The Feasability of Cubic Foot Log Scaling

by

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INTRODUCTION

The fact that board foot log rules inadequately serve the purpose for which they are intended has been recognized to a greater or lesser extent ever since the first board foot rules were devised. This has been very plainly shown in that in the succeeding years more than fifty board foot rules, all based upon the one thing that creates this disturbance, have been devised to get either an accurate determination of volume, a large overrun, or a better standard of weight for shipping the raw material by water or rail. These latter board foot rules were often remodeled old ones, hybrids combining as the case may be, the best or worst features of other rules, or completely new board foot rules.

The occurence of these many board foot rules have caused endless confusion throughout the wood using industry from the woods clear through the manufacturing process, and through these periods of trial and error many have been discarded, but approximately a dozen different board foot rules, all giving entirely different estimates of log volume, are in commercial use today.

Most makes? of board foot log rules intended for them to show with reasonable degree of accuracy the number of board feet that could be attained from logs of different sizes. However, many rules were made to specifically favor a group outside of the manufactureres or buyers. The ease of doing this is quite apparent in that all board foot rules are based on a board foot measure which when applied to manufactured lumber is an exact unit of measure but when applied to a log, is not.

Because of the similarity in names, an impression is created that board feet sclae and board feet of lumber are identical; actually there are decided differences.

A board foot is a board one inch thick and one foot square so that in inch boards the wood in board measure is the same as the number of square feet of surface; with lumber of other dimension, the wideth is expressed in terms of inch boards.

The amount of lumber which can be cut from logs of a given size is not uniform because the factors that determine the amount of waste vary under many circumstances, such as the thickness of the saw, thickness of the boards, width of the smallest board which can be utilized, the skill of the sawyers, the efficiency of the machinery, the defects in the log, the amount of taper, the shrinkage, and, of great importance, the industry which utilizes the material.

There is nearly always a difference between lumber tally and scale. If the lumber yield is more than the scale, result is "overrun"--if the log scale is over the lumber tally, the result is "underrun."

These factors have been the basis of the desire for the industries to make a log rule which would meet all conditions. Many attempts to devise such a rule have been attempted and as a result these many log rules have been constructed with wide divergence in results--in some cases of 120 per cent in 20 to 30 inch logs and as much as 600 per cent in 6 inch logs. Some of these board foot log rules were constructed from mathematical formulae; some by preparing diagrams that represent the top of the log and then determing the amount of waste in sawdust and slab; some have been based on actual averages of logs cut at the mill; and still others have been the results of corrections in existing rules to meet local conditions.

Many manufactories which produce products other than lumber (pulp, veneer, etc.) have found the board foot log scale to be meaningless. It is unreasonable to measure pulp wood logs in terms of manufactured lumber, as the product is entirely different. Also, it is unreasonable to measure veneer logs by board foot scale as the wastes and production are totally unlike that of lumber mills.

It is only a question of time before both buyer and seller will recognize the absolute fairness and benefit to be derived from making sales on the exact content of the logs, as the variations in quality can be adjusted by the variations in price.

> "The large number of log rules, the difference in their values, and the variation in

> their application have led to much confusion and inconvenience. Efforts to reach an agreement among lumbermen on a single standard log rule have failed so far. A number of states have given official sanction to specific rules, but this has only added confusion because the states have not chosen the same rule so that there are six different state log rules and, in addition, three different log rules in Canada. It is probable that a standard method of measuring logs will not be worked out satisfactorily until a single unit of volume, like the cubic foot, is adopted for the measure of logs."
>
> --United States Forest Service Bulletin 36

In the following discussion I will present a proposal that logs should be scaled by cubic foot methods to get a more exact standardization of volumes. Before such standardization can be accepted, it must have the approval of men who are concerned with determining log content, scalers and men engaged in the buying and selling of logs.

COMPARISON OF BOARD FOOT LOG RULES AND THEIR LIMITATIONS

Formula Rules

The Doyle rule is a formula rule in use throughout the entire country and is more widely used than any other rule despite the fact that it is one of the most inaccurate. It is constructed by deducting four inches from the small diameter of the log as an allowance for slab, square one-quarter of the remainder and multiply the result by the length of the log in feet. The important feature of the formula is that the width of the slab is always uniform regardless of the size of the log. The principle is mathematically incorrect for the product of perfect logs of different sizes follows an entirely different mathematical law, and it is astonishing that such an incorrect rule which gives wrong results from both large and small logs should have so general a use.

