A Comparison of
TWO LOG-GRADING SYSTEMS

By C. S. Walters
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A COMPARISON OF TWO LOG-GRADING SYSTEMS

By C. S. Walters and A. M. Herrick[1]

LOG-GRADING SYSTEMS are designed for estimating the quality of the contents of logs. The quality of sawlogs is expressed in terms of the grades of lumber they contain. How closely a system predicts the yields of grade-lumber from a log is important both to persons selling and buying logs and to investigators who use log-grading systems as a research tool. Log grades and lumber-grade yields are also useful in appraising or evaluating standing timber. A system which buyer, seller, and researcher can understand, which can easily be applied, and which predicts recovery accurately, is essential.

The U. S. Forest Service, Forest Products Laboratory (FPL), has developed a log-grading system (2,3)[2] and so has the Purdue University Department of Forestry and Conservation (5,6). The FPL system is designed, first, to classify each log according to its best end-use. Three categories of sawed hardwood products are recognized: factory lumber, structural material, and local-use items. Products in these categories are further classified into subgroups according to generally recognized specifications prepared by the National Hardwood Lumber Association, the American Railway Association, and the American Society for Testing Materials.

Thus, a grader using the FPL system must know the specifications for three major log-use classes. Once he has determined the major class, he must further classify the logs into subgroups or log grades. (At present log grades have been determined only for factory lumber.)

The Purdue system applies to any sawlog, regardless of the quality or end-use of the material it contains. The authors believe the Purdue system is much simpler than the FPL system, and that it is easier to apply by persons with little or no log-grading experience.

If the FPL system is more complicated than the Purdue system, then the following questions are raised: Does this added complexity contribute to a more accurate prediction of log quality? And would the choice of system vary with particular needs? It might be, for example, that a farmer or mill operator would want to use the easier system, provided it were reasonably accurate. On the other hand, a

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[2] Numbers in parentheses refer to "Literature Cited," page 22.

research person would probably choose the more reliable system, even though the system was quite complicated.

The present study was undertaken therefore to provide answers to the foregoing questions, and to compare the precision of the two systems, regardless of their ease of application, when used to grade logs at the mill.

A 16-foot butt log 13 inches in diameter at the small end. More than 5/6 of its grading-face length is clear in two sections 7 and 8 feet long. Less than 40 percent deduction for cull or sweep.

A 10-foot log 16 inches in diameter at the small end. More than 5/6 of its grading-face length is clear in one section 8 feet long. Less than 15 percent deduction for sweep; total cull deduction is less than 40 percent.

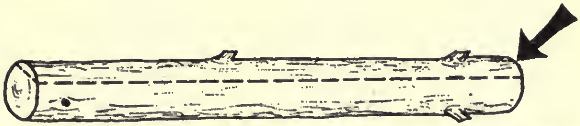
A 12-foot log 20 inches in diameter at the small end. Five-sixths of its grading-face length is clear in two sections 8 and 3 feet long. Deduction for cull and sweep is less than 40 percent.

A 16-foot log 20 inches in diameter at the small end. Less than 15 percent deduction for sweep. Total deduction for sweep and rot is less than 40 percent. There are no surface indications of defect.

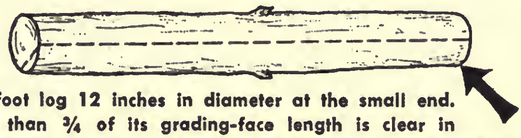
Examples of logs grading F1 by the FPL system. For examples of F2 and F3 grades, see pages 5 and 6. (Fig. 1A)

FIELD METHODS

Data were collected under ordinary working conditions at four sawmills, two in Indiana and two in Illinois. One of the mills (No. 1) had a 7-foot band-type headsaw; the others had circular saws. All the mills produced at least 1,000 board feet of lumber products per hour of sawing time. One day was spent at each of three mills. Mill No. 2 was visited on two days, because it did not operate continuously for a full day.

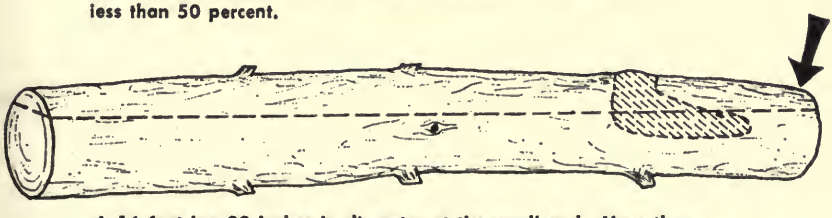


A 10-foot log 11 inches in diameter at the small end. More than ⅔ of its grading-face length is clear in two sections each 4 feet long. Less than 50 percent deduction for cull and sweep.



A 9-foot log 12 inches in diameter at the small end. More than ¾ of its grading-face length is clear in two sections 4 and 3 feet long. Less than 50 percent deduction for cull and sweep.

An 11-foot log 18 inches in diameter at the small end. More than ⅔ of its grading-face length is clear in two sections 5 and 4 feet long. Deduction for sweep is 30 percent. Total deduction is less than 50 percent.

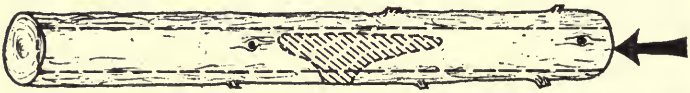


A 16-foot log 22 inches in diameter at the small end. More than ⅔ of its grading-face length is clear in three sections 4, 3, and 4 feet long. Less than 30 percent deduction for sweep. Total deduction is less than 50 percent.

