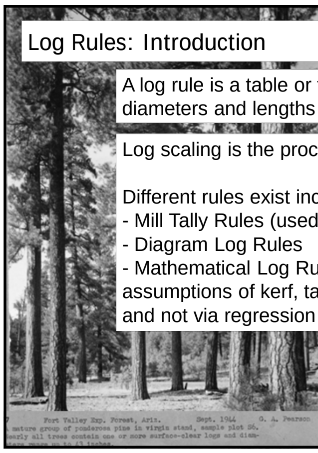
FOR 274: Forest Measurements and Inventory

Log Rules and Scaling

- Introduction to Log Rules
- Schribner, Doyle, and International
- Overrun and Underrun
- Board Foot Scaling
- Defects and Culls
- Measurements

Readings: pp 6-16 and pp 20-113 (lots of detail)

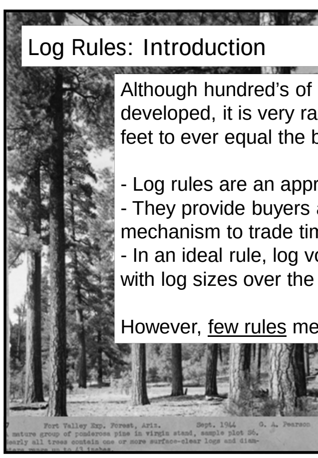


Log Rules: Introduction

A log rule is a table or formula that converts log diameters and lengths into estimated volumes

Log scaling is the process of applying these rules.

Different rules exist including:
- Mill Tally Rules (used in custom sawing runs)
- Diagram Log Rules
- Mathematical Log Rules (formula built based on assumptions of kerf, taper, and milling procedures and not via regression analysis)



Log Rules: Introduction

Although hundred's of board feet log rules have developed, it is very rare for the estimate board feet to ever equal the board feet of useable timber

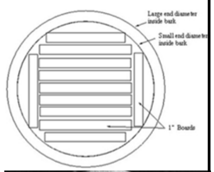
- Log rules are an approximation
- They provide buyers and sellers a consistent mechanism to trade timber
- In an ideal rule, log volumes should be correlated with log sizes over the entire range of sizes

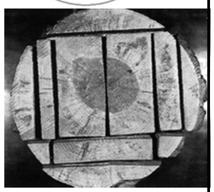
However, <u>few rules</u> meet this standard.

Log Rules: Introduction

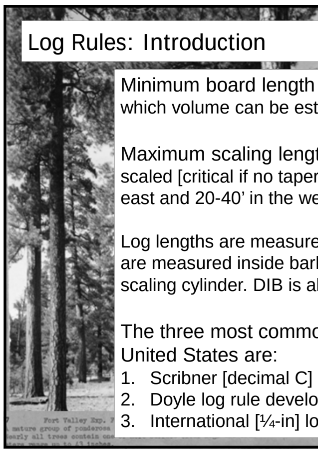
Differences between estimated and actual timber volume are due to the log rule assumptions:

- Logs are cylinders
- Taper is ignored or approximated at a fixed rate per foot
- Assumes all sawmills will operate at a standard level of efficiency
- A standardized sawing pattern is assumed
  - Logs will be sawed into boards of set thickness
  - Logs will be sawed with saws of a special thickness, i.e. the kerf





Log Rules: Introduction



Minimum board length is the narrowest board for which volume can be estimated (usually 4-8")

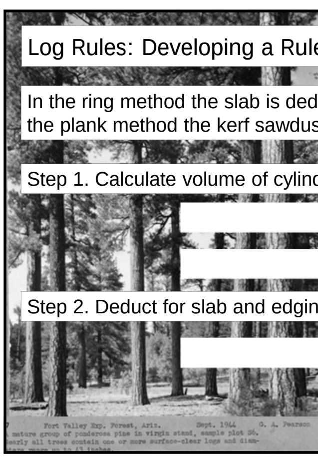
Maximum scaling length is the longest log that can be scaled [critical if no taper is assumed]. Usually, 16' in the east and 20-40' in the west

Log lengths are measured to nearest foot and diameters are measured inside bark (DIB) at the small end of the scaling cylinder. DIB is always rounded down.

