty than is now the case in converting board feet log scale to board feet of lumber, board feet log scale to cords, or board feet log scale to units of pulp chips or to other measures.

The all-important question that sawmill men will ask when cubic-foot scaling is proposed is: "What converting factor must we use? How many board feet of lumber will a cubic foot of logs produce?"

Sawmill men will find that little surmise or conjecture is involved in determining the board foot-cubic foot ratio. This ratio can be computed very easily by comparing the yield of lumber with the cubage of the logs. The number of board feet of lumber per cubic foot of log gives the board foot-cubic foot ratio, just as the number of board feet of lumber per board foot log scale gives the overrun (percent) ratio. Typical ratios appear in table 4.

Table 4. Board foot-cubic foot ratios and overrun ratios[1/]

Location of sawmill	Species	Board foot-cubic foot ratio	Over-run ratio	Log rule used
Montana	West. white pine	7.30	1.21	Scrib. Dec.C
Arizona	Ponderosa pine	7.41	1.08	Do
Montana	Do	7.78	1.21	Do
Oregon	Do	7.74	1.10	Do
Oregon	Do	7.56	1.02	Do
S.Carolina	Loblolly pine	5.50	1.27	Doyle
Montana	Engelmann spruce	6.94	1.09	Scrib. Dec.C
Oregon	Douglas fir	7.69	1.14	Do
Oregon	Do	7.48	1.15	Do
Virginia	Hardwoods	5.99	1.30	Doyle
Virginia	Do	6.30	1.08	Do
Wisconsin	Do	6.68	1.16	Scrib. Dec. C

1/ By the "board foot-cubic foot" ratio is meant the number of board feet of rough-green lumber produced per cubic foot of log. By the "overrun ratio" is meant the number of board feet of rough-green lumber produced per board foot log scale.

As table 4 shows, the board foot-cubic foot ratio is not the same for all mills and runs of timber any more than overrun percent is the same in all instances. In fact, the board foot-cubic foot ratio depends upon the same factors that influence overrun percent.

Converting factors for products other than lumber can be worked out just as simply. Many of the measures used in the timber industry, such as the cord (128 stacked cubic feet) and the unit (200 cubic feet, gross volume), are companions of the cubic foot. Their relations to solid cubic feet for some common products is given in table 5.

Table 5. Approximate[1] equivalents for various measures[2] and products

Material	Measure	Number of solid cubic feet in measure	Ratio of solid contents to space
Sawdust	Unit	80	80:200 or 2.5
Sawdust and shavings, mixed ..	Unit	57	57:200 or 3.5
Hogged fuel	Unit	73	73:200 or 2.7
Pulp chips	Unit	67	67:200 or 3.0
Fuelwood-edgings and slabs	Cord	80	80:128 or 1.6
Forest fuelwood....	Cord	90	90:128 or 1.4

1/ These figures, being averages, are subject to variation.

2/ The "unit" is a measure for bulky materials and contains 200 cubic feet gross volume. The standard cord is 4 by 4 by 8 feet and contains 128 cubic feet.

CHANGE TO CUBIC-FOOT SCALING COULD BE GRADUAL

Changing the method of log measurement from board feet log scale to cubic feet need not be done overnight. Certain agencies might blaze a trail for others to follow. The United States Forest Service, for example, might lead the way and prescribe use of the cubic foot in future sales of national forest timber. Such a change would be gradual and should not apply to existing contracts.

There is no doubt that changing from board feet log scale to cubic feet will, of course, introduce some difficulties. Many cruises of standing timber are on a board-foot-log-scale basis. To be usable, these cruises must be converted to cubic feet by using an appropriate converting factor. In most cases the accuracy of cruises is not essentially affected by using a converting factor provided it is reasonably appropriate. In the forest survey of the northern Rocky Mountain region timber cruises are expressed on both a board-foot-log-scale and a cubic-foot basis, the change being effected by using converting factors which show the number of board feet log scale (as indicated by volume tables) per cubic foot.