Examples of logs grading F2 by the FPL system. (Fig. 1B)

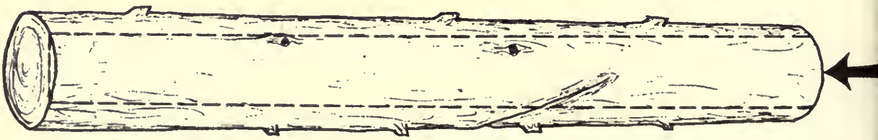
All study logs were numbered, and their diameters and lengths were measured. The board-foot volume of each log was determined by the International (¼″) Scale and by the Doyle Scale. Scaling practices (except for sweep) and volume deductions for cull were in accordance with U. S. Forest Service log-scaling practices (10). Sweep was scaled according to instructions given by the Forest Products Laboratory (2) and Lockard (8).

An 8-foot log 8 inches in diameter at the small end. More than ½ of its grading-face length is clear in two sections of 2 feet or longer. Less than 50 percent deduction for cull and sweep.



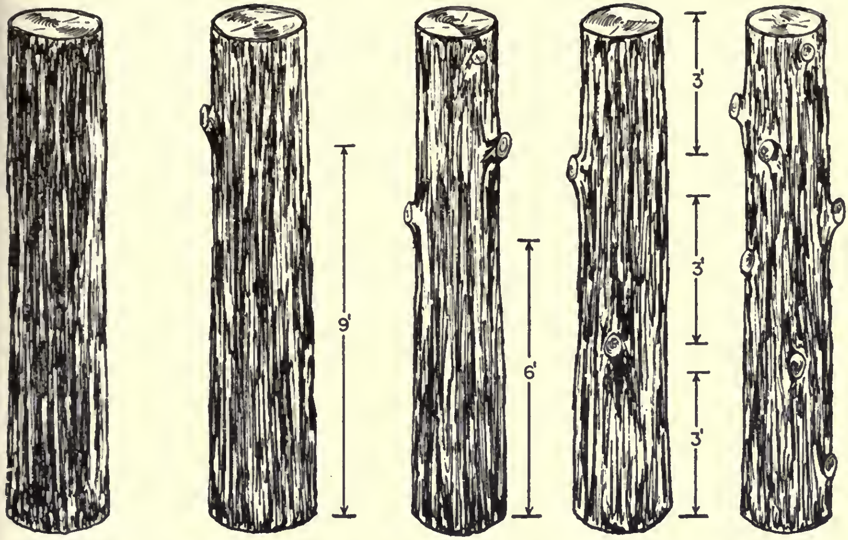
A 12-foot log 14 inches in diameter at the small end. More than ½ of its grading-face length is clear in two sections 4 and 2 feet long. Less than 50 percent deduction for sweep and rot.

A 14-foot log 22 inches in diameter at the small end. More than ½ of its grading-face length is clear in three sections 3, 3, and 4 feet long. Less than 50 percent deduction for sweep and rot.



A 16-foot log 22 inches in diameter at the small end. One-half of its grading-face length is clear in three sections at least 2 feet long. Less than 50 percent deduction for sweep and rot.

Examples of logs grading F3 by the FPL system. (Fig. 1C)



Examples of logs grading Prime, No. 1, No. 2, and No. 3 according to the Purdue system. (Fig. 2)

Whenever possible the logs were graded by both the FPL and the Purdue system.[1] The two systems are presented in brief in Tables 1 and 2 and illustrated in Figs. 1 and 2. They have been described in detail in publications issued by the Forest Products Laboratory (2,3) and Purdue University (6).

The Purdue log grades are based on log diameter and observation of the three visible faces of each log. Most test logs were graded on this basis. However, since all four faces of a log have to be examined to apply the FPL grades, the three poorest faces were sometimes used in determining the Purdue grades.

Two people, each qualified to use one of the systems, did the grading. The graders confidentially gave their analyses to the log tallyman. The tallyman and the two graders cooperatively scaled the logs and measured the defects.

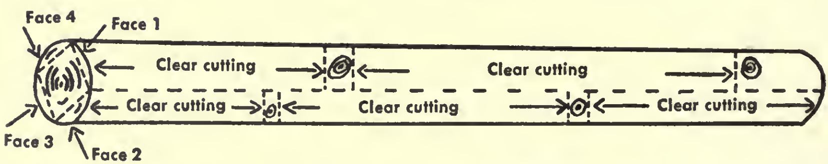
Each piece cut from each log was graded and scaled for board-foot volume by the Assistant Chief Inspector, National Hardwood

[1] For reasons why some logs were not included in the computations, see page 9.

Lumber Association. The lumber yield data were recorded on a form identified with the number of the log from which the lumber was sawed. Most of the logs were cut into 4/4-inch lumber, although all mills produced some heavy-dimension stock and timbers, and the band mill cut a substantial volume of ⅝-inch lumber. The inspector gave a lumber grade to each piece of heavy-dimension stock and timber.