The three most common log rules used in the United States are:

1. Scribner [decimal C] log rule developed in 1846
2. Doyle log rule developed in 1825
3. International [¼-in] log rule developed in 1906

Log Rules: Developing a Rule – The Ring Method

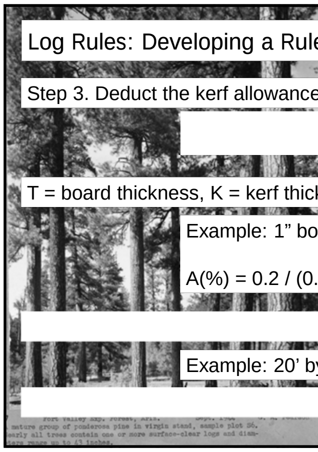


In the ring method the slab is deducted before the sawdust. In the plank method the kerf sawdust is deducted before the slab.

Step 1. Calculate volume of cylinder

Step 2. Deduct for slab and edgings (USFS uses 2")

Log Rules: Developing a Rule – The Ring Method



Step 3. Deduct the kerf allowance

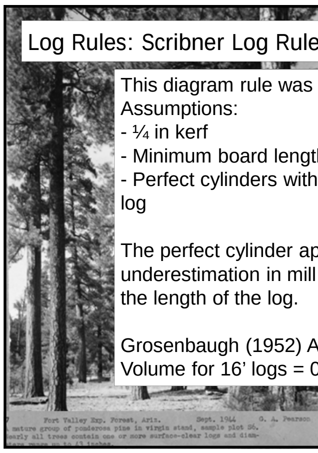
T = board thickness, K = kerf thickness

Example: 1” board with 0.2” kerf

A(%) = 0.2 / (0.2 + 1.0) = 14%

Example: 20’ by 16” log with above A%

Log Rules: Scribner Log Rule



This diagram rule was developed by J.M. Scribner.
Assumptions:
- ¼ in kerf
- Minimum board length around 4’
- Perfect cylinders with no taper from small end of log

The perfect cylinder approximation leads to an underestimation in mill output that increases with the length of the log.

Grosenbaugh (1952) Approximation of Scribner
Volume for 16’ logs = $0.8\,(D-1)^2 - D/2$

Log Rules: Scribner Decimal C Log Rule

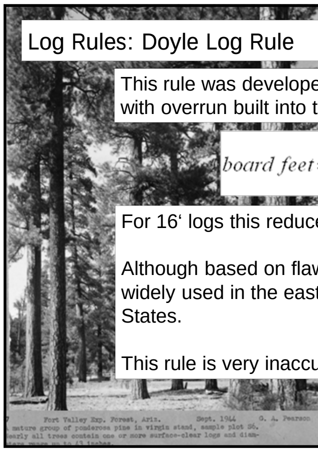
This is a modification to the original Scribner rule where all Scribner volumes are rounded off to the nearest 10 bd ft.

In this example, a 16 foot log with a DIB of 20 = 280 bd ft

APPENDIX TABLE 3
SCRIBNER DECIMAL C LOG RULE FOR LOGS 6 TO 32 FT IN LENGTH

	Length, ft													
Diameter, in.	6	8	10	12	14	16	18	20	22	24	26	28	30	32
	Contents, bd ft in tens													
6	0.5	0.5	1	1	1	2	2	2	3	3	3	4	4	5
7	0.5	1	1	2	2	3	3	3	4	4	4	5	5	6
8	1	1	2	2	2	3	3	3	4	4	5	6	6	7
9	1	2	3	3	3	4	4	4	5	6	6	7	8	9
10	2	3	3	3	4	6	6	7	8	9	9	10	11	12
11	2	3	4	4	5	7	8	8	9	10	11	12	13	14
12	3	4	5	6	7	8	9	10	11	12	13	14	15	16
13	4	5	6	7	8	10	11	12	13	15	16	17	18	19
14	4	6	7	9	10	11	13	14	16	17	19	20	21	23
15	5	7	9	11	12	14	16	18	20	21	23	25	27	28
16	6	8	10	12	14	16	18	20	22	24	26	28	30	32
17	7	9	12	14	16	18	21	23	25	28	30	32	35	37
18	8	11	13	16	19	21	24	27	29	32	35	37	40	43
19	9	12	15	18	21	24	27	30	33	36	39	42	45	48
20	11	14	17	21	24	28	31	35	38	42	45	49	52	56