TECHNIC IN APPLYING THE CUBIC FOOT

When the cubic foot is used for determining log volumes a variation is apt to occur, just as in board-foot scaling, unless the measuring stick is applied in the same way by all scalers. Quite often logs are measured several times, at various stages of handling between stump and sawmill. They may be scaled in the woods to determine the output of log-makers and again at the landing as they are loaded on railroad cars or trucks; they may also be measured by the log-hauler, by the person who owned the stumpage, by the buyer and the seller of the logs, and again by the buyer when they enter his sawmill. These several determinations will not be in reasonable agreement unless measuring technic is uniform. There are certain to be differences of a few percent if some scalers ignore fractional inches in measuring diameters and others round off fractions to the nearest inch above or below the actual diameter. When logs are not round, further discrepancies occur if some scalers measure the narrow diameter and others take measurements at right angles to each other.

Establishing standards for intelligently determining the cubical contents of logs is equally as important as establishing a standard unit of measure. To insure uniformity, the following standards for measuring diameters and lengths and for determining merchantability are suggested. No new procedures are involved. Similar procedures have been used in board-foot scaling for almost a century.

Diameter Measurement - Top End, Butt End, or Middle?

When log diameters are being measured, speed is often of prime importance. Logs often come to the scaling point by the truckload, carload, or trainload. The haulers are in a rush for their empties, and the scaler must measure diameters in a simple, convenient way. In view of these hurry-up conditions it has become the custom in board-foot scaling to measure only one diameter and this at the top end of the log. Since it is just as logical for this same procedure to be followed in commercial cubic-foot scaling, it is recommended that diameters be measured at the top end of each log inside the bark.

"Average" and "Narrow" Diameter

Since all logs are not round, there is some leeway in measuring the diameter of logs that are eccentric. In such cases it should be the practice to determine the diameter by taking the average of two measurements at right angles to each other, as sketched in figure 4.

When logs are scaled in the water, eccentric logs invariably float with the narrow diameter at right angles to the water line. Though the narrow diameter is the most convenient to measure, care should be taken to determine the average.

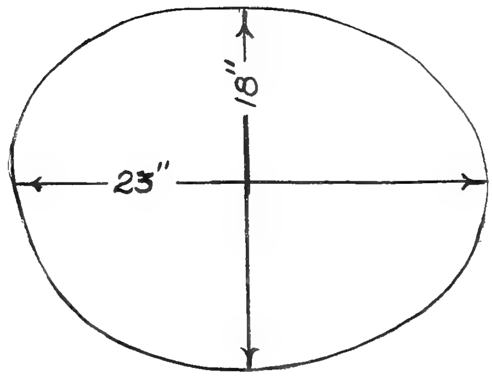


Figure 4. Method of determining the average diameter of a log.

The importance of measuring diameters correctly is shown in figure 5. Here is a portrayal of the difference which results when a diameter is measured too high or too low.

Measuring the diameter and the length of a log correctly is the most important part of an accurate scaling job. Inexperienced men should be able to do this as correctly as old-timers because the measuring is purely mechanical and calls for no special skill or technical knowledge. Gross scales will agree closely if diameters and lengths are measured carefully.