Table 1. — Forest Products Laboratory Standard Grades for Hardwood Factory Logs

Grade factors	Log Grade F1			Log Grade F2				Log Grade F3
	Butts only	Butts and uppers		Butts and uppers				Butts and uppers
Scaling diameter, inches	13[a]-15	16-19	20+	11+[b]	12+	12+	12+	8+
Length without trim, feet	10+	10+	10+	10+	8-9	10-11	12+	8+
Clear cuttings[c] on each of three best faces[d]								
Minimum length, feet	7	5	3	3	3	3	3	2
Maximum number	2	2	2	2	2	2	3	None required
Minimum proportion of total length in clear cuttings	5/6	5/6	5/6	2/3	3/4	2/3	2/3	1/2
Maximum sweep allowance, percent of gross volume								
Less than ¼ of end in sound defects	15	15	15	30	30	30	30	50
More than ¼ of end in sound defects	10	10	10	20	20	20	20	35
Maximum cull and sweep allowance, percent	40[e]	40[e]	40[e]	50[f]	50[f]	50[f]	50[f]	50
End defect requirements	See special instructions							



[a] *Ash and basswood butts can be 12 inches if otherwise meeting requirements for small F1 logs.*

[b] *All species of 10-inch logs can be Grade F2 if otherwise meeting requirements for small F1 logs.*

[c] *A clear cutting is any portion of the face length that is free of log defects over the full width of the face.*

[d] *A face is one-fourth of the surface of the log as divided lengthwise.*

[e] *Logs with 51-60 percent cull that are otherwise F1 can be F2.*

[f] *Logs with 51-60 percent cull that are otherwise F2 can be F3.*

Table 2. — Purdue Hardwood Log Grades

Grade factors	Prime	No. 1	No. 2	No. 3
Minimum diameter inside bark at small end of log, feet	16	14	10	(Will not meet No. 2 specifications)
Percent of surface on three visible faces[a] free of defects in one cutting[b]	90	75	50[c]	

[a] *When all four faces of a log are observed, only the three poorest faces should be used in grading the log.*

[b] *A cutting is the length between surface indications of defect, whether sound or unsound.*

[c] *A log will meet No. 2 requirements if 50 percent of length is surface-clear in two cuttings, neither of which is less than 3 feet long.*

OFFICE METHODS

Deductions were calculated for various defects and applied to gross volumes to obtain net board-foot volume for each log scaled. The following corrections proposed by the Forest Products Laboratory (2) were made to the interior cull deductions to adjust them for the International and Doyle rules:

	International ¼″ scale	*Doyle scale*
Logs 8″–14″, scale multiplied by	1.2	0.7
Logs 15″–20″, scale multiplied by	1.1	0.9
Logs over 20″	No corrections made	

Lumber recovery data were summed by grade for each log, and the total volume recovered from each log (mill tally) was determined. The Saps grade of yellow poplar was included with Selects grade, and the No. 2A and No. 2B grades were combined. The Sound Wormy grade of oak lumber was included with the No. 1 Common grade in the computations.

Altogether, 308 logs were scaled.[1] FPL values were not computed for 101 of these logs (or about one log in three), for the reasons shown below.

Number of logs	*Reasons why FPL values were not determined*
9	No FPL grades or grade-recovery data for logs of structural quality
19	No FPL grades or grade-recovery data for logs of local-use quality
73	No FPL grade-recovery data by diameter class for hickory, ash, sycamore, walnut, and soft maple logs of factory-lumber grades

[1] Sawing times were collected for 292 of these logs, and these data have been analyzed and reported elsewhere (11).

The 101 logs represented about one-fourth of the volume sawed. If grade recovery data by diameter class had been available for hickory, ash, sycamore, walnut, and soft maple, as they were for other species, the FPL system could have been applied to all but 28 (9 percent) of the 308 logs. Even though the Purdue grades were applied to all 308 logs, the two systems have been compared on the basis of the 207 logs for which a complete set of values was obtained.

Grade yield percentages were used to predict the value of each log graded by the FPL system. Two values were predicted with the Purdue system. One was obtained by using grade yield percentages; the other by using the log quality index, known as QI (5).[1]

The grade yield percentages used in estimating the value of the lumber were the "best available." The percentages for the Purdue grading system are based on a combination of species whereas those for the FPL system are for individual species. The percentages for the Purdue system have been published (Table D-1, reference 7), and those for the FPL system were obtained by R. K. Day, Forest Utilization Service, Central States Forest Experiment Station, one of the cooperators in the study.

The FPL grade yield percentages for each species were multiplied by the mill tally volume of each log, and the appropriate grade prices (Table 3) were then applied to the predicted volume of each grade.

When the Purdue grade yields were used, the grade yield percentages for all species combined were multiplied by the mill tally volume of each log to predict the board-foot yields of grade lumber. However, the Purdue percentages include just one figure for the pooled grades of Selects and No. 1 Common lumber (7). Hence, it became necessary to pool price data for the two grades. A weighted mean price was calculated according to the proportions of Selects and No. 1 Common lumber cut at each mill. The mean price was then applied to the predicted pooled-volume of these two grades in calculating the predicted lumber value of each log.

In making the second prediction of lumber value for each log by the Purdue system, the estimated QI (Table D-2, reference 7), the species price of the No. 1 Common grade (Table 3), and the mill tally volume were all multiplied together.

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[1] The quality index of a log shows the estimated average or long-run value of the lumber which a log will yield as a percentage of the price of the No. 1 Common grade. For example, if No. 1 Common lumber is selling for $100 per thousand board feet, a Prime grade log 20 inches in diameter, with a QI of 104, would yield lumber valued at $104 per thousand board feet. If the log contained 200 board feet, its lumber value would be $20.80.