Log Rules: Doyle Log Rule



This rule was developed by Edward Doyle in 1825 with overrun built into the equation:

$$board\ feet = \left(\frac{D-4}{4}\right)^2 * L$$

For 16' logs this reduces to $(D-4)^2$

Although based on flawed algebra this rule is widely used in the eastern and southern United States.

This rule is very inaccurate

Log Rules: Doyle Log Rule

This rule is very inaccurate

In this example, a 16 foot log with a DIB of 20 = 256 bdft

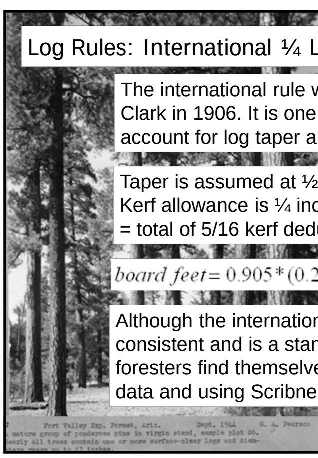
The Doyle log rule underestimates in small logs and overestimates in large logs.

PPENDIX TABLE 5
OYLE LOG RULE FOR LOGS 6 TO 20 FT IN LENGTH

Diameter (small end of log inside bark), in.	Length of log, ft							
	6	8	10	12	14	16	18	20
	Volume, bd ft							
8	6	8	10	12	14	16	18	20
9	9	13	16	19	22	25	28	31
10	14	18	23	27	32	36	41	45
11	18	25	31	37	43	49	55	61
12	24	32	40	48	56	64	72	80
13	30	41	51	61	71	81	91	101
14	38	50	63	75	88	100	113	125
15	45	61	76	91	106	121	136	151
16	54	72	90	108	126	144	162	180
17	63	85	106	127	148	169	190	211
18	74	98	123	147	172	196	221	245
19	84	113	141	169	197	[illegible]	253	281
20	96	128	160	192	224	$\boxed{256}$	288	320
21	108	145	181	217	253	289	325	361
22	122	162	203	243	284	324	365	405
23	135	181	226	271	316	361	406	451
24	150	200	250	300	350	400	450	500
25	165	221	276	331	386	441	496	551
26	182	242	303	363	424	484	545	605
27	198	265	331	397	463	529	595	661
28	216	288	360	432	504	576	648	720
29	234	313	391	469	547	625	703	781
30	254	338	423	507	592	676	761	845
31	273	365	456	547	638	729	820	911
32	294	392	490	588	686	784	882	980
33	315	421	526	631	736	841	946	1,051
34	338	450	563	675	788	900	1,013	1,125
35	360	481	601	721	841	961	1,081	1,201
36	384	512	640	768	896	1,024	1,152	1,280
37	408	545	681	817	953	1,089	1,225	1,361
38	434	578	723	867	1,012	1,156	1,301	1,445
39	459	613	766	919	1,072	1,225	1,378	1,531
40	486	648	810	972	1,134	1,296	1,458	1,620

Source: U.S. Forest Service.

Log Rules: International ¼ Log Rule



The international rule was developed by Judson Clark in 1906. It is one of the few rules that account for log taper and is fairly accurate.

Taper is assumed at ½ inch per 4 ft.
Kerf allowance is ¼ inch + 1/16 inch for shrinkage = total of 5/16 kerf deduction

$$board\ feet = 0.905 * (0.22 * D^2 - 0.71 * D)$$

Although the international ¼ rule is the most consistent and is a standard in many states most foresters find themselves using the rule on inventory data and using Scribner or Doyle on logs.

Log Rules: International ¼ Log Rule

The international rule is considered the most consistent log rule.