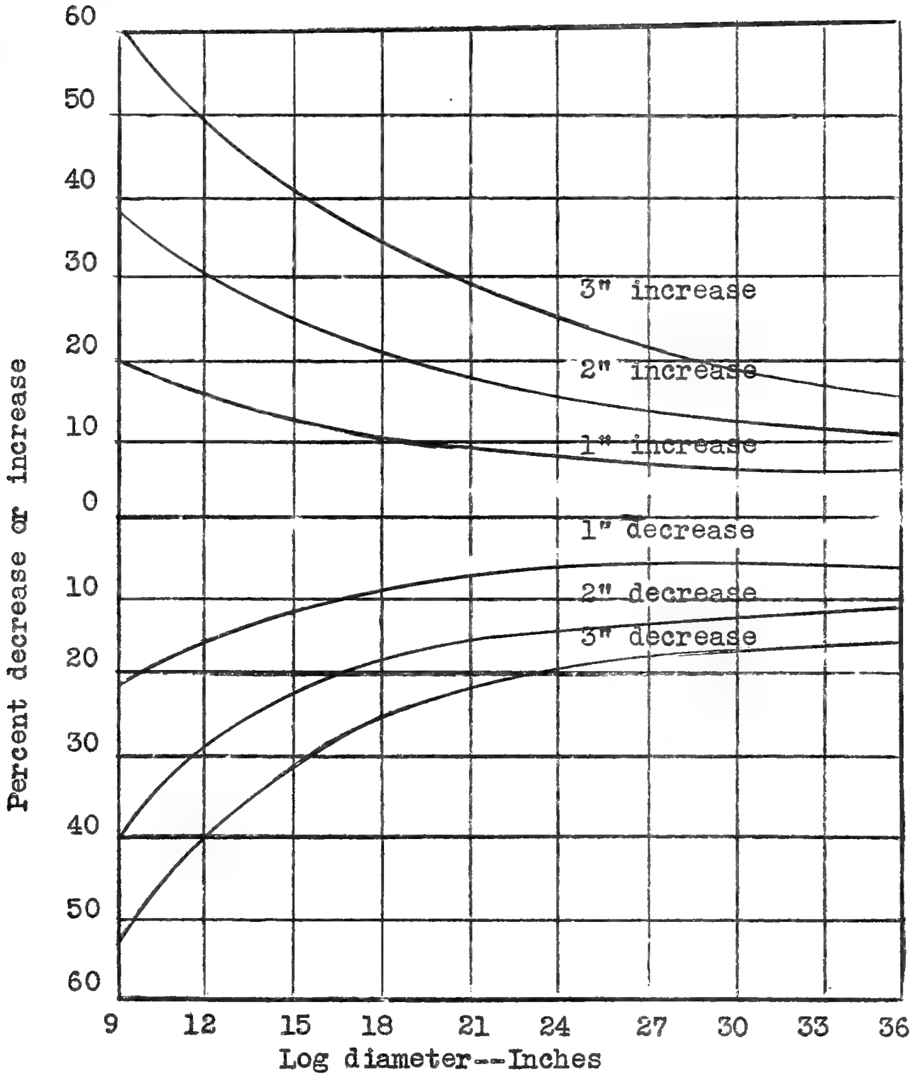


Figure 5. Increase or decrease in log volumes caused by measuring diameters 1 to 3 inches high or low.

The "Nearest" and the "Lower" Inch

Another point on which procedure should be uniform is when diameters fall between inches. In such cases fractional inches should be rounded off to the nearest inch above or below the actual diameter. Logs with a diameter exactly halfway between inches should be placed in the lower inch class. With this system, logs with diameters from 16.0 up to 16.5 inches would be placed in the 16-inch class; logs with diameters over 16.5 and up to 17.0 would be placed in the 17-inch class.

It is poor practice to neglect fractions and scale to the lower inch. Some scalers do this, however, on the assumption that this makes an allowance for hidden defect or, if logs are to be river-driven, for the wear and tear they will receive in the stream. Whether these are legitimate deductions might well be questioned. Even so, the time to make legitimate deductions is after the gross scale has been determined by measuring the log's diameter correctly. Scaling to the lower inch is poor practice because it results in a gross scale which is intentionally low.

Determination of Length

Invariably logs are bucked a few inches longer than their nominal length, the excess being the trimming allowance. Ordinarily the trimming allowance should not be scaled. If the trimming allowance is excessive a penalty scale may be invoked by the owner of the timber, but that is another matter.

Deductions for Defect

If all logs were straight and sound, scaling would be simple. This happens seldom, however, hence deductions must be made for cull material. In cubic-foot scaling, as in board-foot scaling, deductions should be made for defects which render wood unfit for use. No deductions should be made, however, for knots, burls, spiral grain, coarse grain, small pitch pockets, light sap stain, and similar imperfections which may affect the quality of the wood but not its quantity.

Quantitative defects can be roughly classified as follows:

1. Interior defects: internal decay, heart shake, pitch ring, pitch seam, etc.

2. Periphery defects: sap rot, season checks, worm holes, cat face, roughness, etc.

3. Crook defects: sweep or crook and crotch.

4. Operating defects: breakage, end broom, slab, split, etc.

Logs are seldom consistent in their imperfections and show different stages of defect and merchantability. As a result no rules for making reductions can be applied inflexibly. The amount of deduction to make is backed by the good judgment of scalers who are familiar with the timber before them, its characteristic defects, and the way it cuts out.