Table 3. — Values[a] per Thousand Board Feet of 4/4-inch Lumber of Different Species

Species	Lumber grade				
	Firsts and Seconds	Selects	No. 1 Common	No. 2 Common	No. 3[b] Common
	dollars	*dollars*	*dollars*	*dollars*	*dollars*
Ash, brown	155	140	107	75	43
Beech	140	130	105	60	42
Cottonwood	102	96[b]	80	63	32
Hickory	125	115	78	53	31
Maple, hard	205	195	135	75	54
Maple, soft	165	155	115	67	46
Oak, red and black	185	175	115	75	46
Oak, white	200	190	120	70	48
Poplar, yellow	200	190	129	78	52
Sycamore	115	108[b]	95	60	38
Walnut	370	325	180	75	47

[a] *With exception of estimated values, prices are those quoted by* Hardwood Market Report *for week of September 18, 1954* (4).

[b] *Estimated value(s).*

The actual dollar value of the lumber in each log was calculated from lumber recovery data obtained at the mills, and the market prices for lumber as shown in Table 3. This value was the standard with which predicted log values were compared.

Regressions of dollar value predicted by each of the three methods on actual dollar value were calculated, as were the regressions of actual value on each of the three sets of predicted values. The pair of regression lines for each method was averaged into a cofrequency line (9) and compared with a line of perfect correlation and predictions. To find the "mean of the regression lines," the equation for the regression of X on Y was converted to the "Y equals" form, and the slope and constant were averaged with those of the equation for the regression of Y on X. Perfect correlation would be expressed by the line "$Y = X$."

RESULTS AND DISCUSSION

Description of logs in study

According to the International (¼″) scale, the gross volume of the 207 logs in the comparative study was 32,528 board feet, and the net volume, 30,105 board feet. Actually, they were cut into 33,113 board feet of sawed products.

Table 4. — Statistics for 207 Logs Studied at Four Sawmills

Variable	Minimum	Maximum	Range	Average	Standard error
Diameter, inches	9	32	23	16.8	0.3
Length, feet	8	20	12	12.3	0.2
Actual lumber value, dollars	3.08	57.71	54.63	16.10	0.69
Volume, board feet					
Mill tally	36	448	412	160	5
Net Doyle scale	16	370	354	124	5
Net Int. (¼″) scale	27	370	343	145	5

Table 4 shows diameter, length, value, and volume statistics for the 207 logs. The average length of the logs was 12.3 feet, and the average diameter of the logs inside the bark at the top (small) end was 16.8 inches. The average net volume, according to the mill tally, was 160 board feet. This exceeded both the figure obtained by the Doyle Scale (124 board feet) and that obtained by the International Scale (145 board feet). The actual lumber values of the logs ranged from $3.08 to $57.71.

Correlation between the two systems

The correlation between the two grading systems as they applied to the individual logs is shown in Table 5. Also shown are the numbers and percentages of logs of each grade. It may be seen that the lowest correlation between the two systems was in the logs that rated F2 by the FPL system. That is, F2 logs were common among all four of the Purdue grades. There was, however, good correlation between the two systems in the logs that graded F1 or F3. In other words, both systems usually classified the poor logs as such, and gave a top grade to good-quality logs.

Of the two logs that were graded Prime or No. 1 by the Purdue

Table 5. — Correlation of Log Grades Assigned to Individual Logs

Purdue grades	FPL grades			Number	Percent
	F1	F2	F3		
Prime	30	18	1	49	24
No. 1	20	13	1	34	16
No. 2	10	43	12	65	31
No. 3	0	18	41	59	29
Number	60	92	55	207	...
Percent	29	44	27	...	100

Table 6. — Value Statistics for FPL and Purdue Log Grading Systems

Grading system and log grade	Number of logs	Mean ($\bar{y}$)	Standard deviation (s_y)	Standard error ($s_{\bar{y}}$)	Coefficient of variation (v)	Standard error of estimate ($s_{y.x}$)[a]	Coefficient of correlation ($r_{y.x}$)[a]
Actual Lumber Values of 207 Logs							
		dollars	*dollars*	*dollars*	*percent*	*dollars*	
FPL							
F1	60	24.98	10.79	1.39	43.2	8.50	.625
F2	92	15.02	6.72	0.70	44.7	4.79	.703
F3	55	8.22	4.48	0.60	54.5	3.47	.636
All	207	16.10	9.93	0.69	61.7	6.74	.736
Purdue							
Prime	49	24.08	12.07	1.72	50.1	9.11	.665
1	34	18.95	7.36	1.26	38.8	6.09	.579
2	65	13.63	7.24	0.90	53.1	5.54	.650
3	59	10.54	6.66	0.87	63.2	4.73	.710
All	207	16.10	9.93	0.69	61.7	6.74	.736
Predicted Lumber Values of 207 Logs							
FPL							
F1	60	25.50	10.33	1.33	40.5	7.45	.700
F2	92	14.40	6.90	0.72	47.9	4.88	.710
F3	55	7.31	3.92	0.53	53.6	3.03	.643
All	207	15.74	10.13	0.70	64.4	6.60	.760
Purdue — QI							
Prime	49	23.64	11.02	1.57	46.6	7.33	.753
1	34	17.16	6.72	1.15	39.2	5.28	.634
2	65	12.91	6.56	0.81	50.8	4.38	.749
3	59	10.71	6.91	0.90	64.5	4.61	.749
All	207	15.52	9.34	0.65	60.2	5.63	.799
Purdue — grade yields							
Prime	49	26.64	12.38	1.77	46.5	8.72	.739
1	34	19.01	7.49	1.28	39.4	6.05	.607
2	65	14.54	7.50	0.93	51.6	5.12	.735
3	59	11.43	7.40	0.96	64.7	5.03	.739
All	207	17.25	10.64	0.74	61.7	6.46	.790

[a] *Dependent variable (y) is dollar value and independent variable (x) is log diameter inside bark.*

system but were graded F3 by the FPL system, one did not meet the FPL minimum length requirements and the other was downgraded because of the location of its defects.