Lumber tally overruns the Doyle log scale by about 25% for logs 12 to 20 inches in diameter; and for long logs with a small top diameter, the overrun is much highers. The inaccuracies of the Doyle rule by which small logs are under-scaled and large logs over-scaled lend to its conjunction with the Scribner rule as the valued of the latter rule dropped below the Doyle rule at 28 inches. The reason for this is quite apparently to favor the buyer of logs as this gives low values of all sizes of logs.

The British Columbia log rule is another formula rule in common use that favors the buyer very much, even more so than the Scribner rule. The formula for this rule is deduct one and one-half inches from the mean diameter in inches at the small end of the log, square the result and multiply by .7854, divide area, deduct three-elevenths, divide by 12 to bring to board measure and multiply by the length of the log in feet.

During 1918, the United States Shipping Board adopted the Square of the Mean Diameter rule because of the one-sided errors of the Spaulding, Scribner, and British Columbia log rules; the use of which was responsible for a greater loss in freight revenue and endless controversy. As the Square of the Mean Diameter rule gives 20 per cent more contents than the log actually contains, this change did not remedy the situation but met with strong opposition from the shippers since they became aware of the fact that they were paying freight on 20 per cent more than the shipment contained. Owing to the unsatisfactory results, another change was made in 1919 by substituting the Brereton Log Scale with the results that all parties were fairly well satisfied and its use in the export trade has not become general.

Although the Brereton rule usually gives underrun because of the small allowance for slab and saw kerf, it is coming into favor in parts of the country, notably the

New England States because it does give the most consistently accurate board foot volume of logs of different sizes.

Diagram Rules

Rules of this type are based on diagrams of top diameter of logs. One of the best know rules of this type is the Scribner Log Rule constructed in 1846. It is a relic of old-fashiond saw mill pictures and though still in use is going out-of-date.

REASONS FOR CUBIC FOOT RULE

The most basic reason for cubic foot scale is the fact that it is impossible to make an accurate board foot log rule. The reason for the inaccuracy in log rules is that in constructing the rule it is necessary to make certain assumptions as to the specific closenss of utilization, allowance for the efficiency of mill machinery, and the size of boards produced, not one of which can be made for any individual log or operation. In constructing a cubic foot rule there is no assumption of what can be derived from the log but rather it is based upon the actual contents of the log.

Also an advantage of using cubic foot log rules would be the advantage that it gives to scalers. Scalers when using the board foot rule are thinking of the intensity of utlization and of lumber as a final product, and realize that the intensity of utilization and skill of the men in the industry will very directly affect the accuracy of their estimates. Scalers would, therefore, no doubt, be at peace with the world if they scaled logs by the cubic foot because there is no assumption of products that are to be manufactured or changed in utilization. Therefore, the scaler can direct his mind to measuring diameters and lengths correctly and taking logical deductions for defects without judging subconsciously what the standards of utilization ought to be.

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

> "The cubic method 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 standard 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 or variation between the different scales is always the same if the log of wood is scaled either a repeated number of times by the same scaler or by many scalers. . ."

Board foot log scales are not such an advantage to the lumber industry as might be supposed. Less than one fourth of the lumber sold in the United States is of one inch dimension, and often the board foot is not used in transactions of lumber. Many times it is by the piece and is converted to a board foot basis for bookkeeping purposes.

Scaling to get an overrun is a common practice with many mills, and as long as they consistently get from 5 per cent to 10 or 15 per cent overrun, the mill manager can afford to sit back and relax. But if the mill manager only knew that his overrun should be higher than it is, he would not have the complacent feeling. As it is, he thinks he is getting more than he pays for. But if he could determine from the actual volume that he bought that he really should be getting more lumber, he would immediately take steps to see that he got it. If he knew a definite ratio of volume to mill tally, he could easily know whether he was geting full value received, and this could easily be determined from a cubic foot log scale.

While it is true that lumber is the most important single product of the forest, consuming about 40 per cent of the timber cut, less than 25 per cent of this lumber is in one inch boards, the basis of all board foot log rules, another anomaly in the use of board foot log scales.