In this example, a 16 foot log with a DIB of 20 = 290 bdft

APPENDIX TABLE 4
INTERNATIONAL LOG RULE, ¼-IN. SAW KERF, FOR LOGS 8 TO 20 FT IN LENGTH

Diameter (small end of log inside bark), in.	Length of log, ft 8	10	12	14	16	18	20	Diameter, in.
	Volume, bd ft							
4	....	5	5	5	5	5	10	4
5	5	5	10	10	10	15	15	5
6	10	10	15	15	20	25	25	6
7	10	15	20	25	30	35	40	7
8	15	20	25	35	40	45	50	8
9	20	30	35	45	50	60	70	9
10	30	35	45	55	65	75	85	10
11	35	45	55	70	80	95	105	11
12	45	55	70	85	95	110	125	12
13	55	70	85	100	115	135	150	13
14	65	80	100	115	135	155	175	14
15	75	95	115	135	160	180	205	15
16	85	110	130	155	180	205	235	16
17	95	125	150	180	205	235	265	17
18	110	140	170	200	230	265	300	18
19	125	155	190	225	260	300	335	19
20	135	175	210	250	$\boxed{290}$	330	370	20
21	155	195	235	280	320	365	410	21
22	170	215	260	305	355	405	455	22
23	185	235	285	335	390	445	495	23
24	205	255	310	370	425	485	545	24
25	220	280	340	400	460	525	590	25
26	240	305	370	435	500	570	640	26
27	260	330	400	470	540	615	690	27
28	280	355	430	510	585	665	745	28
29	305	385	465	545	630	715	800	29
30	325	410	495	585	675	765	860	30

Log Rules: Comparison

In Summary:

International ¼ considered most accurate

Scribner is always more conservative than the international rule

Doyle is to be avoided due to large errors.

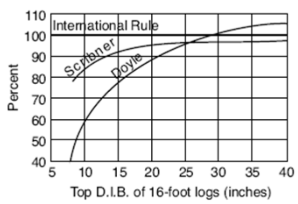
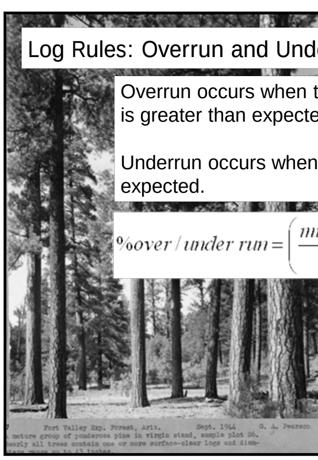


TABLE 5-1
COMPARISON OF BOARD-FOOT LOG RULES FOR 16-FT LOGS

Log diameter, in.	Log rule: International ¼-in., bd ft	Scribner, bd ft	Scribner Decimal C, bd ft	Doyle, bd ft	Doyle-Scribner, bd ft
8	40	32	30	16	16
12	95	79	80	64	64
16	180	159	160	144	144
20	290	280	280	256	256
24	425	404	400	400	400
28	585	582	580	576	582
32	770	736	740	784	736
36	980	923	920	1024	923
40	1220	1204	1200	1296	1204

Imagery source: Avery and Burkhart

Log Rules: Overrun and Underrun



Overrun occurs when the lumber output at the mill is greater than expected by the log rule.

Underrun occurs when the mill output is lower than expected.

$$\%over/under\ run = \left(\frac{mill\ tally - \log scale}{\log scale}\right) * 100$$

Log Rules: Overrun and Underrun

Comparison of overrun in the Doyle and International ¼ rule for real mill data.

The overall error in the International ¼ rule was 3.3%, while the Doyle was 36.9%,

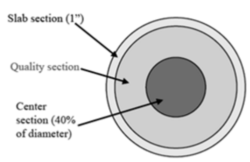
TABLE 5-2
SCALE AND OVERRUN COMPARISON OF DOYLE AND INTERNATIONAL 1/4-IN. LOG RULES*