Comparison of predicted values with actual values

How closely did the mean predicted values approximate the mean actual values? As shown in Table 6, the average actual lumber value for all logs was $16.10 ± 0.69. The average value predicted from FPL grade yield percentages was $15.74 ± 0.70. With the Purdue grading system, a mean value of $17.25 ± 0.74 was predicted from grade yields, and $15.52 ± 0.65 from quality indexes. Thus, although all three systems gave good estimates, the FPL system was most accurate, with the difference between mean actual value and mean predicted value being just 36 cents. This difference was not statistically significant at the .05 level of probability (Table 7). The difference of 58 cents between actual value and the value predicted by the Purdue quality indexes was statistically significant, however, as was the difference of $1.15 between actual value and the value predicted by Purdue grade yields.

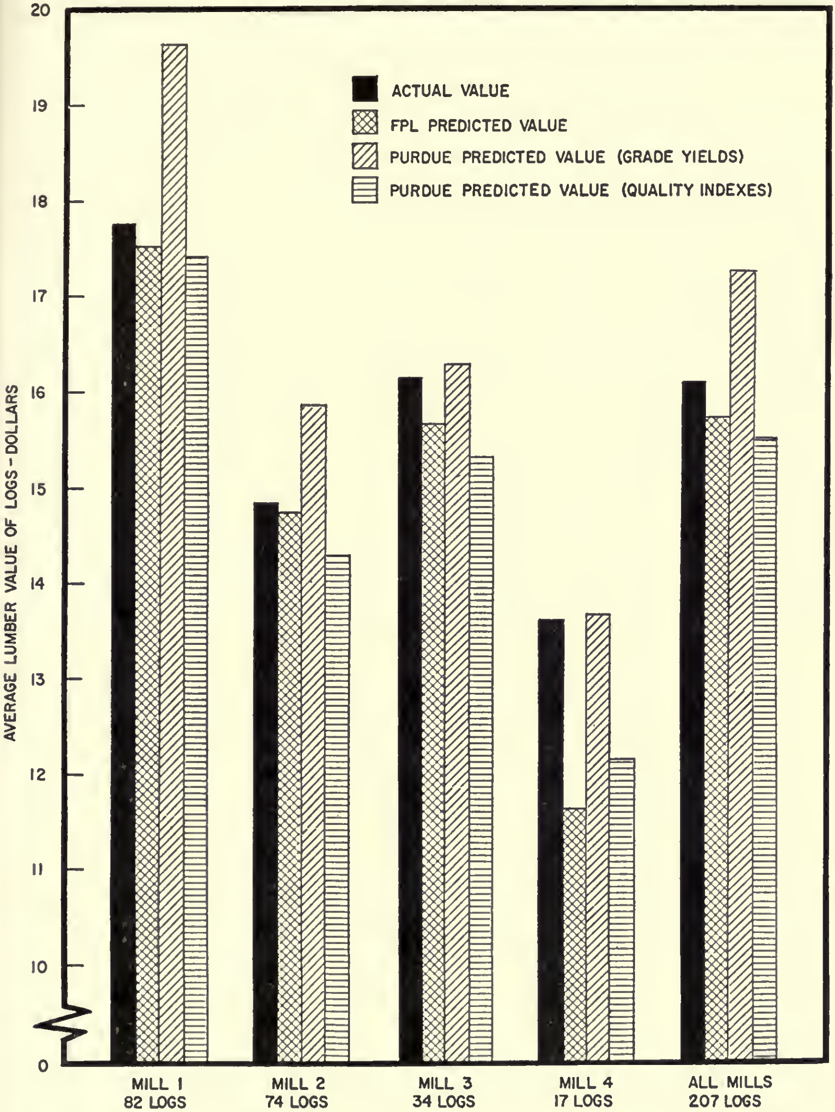
Table 7. — Relation of Actual Value to the Predicted Values

Predicted value from—	Correlation coefficient	Difference of means	Standard error of the difference	t[a]
FPL grade yields	0.948	−0.36	0.225	1.60[NS]
Purdue grade yields	0.940	+1.15	0.252	4.56*
Purdue quality indexes	0.939	−0.58	0.237	2.45*

[a] NS = *not significant*
* = *significant at .05 level of probability*

As shown in Fig. 3, the FPL predictions and the Purdue estimates based on quality indexes were lower than the actual value at each one of the four mills. On the other hand, Purdue predictions based on grade yield percentages were higher than actual value at every mill. Some explanations are warranted.