Other industries such as pulp, veneer, plywood, shingles, charcoal, charcoal distillates, fuelwood, etc., use more than one half the timber consumed in the United States. In industries of this sort, board foot log rules are poor indicators of actual volumes because they presuppose considerable actual waste and are merely a basis of price competition. These manufacturers need a unit of measure that will tell them what the log actually contains. The board foot rules does not do this; the cubical rules do.

Board foot log rules lead to the large waste of small timber that is left in the woods because of their low board foot scale. The reason for this is the large number of cubic feet per thousand board feet. This is very neatly hidden to gain a large overrun on small logs. Although it is true that these small logs do not contain the higher quality lumber, they still contain good lumber and would be brought in from the woods if their volume was on the same basis as the larger trees.

Industries that gain their revenue from the transportation of logs would undoubtedly favor the cubic foot log rule as this would give a much better basis for rates than the thousand foot log scale. Rates for logs are either on a thousand feet log scale basis or on a carload basis. In either case, the rates depend primarily on weight. If it is worth 30¢ a ton to haul logs between two points, and a thousand feet of logs average four tons in weight, the rate becomes $1.20 per thousand feet.

Although the rate is figured on a per thousand feet basis, the fact that logs average so much weight per thousand is the basis of the rating. It is true that cubic volume is not a perfect criterion of rate because of certain factors such as heavy butt logs, heavy sap wood, and other things, but the basic fact exists that cubic volume is a better expression of weight than board foot log rule.

The board foot log scale is not in use anywhere except in North American, while in almost every other country either cubic foot or cubic meter is used. Central Europe, France, Switzerland, Scandinavia, South America, South Africa, the Far East, and Australia use cubic measure.

Another anomaly in the use of the board foot log rule is the more inaccurate the rule, that is the less equity between the log scale and mill tally, the more popular it is with buyers of logs and mill men. The result is that inaccurate log rules flourish and tend to drive out the accurate rules. The reason behind that is to gain overrun, that bonus the industry seems to need to compensate for unforeseen circumstances.

An attempt to study three rules in common use in the northeast was attempted by the Department of Forestry at Cornell, Northeast Forest Experimental Station, the Forest Products Laboratory, and Department of Forest Management at New York State College of Forestry at Syracuse University in an actual mill study in 1937. In all, about fifty mills were visited but only a small proportion contributed greatly to the study. The study was limited to hardwoods cut at mills of a permanent nature. The logs were scaled, the cut tallied on the grading table at the mill in terms of one inch boards. The result:

International Rule

~~Mills~~ Mill tally overran the log scale by an average of 4.4. Overrun was on logs of less than 12 inches with the maximum of 8½ per cent on 9 inch logs which were only 27 per cent of the logs cut and only 16½ per cent of the value. Above 12 inches the International consistently produced an increasing underrun, 2 per cent at 13 inches, 4½ per cent at 14 inches, 8½ per cent at 16 inches, 9½ per cent at 20 inches.

Doyle Rule

The Doyle Rule gave an overrun for all size and lengths up to 24 inches in diameter. The average overrun amounted to 29½ per cent. A 9 inch gave 103 per cent overrun. However, this only accounted for 4 per cent of the volume. A 12 inch log gave 45 per cent overrun, 16 inch log a 14½ per cent, a 20 inch log 2½ per cent. (Very few logs were cut above 22 inches so that logs gave an underrun amounting to only 6 per cent of the value, therefore, giving a decided advantage to the mill man.,?)

Scribner Rule

The Scribner Rule occupies a very favorable medium between the Doyle and International Rule. It gave an average of approximately 8 per cent overrun starting with a 27 per cent overrun at 9 inches, decreasing to about 17 or 18 inches where it changed to a slight underrun.

From this study it is very easy to see that board foot log rules do not serve the purpose for which they are intended as they are not even approximately accurate in many cases and not all accurate for some sizes of logs. Another thing brought out in this investigation was that 70 per cent of the inch lumber produced in New York was a product of six or eight of the larger mills. The greater number of mills were producing mine timbers, piling, railroad ties, etc., in which the production of a few hardwood boards was incidental to reducing the timber to the desired dimensions. Yet, these mills buy their logs on a board foot basis and sell their product by the piece, lineal foot, or even cubic foot.