Ordinarily reduction for defect can be made in one of three ways, namely:

1. By reducing the diameter (for sap rot, etc.)
2. By reducing the length (for butt rot, etc.)
3. By use of diagrams (for most internal defects)

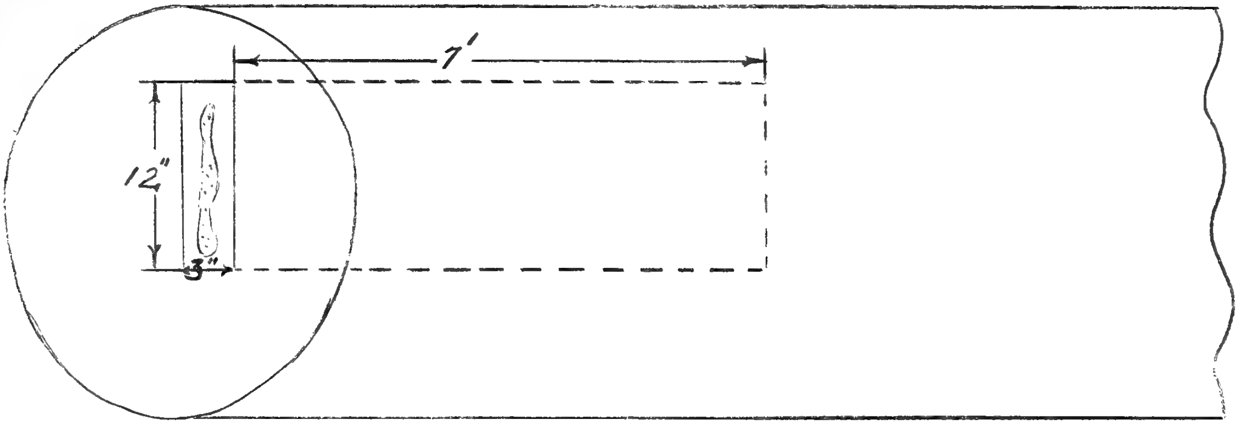
The first two methods are self-explanatory. If sap rot or similar peripheral defects are present, a reduction in diameter is appropriate. A reduction in length often fits the following: butt rot, stump (heart) shake, sweep, crook, crotch, and end broom. Most internal defects (interior decay, pitch ring, pitch seam, heart check, etc.) are best handled by diagrams and the diagram formula. The formula which applies is:

Deduction (cubic feet)

$$= \frac{\text{Width (inches)} \times \text{Thickness (inches)} \times \text{Length (feet)}}{144}$$

$= \frac{W \times T \times L}{144}$; for a rapid mental calculation the formula can be restated: Deduction $= \frac{W \times T \times L}{14}$ and divide by 10 (point off one decimal place).

A similar formula which makes allowance for 1/4-inch saw kerf applies to scaling with board-foot log rules. This formula is: $\frac{W \times T \times L}{15} =$ deduction (board feet of lumber).



Deduction in board feet of lumber is $\frac{3 \times 12 \times 7}{15}$ or 17.

Deduction in cubic feet is $\frac{3 \times 12 \times 7}{14}$ and divide by 10, or 1.8.

Figure 6. Method of deducting for defect by using diagrams.

Culling Logs

The definition of a cull log is largely a local affair which need not be discussed here in detail. Merchantability varies with different species, with business conditions and other factors. In cubic-foot scaling as in board-foot scaling there should, of course, be merchantability or minimum grade specifications which state that to be merchantable a log must have a minimum length of so many feet, a minimum diameter of so many inches, and not over a stated percentage of cull material. Definitions of merchantability which now apply to board-foot scaling will in all probability be applicable in cubic-foot scaling.