The low estimates of value obtained from the FPL system can be attributed primarily to the fact that FPL log grades were usually lower than the quality actually sawed. This is indicated by Table 8, which shows the FPL predicted lumber grade recovery and actual



Average actual and predicted values of lumber cut from 207 logs by four sawmills. Note that the values predicted with Purdue grade yields are consistently high, while FPL values and Purdue values based on quality indexes are consistently low. (Fig. 3)

Table 8. — Lumber Volumes Predicted by FPL Yield Data and Actual Volumes Cut from Logs at One Sawmill

Log number	Predicted lumber volumes, bd. ft.						Measured lumber volumes, bd. ft.					
	FAS	Sel.	#1C	#2C	#3C	Total	FAS	Sel.	#1C	#2C	#3C	Total
7	20	7	80	33	34	174	49	44	68	13	..	174
9	0	1	6	11	49	67	..	7	3	22	35	67
10	0	1	11	17	54	83	..	12	29	14	28	83
13	14	7	71	37	54	183	..	..	82	80	21	183
16	0	1	5	10	45	61	7	..	..	47	7	61
18	5	4	33	22	39	103	..	45	28	..	30	103
19	4	3	24	18	34	83	8	27	12	15	21	83
23	5	4	33	21	38	101	9	17	27	21	27	101
24	40	14	39	14	27	134	75	14	40	..	5	134
33	7	8	39	30	49	133	7	23	58	17	28	133
34	46	13	40	14	26	139	17	15	24	37	46	139
35	19	8	85	36	41	189	9	23	80	77	..	189
36	0	0	7	11	34	52	..	..	..	34	18	52
38	44	17	46	18	35	160	82	23	55	..	..	160
39	2	1	26	32	69	130	..	..	8	88	34	130
42	9	5	49	27	43	133	..	..	68	50	15	133
44	1	1	23	30	73	128	..	..	36	..	92	128
Total	216	95	617	381	744	2,053	263	250	618	515	407	2,053
Percent of total	10.5	4.6	30.1	18.6	36.2	100.0	12.8	12.2	30.1	25.1	19.8	100.0

Table 9. — Lumber Volumes Predicted by Purdue Yield Data and Actual Volumes Cut from Logs at One Sawmill

Log number	Predicted lumber volumes, bd. ft.					Measured lumber volumes, bd. ft.				
	FAS	Select and #1C	#2C	#3C	Total	FAS	Select and #1C	#2C	#3C	Total
7	24	89	30	31	174	49	112	13	..	174
9	1	10	29	27	67	..	10	22	35	67
10	1	17	35	30	83	..	41	14	28	83
13	18	83	42	40	183	..	82	80	21	183
16	1	10	26	24	61	7	..	47	7	61
18	7	41	28	27	103	..	73	..	30	103
19	6	32	23	22	83	8	39	15	21	83
23	7	41	27	26	101	9	44	21	27	101
24	24	58	25	27	134	75	54	..	5	134
33	9	51	37	36	133	7	81	17	28	133
34	26	60	25	28	139	17	39	37	46	139
35	25	92	36	36	189	9	103	77	..	189
36	0	11	22	19	52	..	..	34	18	52
38	29	67	32	32	160	82	78	..	..	160
39	3	40	48	39	130	..	8	88	34	130
42	12	58	32	31	133	..	68	50	15	133
44	3	34	50	41	128	..	36	..	92	128
Total	196	794	547	516	2,053	263	868	515	407	2,053
Percent of total	9.5	38.7	26.7	25.1	100.0	12.8	42.3	25.1	19.8	100.0

lumber yields from all 17 logs sawed at Mill No. 4 and used in the comparative analysis.[1] The overestimate of No. 3 Common and the underestimate of FAS, Selects, and No. 2 Common lumber are apparent.

Table 9 gives the lumber grade recovery predicted by Purdue grade yields and the actual yields for the same logs used in preparing Table 8. As shown by Table 9 and also by Fig. 3, the Purdue percentages gave very good results at Mill No. 4. The overestimates at Mills 1 and 2 were traced to a few logs whose values were badly overestimated. A considerable proportion of heavy-dimension stock and timbers was sawed from these particular logs, giving an inordinately high yield of No. 3 Common material. The actual dollar value of the logs was thus depressed.

It was to be expected that predictions based on Purdue grades and QI's would be lower than actual values. This is because the standard price relatives used in determining the QI's of the two highest grades are lower than the actual relationships between the grade prices shown in Table 3. To illustrate, the standard price relatives and those actually prevailing for red oak and soft maple on September 18, 1954, were as follows:

Lumber grade	*Standard price relatives*	*Actual price relatives*	
		Red oak	*Soft maple*
FAS	1.4	1.61	1.43
Selects	1.3	1.52	1.35
No. 1 Com.	1.0	1.00	1.00
No. 2 Com.	0.6	0.65	0.58
No. 3 Com.	0.4	0.40	0.40

The standard price relatives for the FAS and Select grades used in determining QI's were intended to be conservative. The reasons for this deliberate conservatism are beyond the scope of this report but are fully explained in another publication (1).

The correlation coefficients shown for the three methods of predicting dollar values in Table 7 are quite high, showing good correlation between predicted and actual values for both grading systems.[2]

The regression equations for predicted value (Y) on actual value (X) and for X on Y are as follows.

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[1] Mill No. 4 was chosen because no bias was introduced in the selection of logs for the analysis.

[2] When all 308 logs were used in the calculations, the correlation coefficients for the Purdue system were as follows:

Based on quality indexes, 0.943
Based on grade yields, 0.945

For the FPL system, using grade yields:

$$Y = 0.968\ (X) + 0.16 \text{ and}$$
$$X = 0.930\ (Y) + 1.47$$

For the Purdue system, using grade yields:

$$Y = 1.007\ (X) + 1.04 \text{ and}$$
$$X = 0.877\ (Y) + 0.96$$

For the Purdue system, using quality indexes:

$$Y = 0.883\ (X) + 1.30 \text{ and}$$
$$X = 0.998\ (Y) + 0.61$$

These regression lines were "averaged" for comparison with lines for perfect correlation of X and Y values.