The arguments for a cubic foot log rule summed up thus:

1. The cubic foot is an absolute measure of volume and is independent of standards of utilization.

2. The cubic foot is a precise value and tends itself to standard methods of accounting and will produce a truer picture of operating costs.
3. Its adoption would avoid confusion and disparity existing between log scale and mill tally in bookkeeping transactions, appraisals, and business negotiations.
4. It necessitates no assumption as to the products to be made, efficiency or intensity of manufacturing, or necessity of a bonus for inefficient or badly managed manufacturing setups.
5. Cubic contents can be more easily and exactly computed than board foot contents. Easily lends itself to scaling practices, and offers standarized and exact methods of culling.
6. Conversion from cubic foot to unit measure for each plant could be simply done and offers no greater undertainty than involved now in converting log scale to lumber tally.
7. If it is set up within each mill, there is a definite standard of efficiency--yield per cubic foot of raw material.
8. It would be a definite advantage to allied industries that depend upon the hauling of

raw materials for a more exact criterion of weight and bulk.

CONVERSION FROM CUBIC FOOT TO MANUFACTURED UNITS

Manufactured units consist of board foot of lumber, cords, units, squares, or bolts. These manufactured units of measure, appropriated to each different manufacturing setup, can be converted from cubic feet with less uncertainty and difficulty that is often the case in converting board foot log scales to these different units. Possibly the most important single unit of measure would be that of board feet. This ratio would undoubtedly fluctuate with the type of timber cut, the mill equipment, and most important, the type of lumber produced, all other things being equal. The ratio of board feet of one inch boards could be very easily computed. But to get an accurate ratio for each individual mill, a mill study would necessarily have to be made for each individual manufacturing setup. The board foot-cubic foot ratio would not be the same for all mills and runs of timber more than the "overrun" per cent is the same in all instances. In fact, the board foot-cubic foot ratio depends upon the same factors that influence overrun per cent.

Converting factors for products other than lumber can be worked out simply. Many of the measures used in the timber industry, such as the cord (128 stack cubic feet), and the unit (200 cubic feet, gross volume), are companions of the cubic foot.

Scales of plywood factors would have to be worked out from actual mill studies as different logs have different trim, and cores vary in size with different logs and grades. Loss factors must be determined also from pitch rings which have a different loss value in plywood manufactories than in lumber.

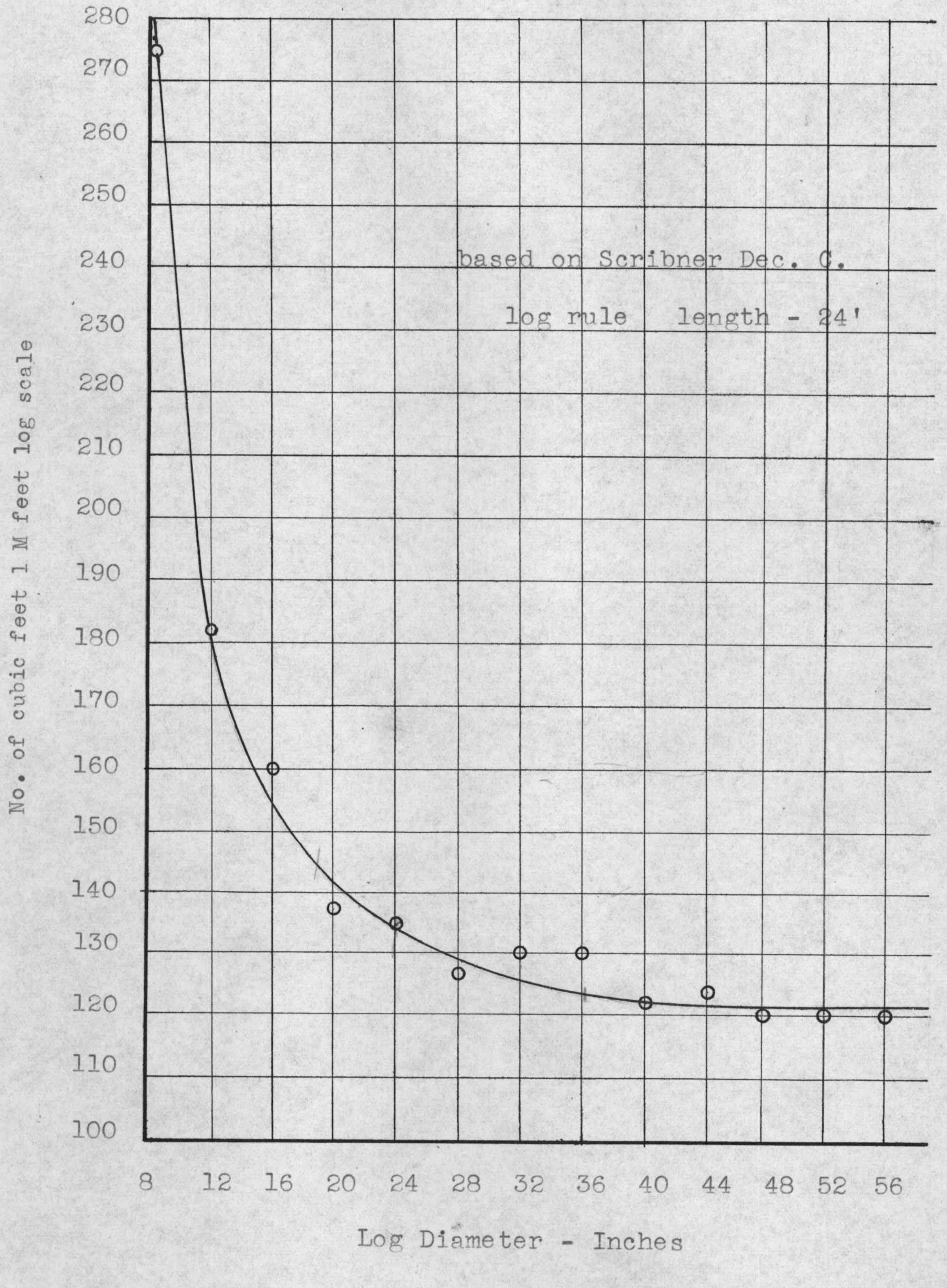
Material	Measure	No. of solic cu. feet in measure	Ratio of solid contents to space
sawdust	unit	80	80:200 or 2.5
sawdust and shavings mixed	unit	57	57:200 or 3.5
log fuel	unit	73	73:200 or 2.7
fuel chips	unit	67	67:200 or 3.0
fuelwood edge and slabs	cord	80	80:128 or 1.6
forest fuelwood	cord	90	90:128 or 1.4