Log no.	Scaling diameter, in.	Log length, ft	Doyle scale, bd ft	International scale, bd ft	Lumber tally, bd ft
1	13	10	50	70	83
2	11	14	43	70	70
3	16	12	108	130	127
4	11	16	49	80	107
5	11	16	49	80	70
6	15	12	91	115	112
7	18	12	147	170	174
8	11	12	37	55	55
9	10	12	27	45	45
10	13	12	61	85	82
11	10	14	32	55	55
12	16	12	108	130	124
13	11	12	37	55	65
14	19	12	169	190	190
15	12	12	48	70	87
Totals, bd ft			1056	1400	1446
Overrun, percent			+36.9	+3.3	

Source: MTU FW 2050 lecture notes / Avery and Burkhart 5th Edition

Log Scaling: Introduction

When deducting defect from logs there are two classes: Grading defects and Scaling defects. Grading defects only impact quality and do not result in loss of wood volume. Scaling defects will result in volume being subtracted from the gross scale.



The location of the defect will affect the grading/scaling:
- Defects in the slab section don't impact log products
- Defects in the center section <u>will not</u> be "grading defects"
- Defects in the quality section might also impact the volume.

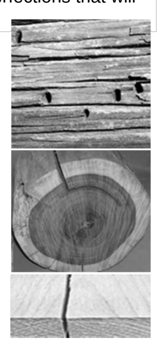
Log Scaling: Introduction

As covered in an earlier lecture, defects are imperfections that will result in losses of wood volume during sawing:

- Interior Defects (Rot, insects, etc)
- Crooks, forks, and sweeps
- Wormholes
- Mechanical damage during felling and transportation

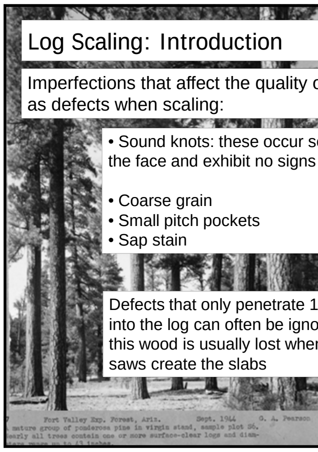
- Ring or cup shakes: the wood separates along the boundary between early and late growth

- Splits: lengthwise separations of the wood, due to the tearing apart of wood cells.
- Checks: splits that occur across growth rings



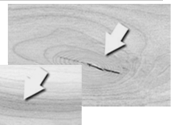
Imagery source: http://www.buyalder.com

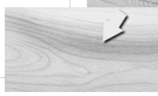
Log Scaling: Introduction



Imperfections that affect the quality of the wood are not considered as defects when scaling:

- Sound knots: these occur solid across the face and exhibit no signs of decay



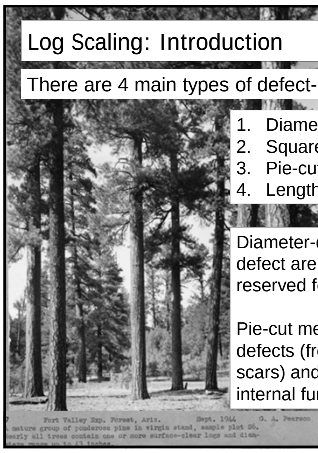


- Coarse grain
- Small pitch pockets
- Sap stain

Defects that only penetrate 1" or less into the log can often be ignored as this wood is usually lost when the saws create the slabs

Imagery source: http://www.buyalder.com

Log Scaling: Introduction



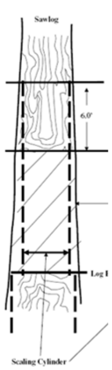
There are 4 main types of defect-deduction methods

1. Diameter-deduction methods
2. Squared-defect methods
3. Pie-cut methods
4. Length-deduction method

Diameter-deduction and squared-defect are not used in the field (usually reserved for scaling downed logs)

Pie-cut methods are used for surface defects (frost cracks and lightning scars) and length-deduction is used for internal fungus or structural defect

Log Scaling: Introduction



Logs are scaled as long as they fall within the scaling cylinder. Defects are only considered if they are within the scaling cylinder.