To illustrate the determination of the "mean regression" or co-frequency line, the regression of "actual value" on "FPL predicted value" (X on Y) is:

$$X = 0.930\ (Y) + 1.47, \text{ or, transposed}$$
$$Y = 1.075\ (X) - 1.58$$

This equation was then "averaged" with the regression of "Y on X," thus:

$$Y = 1.075\ (X) - 1.58$$
$$Y = 0.968\ (X) + 0.16$$
$$\overline{Y = 1.021\ (X) - 0.71}$$

The line represented by this last equation is to be compared with:

$$Y = 1.000\ (X) \pm 0$$

It may be seen that although the FPL system predicts values that are low, on the average, by 36 cents, the "mean regression" line (Fig. 4A), has a Y intercept of −71 cents and gradually approaches the line showing perfect correlation of values at the higher values of X and Y. This means that the predicted values tend to become more precise, on the average, as log value increases.

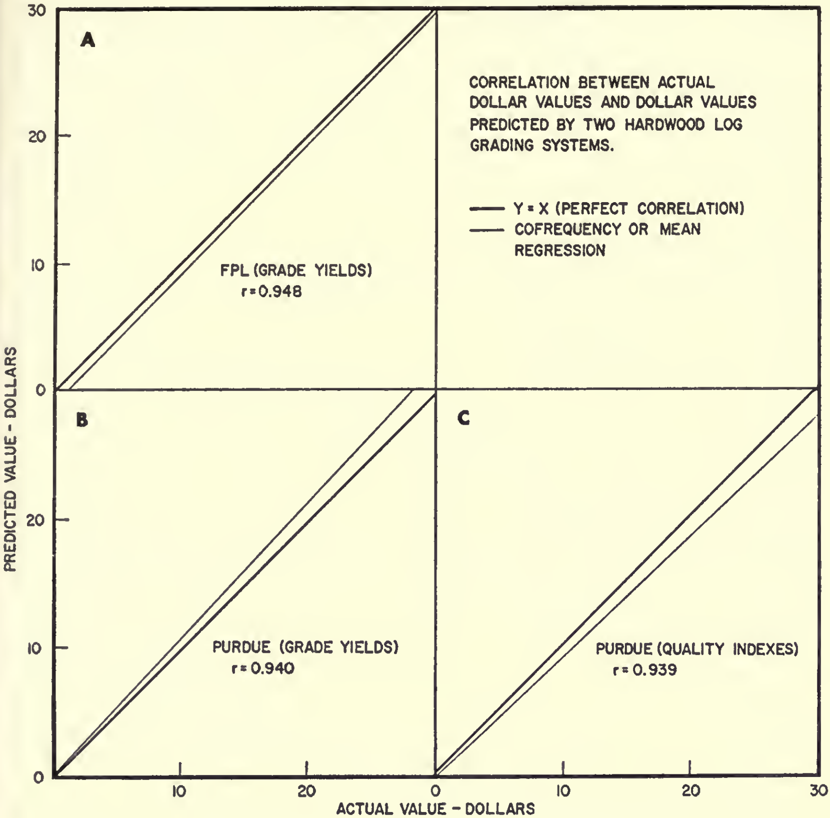
Determined by the same process, the "mean regression" for the Purdue system using grade yields was:

$$Y = 1.073\ (X) - 0.03$$

For the Purdue system, using quality indexes, the mean regression was:

$$Y = 0.942\ (X) - 0.34$$

The Purdue system using grade yields shows the best orientation considering the Y intercept (only 3 cents low), but has a slope that is too great (Fig. 4B). This means that the predictions of value become less precise (increasingly high) as log value increases. When quality indexes are used for the prediction, the regression is consistently low, becoming less precise (increasingly low) as log value increases (Fig. 4C).