Table 1

Ratios of Manufactured Units of Measure

Graph I

Relation of Board Feet Log Scale to Cubic Volume by Log Diameters



RULES FOR MEASURING LOGS TO DETERMINE CUBICAL CONTENT

Establishing uniform rules of measruing logs is as important as establishing a standard unit of volume.

Logs are often measured at several differnt places from the woods throughout the manufacturing processes, and unless standard means of measuring are adopted, variations are as apt to occur as they commonly occur under the board foot methods of log scaling now practiced. To insure uniformity the following standards of measuring diameter and lengths and for determing the amount of merchantable timber within the logs are suggested. No procedures are recommended as similar means have been used by good scalers for many years.

Measuring diameter is an important function in log scaling and has considerable bearing on the quantity and consequently on the logs being scaled. The following system has been in general use with good scalers with satisfactory results. As in all other departments of log scaling, the rule establishes the basic principle and the log scaler's judgment is the deciding factor.

The fractional parts of the inch are not designated on scaling rules and a quarter-inch margin would be considered accurate from either side of the inch mark. The method of treating the fractional part in measuring diameter has a great deal to do with the final results of the scale, and an? uniform plan of contending with these fractional parts is very necessary. Small logs and medium sized logs up to 36 inches should have the fractions dropped. Logs over 36 inches should have all fractions carried to the next inch if the log is thirty-two feet or over.

Since all logs are not round, there should be some leeway in measuring the diameter of logs that are eccentric. This should be done by taking the average of measurements at right angles to each other. When logs are floating in the water, as a rule the narrow diameter is at right angles to the water line. Although the narrow diameter is the most convenient to measure, care should be taken to determine the average.

Lengths should be determined in the most accurate way that time will allow, preferably with a tape. As this is often difficult, and good scalers can determine the lengths by pacing the log as they look it over, this will undoubtedly be the most common way of measuring the logs.

If all logs were straight and sound, scaling would be simple. This very seldom happens; therefore, deductions must be made for defect that makes wood unfit for use. No deductions should be made for knots, burls, spiral grain,? cross grain, small pitch pockets, light sap stains, and similar imperfections which affect the quality rather than the quantity of the log. Imperfections that affect the quantity of the log may be roughly classified as follows:

1. Interior defect: internal decay, heart shake, pitch rings, pitch seem defects, sprangles, etc.
2. Periphery defects: sap rot, season checks, catface, roughness, etc.
3. Crook defects: sweep, crook, and crotch.
4. Operating defects: breakage, end broom, slab, split, etc.