The Form of Record

Each scaler should make a record of the logs he scales. This record should include the essential details for each log, such as the species, diameter, length, amount of defect, and net volume. Listing the log number, gross volume, and kind of defect is optional. The form of record might be somewhat like the following:

Log No.	Dia.	Lgth.	Gross Vol.	Deduction	Net volume by species: WP	DF	WL	PP	Spr.	Kind of defect
1	16	16	25	2		23				Cat face
2	14	12	14		14					
3	10	16	11	3	8					Shake
4	12	14	13	1				12		Pitch ring

A record in a scalebook of important details serves two purposes:

1. It is a guarantee of satisfactory work from the scaler and a guarantee to the buyer and the seller that the work has been carefully done. When a complete record is required of the species, diameter, length, cull deduction, and net volume, the scaler will be more apt to make these measurements carefully. Then too, the buyer and the seller, knowing what these measurements are, can if necessary recheck them for a group of logs.

2. It serves as the basis of eliminating the personal element in scaling. If timber is defective, scaling is often a matter of individual judgment; and since one unproved opinion is as good as another, it seems desirable to have procedures rendered as uniform as possible by frequent check scales made by a competent individual whose job it should be to maintain a high scaling standard within the organization. Check-scaling is more effective when the data for each log are completely recorded, since causes for variation can then be corrected.

CONSTRUCTION OF A CUBIC-FOOT RULE

How Much Taper Allowance?

Since many of the board-foot log rules in use assume that the contents of a log are contained in a cylinder having a diameter equal to the top diameter of the log, it becomes necessary when long logs are scaled to apportion them into as equal lengths as possible, and scale the parts separately after making allowance for taper. Some of the better built board-foot log rules have an allowance for taper incorporated in the rule which makes it unnecessary to scale long logs in short lengths.

Taking into account convenience, practicability, and accuracy, no better principle can be followed in constructing a commercial cubic-foot rule than to do as was done in making the best board-foot rules: choose the top end of logs as the place for diameter measurement and incorporate a taper allowance in the rule.

A taper of 0.5 inch in 4 feet is about average for every timber type in the United States. This matter of taper was thoroughly discussed with James W. Girard, assistant director of the forest survey. Mr. Girard has

cruised in every important timber type in this country and undoubtedly knows more about the form of trees and their taper than any other individual.

A taper of 0.5 inch in 4 feet is applicable to almost all timber types with the possible exception of old-growth southern pines, some species of hardwood in the Mississippi delta, and some very short (stunted or open grown) second growth. Even to these a 0.5-inch taper can be applied without much inaccuracy. The old-growth southern pines (longleaf, shortleaf, loblolly, and slash) usually taper at the rate of 0.4 inch in 4 feet. Some but not all of the Mississippi delta hardwoods and bottomland hardwoods in the South have a heavy taper which averages 0.6 inch in 4 feet. The short second growth referred to has 0.6-inch taper, but from a type standpoint is unimportant.

It is recognized, of course, that all the logs in a tree may not have exactly the taper presupposed by the cubic-foot rule adopted for use. Top logs are apt to have more taper than average and contain slightly more volume than the rule indicates. In most commercial scaling, however, the slight variations which will occur because individual logs deviate slightly from the average shape seem to be of slight importance.

The Computation of Cubical Volume

A careful inspection shows that the surface lines lengthwise of a log are not perfectly straight but usually slightly curved. In the majority of logs the curving shows convexity and the shape of the entire log is comparable to that of a frustum of a paraboloid, illustrated in figure 7. Such being the case, the cubical volume of logs can be computed by use of the Smalian formula, which gives the volume of the frustum of a paraboloid based on its length and end areas. The formula reads: $V = \frac{A + a}{2}L$, where "V" is the volume, "A" the area of the large end, "a" the area of the small end, and "L" the length.

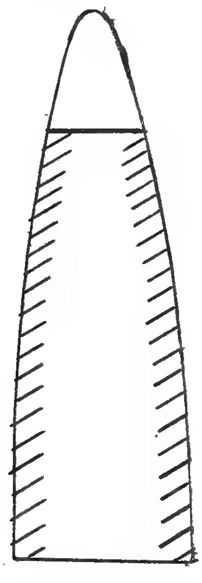


Figure 7. The frustum of a paraboloid. A paraboloid is a solid generated by revolving a parabola on its axis.