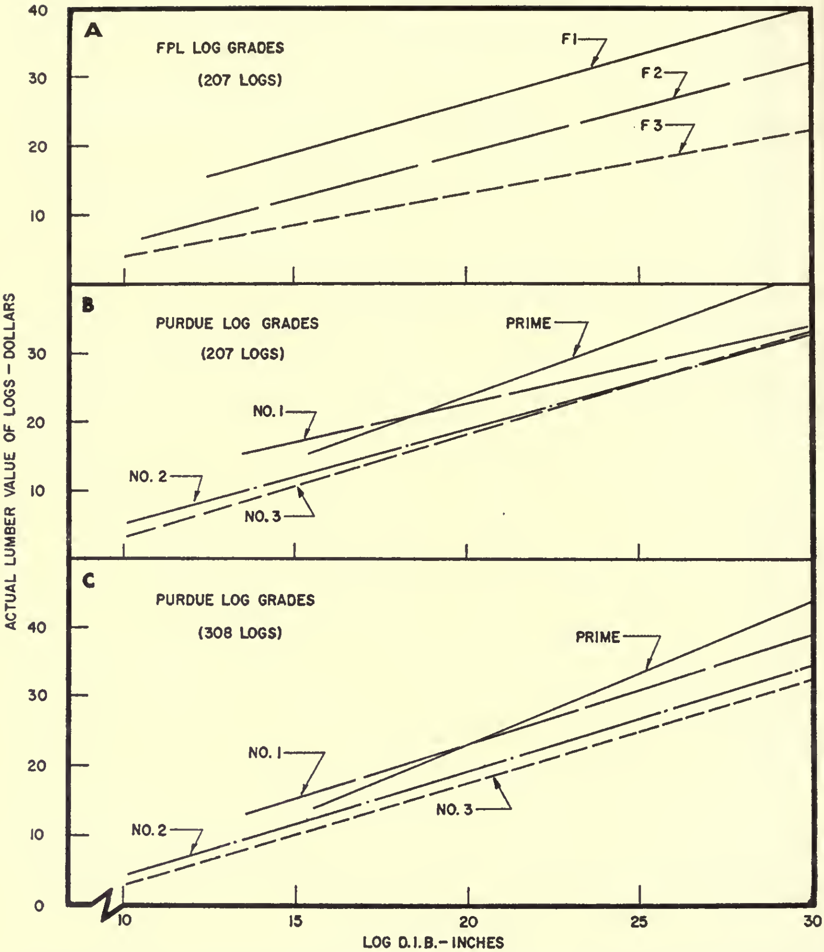


How predicted dollar values of lumber cut from 207 logs correlated with actual lumber values. (Fig. 4)

Separation of logs into quality groups

So far we have compared the two systems mainly on the basis of how well they predicted average lumber values for a group of 207 logs. The grader, however, may also wish to know how well each system stratified the logs into quality classes. An answer may be found in Fig. 5, which shows the regression of actual lumber value on log diameter inside bark for each log grade. A comparison of Fig. 5A and Fig. 5B shows that the FPL system was superior to the Purdue system in separating the 207 logs into quality groups.

This group of logs, however, was not representative of the population from which the Purdue grade-yield data were obtained, since some of the data came from low-quality logs and 28 such logs were



How the two grading systems separated logs into quality groups, as shown by regression of actual lumber value on log diameter inside bark. (Fig. 5)

excluded from the comparative study. Also there was a possibility that if species were correlated with log diameter and log grade, as is quite likely the case, then pricing (lumber values) also might have affected the Purdue regressions of actual value on log diameter.

For these reasons, regressions of actual value on log diameter were prepared for the Purdue log grades, using all 308 logs (Fig. 5C). The differences between the quality classes were more clearly defined when all 308 logs were considered than when only 207 logs were included. The results, however, were still poorer than those obtained with the FPL system. Moreover, the regressions for these logs suggest that there is not enough definition among them to warrant the use of as many as four log grades. There particularly seems to be confusion between the Prime and No. 1 grades, at least in the smaller diameter classes.

The relative size of the standard deviations of the actual dollar values (Table 6) indicates that both systems had considerable within-grade variation. This point is emphasized by the fact that the coefficients of variation for the actual values exceeded 40 percent for all but one grade.

The standard error of estimate ($s_{y.x}$, Table 6) for the FPL predicted values ($6.60) was about the same as that for Purdue grade yields ($6.46), but both of them were somewhat higher than the $s_{y.x}$ for values based upon quality indexes ($5.63). A comparison of the standard errors of estimate for actual values with their respective standard deviations indicates that there was a relatively large amount of scatter about the regression lines. Hence, reliability is certain to be quite low, even for lumber values predicted from log grade and log diameter. As a further illustration of this point, compare the standard errors for estimating actual value from FPL grades (Table 6) with the spacing of the regressions in Fig. 5A. This inherent variability in lumber yields necessarily limits the precision with which any hardwood log grading system can forecast the quality of lumber yield.

SUMMARY AND CONCLUSIONS

Three hundred eight logs were measured and graded at four sawmills, two in Indiana and two in Illinois. One of the mills had a band headsaw, and the others were equipped with circular headsaws. The logs were graded by a qualified grader using a system developed by the U. S. Forest Products Laboratory and again by a grader using a system developed by Purdue University. An inspector from the National Hardwood Lumber Association scaled and graded the lumber products recovered from each log.

Three methods of predicting dollar values were used: (1) FPL log grades and accompanying lumber grade yields in percent, (2) Purdue log grades and percentage grade yields, and (3) Purdue grades and quality indexes. Price data were taken from the *Hardwood Market Report* for the week of September 18, 1954. Graphs and regression and correlation statistics were prepared showing the relationships between predicted and actual dollar values for 207 logs which were cut into 33,113 board feet of sawed products.

The results of the study showed:

1. Only about two logs out of every three scaled and sawed at the four mills could be included in the comparative study. FPL grade recovery data by diameter classes were lacking for most of the logs not included. The rest of these logs — about 9 percent of all those scaled — did not meet the FPL specifications for factory lumber.

2. The two grading systems generally agreed in their rating of poor-quality and high-quality logs, with less agreement being found in the grade assigned to medium-quality logs.

3. The actual lumber recovery at the study mills was better in average quality than the recovery predicted by the FPL log grades. Purdue grade yields gave excellent results at two of the study mills, but overestimated recoveries at the other two mills.

4. There was no appreciable difference among the three methods in degree of correlation between predicted and actual dollar values.

5. The FPL grades gave the best mean predicted value, but the prediction was only slightly better than that obtained from Purdue quality indexes. Purdue grade yields gave the poorest result according to this criterion.

6. The FPL mean predicted value was not significantly different from the mean actual value. The differences between mean actual value and mean values predicted by the two Purdue methods were statistically significant.

7. The FPL system was better than the Purdue system in stratifying the study logs into value categories.

8. Considerable variation in dollar value was found within each group of graded logs, suggesting that the reliability of any grading system in predicting dollar values or the quality of lumber yields will be quite low.

9. Because of inherent variability in the quality of lumber yields, no more than three grades appear to be necessary for sorting hardwood sawlogs into quality classes.

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