Scaling practices now deduct for defects by cuts in diameters or lengths. This is often quite unfair as arbitrary cuts for defects are not exact enough because of the different effect defects have upon logs depending on where the defects are located in the log.

Ordinarily, reductions for defects are made by reducing the diameter or the length. Diameter reductions are taken for sap rot, pitch circles, heart check, catface, and seaons checks, and length reductions are taken for rot, broken ends, crook, and worms, but these methods vary the amount taken from the log in accordance with the size of the log. One inch from a large log is a great deal more than one inch from a small log.

The best means of reducing the quantity in a log for defects other than periphery defects should be by a reduction in the percentage of the volume. This reduction would be determined by diagrams, the formula for which should be $\frac{W \times T \times L}{12}$, in which "W" equals the width, "T", the thickness, and "L", the length. This is often difficult to apply in the field, but a percentage can very easily be caculated by an experienced scaler.

Periphery defects should be cut by scaling inside the defects.

Culling Logs

Culling logs is largely a log affair which varies as to business conditions and other factors. However, this can very easily be taken care of in the same way that logs are now culled.

Forms

Forms for recording the scale of logs by cubic foot scale can be very easily converted from standard forms in use today.

CONSTRUCTION OF THE CUBIC FOOT RULE

The better board foot rules in use today take into account the taper of the log so that long logs may be scaled as one log, so no better principle can be followed in constructing a cubic foot log rule, especially if this rule is built for the primary purpose of determining the actual volume of the log. A taper of about five-tenths of an inch in four feet is approximately average for every timber type in the United States. This is the finding of 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. There are some timber types that this does not fit too well--in some trees such as old growth southern pines, some species of hardwood, and some very short second growth. Even to these a five-tenths inch taper can be applied without much inaccuracy.

It is true that all logs in trees may not have exactly the taper presupposed by the cubic foot rule adopted for use. Top logs and butt logs contain more taper than average and will undoubtedly contain more volume than the rule indicates. However, slight variations will occur but these will not be important from a commercial standpoint.

In this cubic foot rule I have incorporated a one-inch taper in ten feet rather than the more accurate five-tenths of an inch in four feet. This will give slight less volume than what is actually in the log, but present means of utilization are not exacting enough to demand exact volumes, and also, common scaling practices in scaling long logs allow for one-inch tapering in ten feet.

So that this cubic foot rule will very readily conform to present-day scalers' methods of scaling, this cubic foot rule adds one inch to the end diameter for every ten feet or large fraction thereof, so that a 16 foot log will have a 2 inch larger diameter on the butt than on the top. Another inch will be added at 26, 36, etc.

My volumes were determined on the Smalian formula which gives the volume of the frustrum 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" is the area of the large end, and "a", the area of the small end, and "L", the length.

Thus, a 16 foot log with the top end diameter of 12 inches, (area 1.7854), and a large end diameter of 14 inches, (area 1.0690), has a volume of 15 cubic feet, computed as follows: $\left(\frac{0.7854 \quad 1.0690}{2}\right) 16= 14.8352=$ rounding off to 15.

CUBIC FOOT LOG SCALE

Diameter ? top?

Length? Feet	6	7	8	9	10	11	12	13	14
10	2	3	4	5	6	7	9	10	11
12	3	4	5	6	7	9	10	12	14
14	3	4	6	7	8	10	12	14	16
16	4	6	7	8	11	13	15	17	20
18	5	6	8	9	12	14	17	19	22
20	5	7	9	10	13	16	19	22	25
22	6	8	10	11	15	17	20	24	27
24	6	9	11	12	16	19	23	26	30
26	8	11	13	16	19	23	26	30	34
28	9	11	14	17	21	24	28	32	37
30	10	12	15	18	22	26	30	35	40
32	10	13	16	20	23	28	32	37	43
34	11	14	17	21	25	29	34	39	46
36	13	17	21	25	29	35	39	45	51
38	14	18	22	26	31	37	41	47	54
40	15	19	23	27	32	39	44	50	57