Diameter-reduction: Used for exterior defects (sap rot, checks, etc) – i.e. use a smaller cylinder

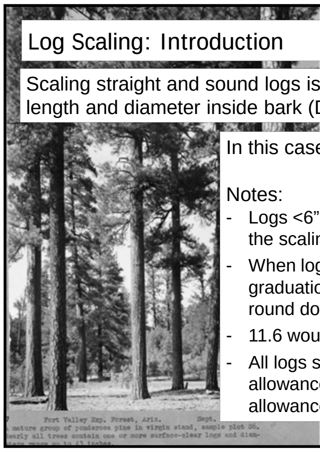
Squared-defect methods: Used on singular defects that are easily measured by the scaler

Pie-cut methods: Used when the defect is confined into pie-shaped sections of the log

Length-reduction: Used for butt-rots and crook defects – i.e use a shorter cylinder

USDA FS Region 6 Cruising Manual

Log Scaling: Introduction



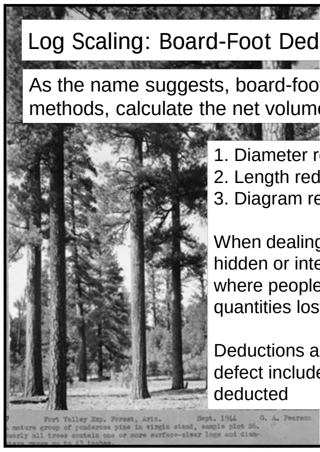
Scaling straight and sound logs is achieved by measuring its length and diameter inside bark (DIB)

In this case the gross scale = net scale

Notes:

- Logs <6" are culled and not included in the scaling
- When logs are halfway between graduations (e.g., 11.5), it's usually to round down to 11.
- 11.6 would be scaled up to 12.
- All logs should have a 2-6" trim allowance. Cutting logs without this allowance are termed "cutting scant"

Log Scaling: Board-Foot Deduction Methods



As the name suggests, board-foot scaling and deduction methods, calculate the net volume in board feet.

1. Diameter reduction
2. Length reduction
3. Diagram reduction

When dealing with defects that are partially hidden or internal it is best to use a diagram where people have worked out typical quantities lost to defects

Deductions are made as 1" boards but if the defect includes wood lost in the kerf it is not deducted

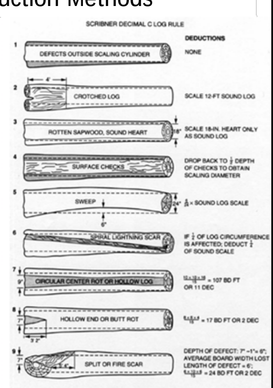
Log Scaling: Board-Foot Deduction Methods

For Scribner and other cylinder log rules the standard "squared defect bd ft" deduction formula is given by:

$$defect = \left(\frac{w * t * l}{15}\right)$$

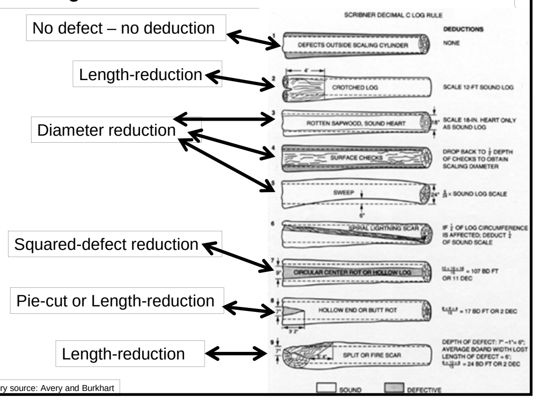
This assumes 1" boards and a ¼" kerf: w = width of defect (in) , t = thickness (in) , and l = length (ft).

The "15" in the denominator accounts for the wood lost to the kerf → 20% of gross board feet.



Imagery source: Avery and Burkhart

Log Scaling: Board-Foot Deduction Methods



Imagery source: Avery and Burkhart

Log Scaling: Cull Percent Deduction Methods

Board-foot deduction methods require a new formula for each defect. A more general approach is achieved by deducting a percentage of the total log volume.

This cull percentage method was developed by L.R. Grosenbaugh.