Thus a 16-foot log with a top end diameter of 12 inches (area 0.7854 square feet) and a large end diameter of 14 inches (area 1.0690 square feet) has a volume of 15 cubic feet, computed as follows:

$$V = \frac{A + a}{2} L = \left(\frac{0.7854 + 1.0690}{2}\right) 16 = 14.8352, \text{ rounded off to } 15.$$

Table 6, which follows, was prepared in the manner just described, except that a taper allowance of 0.5 inch for each 4 feet of log was arbitrarily used. Similar tables can be prepared using tapers of 0.4 inch and 0.6 inch or any taper, for that matter, which is appropriate for the scaling conditions encountered.

Table 6. Cubic Volume [1] of Logs

Top Diameter of Log (Inches)	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44
	LOG LENGTH - FEET																		
	CUBIC FEET																		
6	2	2	3	4	4	5	6	7	8	9	10	11	12	13	14	16	17	19	20
7	2	3	4	5	6	7	8	9	10	11	12	13	15	16	18	19	21	23	25
8	3	4	5	6	7	8	10	11	12	14	15	17	18	20	22	23	25	27	30
9	4	5	6	8	9	10	12	13	15	16	18	20	22	24	26	28	30	33	35
10	5	6	8	9	11	12	14	16	18	20	22	24	26	28	30	33	35	38	41
11	6	7	9	11	13	15	17	19	21	23	25	28	30	33	35	38	41	44	47
12	7	9	11	13	15	17	19	22	24	27	29	32	35	38	41	44	47	51	54
13	8	10	12	15	17	20	22	25	28	31	34	37	40	43	47	50	54	58	61
14	9	12	14	17	20	23	26	29	32	35	38	42	45	49	53	57	61	65	69
15	10	13	16	19	22	26	29	32	36	40	43	47	51	55	59	64	68	73	77
16	12	15	18	22	25	29	33	36	40	44	49	53	57	62	66	71	76	81	86
17	13	17	21	24	28	32	37	41	45	50	54	59	64	69	74	79	84	90	95
18	15	19	23	27	32	36	41	45	50	55	60	65	71	76	82	87	93	99	105
19	17	21	26	30	35	40	45	50	55	61	66	72	78	84	90	96	102	109	115
20	18	23	28	33	39	44	49	55	61	67	73	79	85	92	98	105	112	119	126
21	20	26	31	37	42	48	54	60	67	73	80	86	93	100	107	114	122	129	137
22	22	28	34	40	46	53	59	66	73	80	87	94	101	109	116	124	132	140	149
23	24	30	37	44	50	57	64	72	79	86	94	102	110	118	126	135	143	152	161
24	26	33	40	47	55	62	70	77	85	93	102	110	119	127	136	145	155	164	174
25	28	36	43	51	59	67	75	84	92	101	110	119	128	137	147	156	166	176	187
26	31	39	47	55	64	72	81	90	99	109	118	128	138	148	158	168	179	189	200
27	33	42	50	59	69	78	87	97	107	117	127	137	147	158	169	180	191	203	214
28	35	45	54	64	73	83	93	104	114	125	136	147	158	169	181	192	204	216	229
29	38	48	58	68	79	89	100	111	122	133	145	157	168	181	193	205	218	231	244
30	41	51	62	73	84	95	107	118	130	142	154	167	179	192	205	218	232	245	259
31	43	55	66	78	89	101	114	126	139	151	164	177	191	204	218	232	246	261	275
32	46	58	70	83	95	108	121	134	147	161	174	188	202	217	231	246	261	276	292
33	49	62	75	88	100	114	128	142	156	170	185	200	215	230	245	261	276	292	309
34	52	65	79	93	107	121	136	150	165	180	196	211	227	243	259	275	292	309	326
35	55	69	84	98	113	128	144	159	175	191	207	223	240	256	273	291	308	326	344
36	58	73	88	104	120	135	152	168	184	201	218	235	253	270	288	306	325	343	362
37	61	77	93	110	126	143	160	177	194	212	230	248	266	285	303	322			
38	65	81	98	115	133	150	168	186	205	223	242	261							
39	68	86	103	121	140	158	177	196											
40	72	90	109	128	147														

1/ Taper Allowance: 0.5 inch in 4 feet of length. Volumes listed are subject to correction.

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