Length	Diameter 15	16	17	18	19	20	21	22	23
10	13	15	17	19	21	23	25	28	30
12	16	18	20	22	25	28	30	33	36
14	18	21	23	26	29	32	35	39	42
16	22	25	28	32	35	39	42	46	50
18	25	28	32	36	39	43	48	52	57
20	28	32	35	39	44	48	53	58	63
22	31	35	39	43	48	53	58	64	69
24	34	38	43	47	52	58	63	69	76
26	39	44	49	54	60	66	72	78	86
28	42	47	53	58	65	71	78	85	92
30	45	50	56	63	69	76	83	91	98
32	48	54	60	67	74	81	89	97	105
34	51	57	64	71	78	86	94	103	111
36	58	64	72	79	87	96	105	114	124
38	61	68	76	84	92	101	110	120	130
40	64	72	80	88	97	106	116	127	137

Length	Diameter 24	25	26	27	28	29	30	31	32
10	33	36	38	41	44	48	51	54	58
12	39	43	46	50	53	57	61	65	69
14	46	50	53	58	62	67	71	76	81
16	55	59	64	69	74	79	84	89	95
18	61	67	72	77	83	89	95	101	107
20	68	74	80	86	92	98	105	112	119
22	75	81	88	94	101	108	116	123	131
24	82	89	96	103	110	118	126	134	143
26	93	100	108	116	124	132	141	150	160
28	100	108	116	124	133	143	152	162	172
30	107	115	124	133	143	153	163	173	184
32	114	123	132	142	152	163	174	185	196
34	121	131	141	151	162	173	184	196	209
36	134	144	155	166	178	190	202	215	228
38	141	152	163	175	188	200	213	226	241
40	148	160	172	184	197	211	224	238	253

Length	Diameter 33	34	35	36	37	38	39	40	41
10	61	65	69	73	77	81	85	90	94
12	73	78	83	87	92	97	102	107	113
14	86	91	96	102	107	113	119	125	132
16	101	107	113	120	126	133	140	147	154
18	114	120	127	135	142	150	157	165	173
20	126	134	142	150	158	166	175	184	193
22	139	147	156	165	174	183	192	202	212
24	151	161	170	179	189	199	210	220	231
26	169	179	189	200	211	222	233	245	256
28	182	193	204	215	227	239	251	263	276
30	195	207	218	231	243	256	269	282	296
32	208	220	233	246	259	273	287	301	316
34	221	234	248	261	275	290	305	320	335
36	241	255	270	284	300	315	331	347	364
38	255	269	285	300	316	333	349	367	384
40	268	284	299	316	333	350	368	386	404

Length	Diameter 42	43	44	45	46	47	48	49	50
10	99	103	108	113	118	123	128	134	139
12	118	124	130	135	142	147	154	160	167
14	138	144	151	158	165	172	180	187	195
16	161	169	177	185	193	201	210	218	227
18	182	190	199	208	217	226	236	246	256
20	202	211	221	231	241	251	262	273	284
22	222	232	243	254	265	277	288	300	312
24	242	253	265	277	289	302	315	327	241
26	272	281	294	307	320	334	348	362	377
28	293	303	317	331	345	360	375	390	406
30	313	324	339	354	370	385	401	418	435
32	334	346	362	378	394	411	428	446	464
34	355	368	384	401	419	437	455	473	493
36	381	398	416	435	453	472	492	512	532
38	402	420	439	459	478	499	519	540	561
40	403	443	463	483	504	525	546	568	591

Length \ Diameter	51	52	53	54	55	56	57	58	59	60
10	145	150	156	162	168	174	180	187	193	200
12	174	180	187	194	202	208	216	224	232	240
14	203	210	219	227	235	244	252	261	270	280
16	236	245	255	264	274	284	294	304	314	325
18	266	276	286	297	308	319	330	342	354	365
20	295	307	318	330	342	355	367	380	393	406
22	325	337	350	363	376	390	404	418	432	447
24	354	368	382	396	410	425	441	456	471	487
26	391	406	421	437	453	469	486	502	519	537
28	421	438	454	471	488	505	523	541	559	578
30	451	469	486	504	523	541	560	580	599	619
32	481	500	519	538	558	577	598	618	639	660
34	512	531	551	572	592	613	635	657	679	702
36	552	573	595	617	639	661	684	708	732	755
38	583	605	628	651	674	698	722	747	772	797
40	614	637	661	685	710	735	760	786	813	839