Rule 1 – cull percent = length of defective section / L (L is length of log in ft)

Rule 2 – cull percent = (length of defective section / L) x (angle of defect / 360)

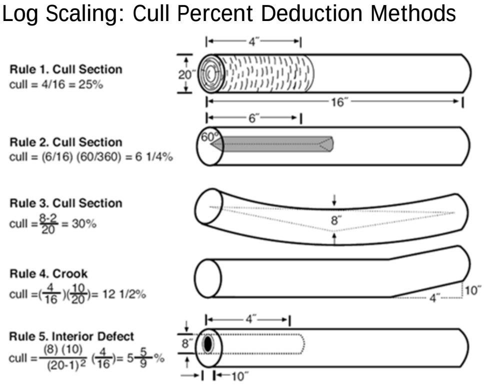
Rule 3 – cull percent = (maximum departure - 2") / d (d is diameter of log, inches)

Rule 4 – cull percent = (length of deflecting section / L) x (maximum deflection / d)

Rule 5 – cull percent = (major x minor) / $(d-1)^2$ x (length of defect / L)

Source: MTU FW 2050 lecture notes / Avery and Burkhart 5th Edition

Log Scaling: Cull Percent Deduction Methods



Imagery source: Avery and Burkhart

Log Rules: Measurements

In all western regions of the US Forest Service (except parts of OR, WA, and AK), the maximum scaling length is 20 feet. 40 feet is standard in western OR and WA.

If the log length exceeds 20 feet it is usually divided into two logs of similar size. Taper should be taken into account to minimize the impact on the larger logs.

The US Forest Service uses Scribner Decimal C Log Rule, the International ¼ Inch log rule, or the Smalian cubic volume rule {36 CFR 223.3}

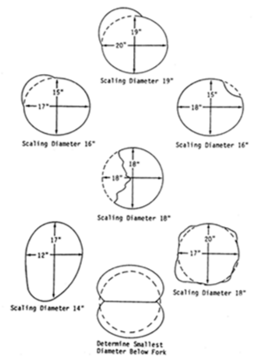


Figure 5.-How to measure logs with abnormal conditions and average the diameters.

Log Rules: Measurements

Measuring log lengths when sweeps and crooks are present is achieved by measuring the horizontal distance.

If a log length exceeds the point where the minimum diameter occurs, the log length ends at that point (i.e. it assumes the bucking was done correctly).

Only deduct defects that penetrate the scaling cylinder.

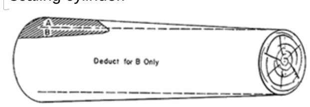
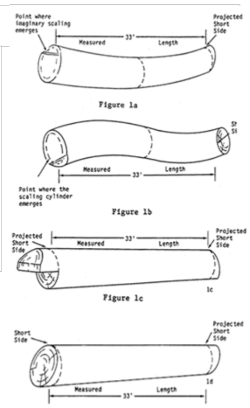


Figure 12. -Defect both inside and outside the scaling cylinder.



Defects: Defect Tables

CUBIC PERIMETER DEFECTING GUIDE (07/09)
(DEFECT PERCENT BASED ON 16' LOG VOLUMES)

DEPTH OF DEFECT IN INCHES - 2 SIDES

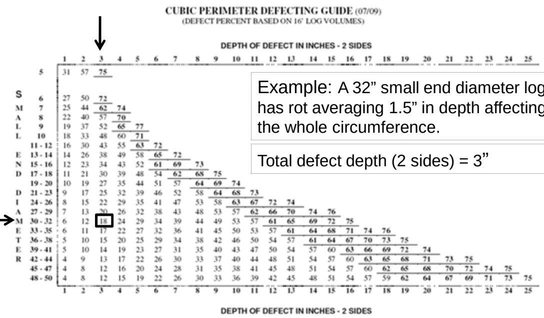
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	5	31	57	75																						
S	6	27	50	72																						
M	7	25	44	62	74																					
A	8	22	40	57	70																					
L	9	19	37	52	65	77																				
L	10	18	33	48	60	71																				
	11 - 12	16	30	43	55	63	72																			
E	13 - 14	14	26	38	49	58	65	72																		
N	15 - 16	12	23	34	43	52	61	69	73																	
D	17 - 18	11	21	30	39	48	54	62	68	75																
	19 - 20	10	19	27	35	44	51	57	64	69	74															
D	21 - 23	9	17	25	32	39	46	52	58	64	68	7[illegible]														
I	24 - 26	8	15	22	29	35	41	47	53	58	63	67	72	74												
A	27 - 29	7	13	20	26	32	38	43	48	53	57	62	66	70	74	76										
M	30 - 32	6	12	18	24	29	34	39	44	49	53	57	61	65	69	72	75									
E	33 - 35	6	11	17	22	27	32	36	41	45	50	53	57	61	64	68	71	74	76							
T	36 - 38	5	10	15	20	25	29	34	38	42	46	50	54	57	61	64	67	70	73	75						
E	39 - 41	5	10	14	19	23	27	31	35	40	43	47	50	54	57	60	63	66	69	72	74					
R	42 - 44	4	9	13	17	22	26	30	33	37	40	44	48	51	54	57	60	63	65	68	71	73	75			
	45 - 47	4	8	12	16	20	24	28	31	35	38	41	45	48	51	54	57	60	62	65	68	70	72	74	75	
	48 - 50	4	8	12	15	19	22	26	30	33	36	39	42	45	48	51	54	57	59	62	64	67	69	71	73	75
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

DEPTH OF DEFECT IN INCHES - 2 SIDES

Sap rot: deduct the full %
Weather checks: deduct half the % if straight defect and full % of spiral
If defect > 60%: Log is non-saw with no defect

USDA FS Region 6 Cruising Manual

Defects: Defect Tables



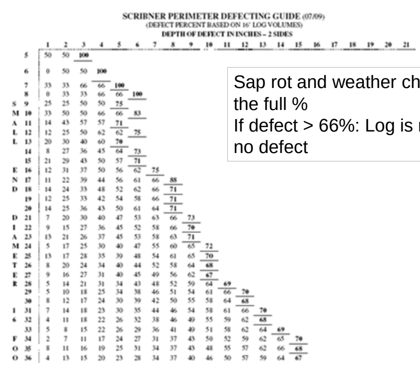
Example: A 32" small end diameter log has rot averaging 1.5" in depth affecting the whole circumference.

Total defect depth (2 sides) = 3"

Total log defect = 18%

USDA FS Region 6 Cruising Manual

Defects: Defect Tables

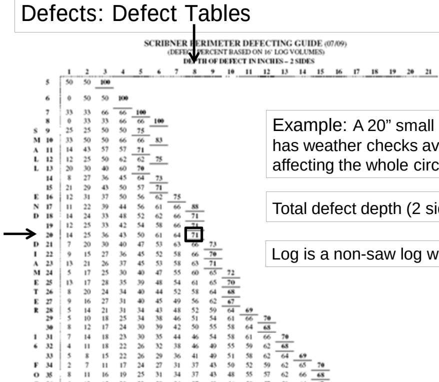


Sap rot and weather checks: deduct the full %

If defect > 66%: Log is non-saw with no defect

USDA FS Region 6 Cruising Manual

Defects: Defect Tables



Example: A 20" small end diameter log has weather checks averaging 4" in depth affecting the whole circumference.

Total defect depth (2 sides) = 8"

Log is a non-saw log with no defect

Total log defect = 71%

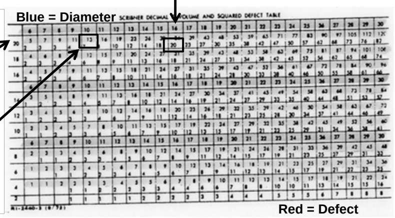
USDA FS Region 6 Cruising Manual

Log Rules: Useful Cheat Sheets

The Scribner Decimal C log rule cheat sheet allows you to quickly deduct defect from the estimated log volume.

Example:
A 20 foot log with 16" diameter with no defect = 200 bd ft

If the same log has a 10" diameter defect affecting 1/5th of the log, then the deduction = 130 (x 0.2) = 26 bd ft



Net Scale = Gross – Defect Scale = 200 – 26 = <u>174 bd ft</u>