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A STUDY OF TIME-VALUE RELATIONSHIPS IN A SOUTHERN MICHIGAN BAND MILL

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

Melvin D. Brown

1949

THESIS

This is to certify that the

thesis entitled

A STUDY OF TIME-VALUE RELATIONSHIPS IN A SOUTHERN MICHIGAN BAND MILL

presented by

MELVIN D. BROWN

has been accepted towards fulfillment
of the requirements for

MASTER OF SCIENCE degree in FORESTRY

A. J. Panshin
Major professor

Date 9-1-49

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A STUDY OF TIME-VALUE RELATIONSHIPS
IN A SOUTHERN MICHIGAN BAND MILL

by

Melvin D. Brown

A THESIS

Submitted to the School of Graduate Studies of Michigan
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INTRODUCTION

The findings, discussed in this paper, deal primarily with band-sawn Michigan hardwoods. It is important to keep in mind the great variability in the quality and size of logs, within the same species, as well as between the species. Furthermore, mills are as variable as the logs that are cut in them. Each mill owner is confronted by problems that are peculiar to his own economic sphere and each mill has definite characteristics which influence the quality and the rate of manufacture of lumber.

The results of this study provide evidence that it should be of vital interest to both the producer of timber and manufacturer of lumber to follow good forestry practices in utilizing the timber crop. It is hoped that this study will aid in promoting more efficient timber utilization.

THE PROBLEM

Objectives

The main objective of this study is to bring to the attention of mill operators the correlation that exists between log quality and the time required to manufacture logs into salable lumber.

In order to achieve the above objective, the following points were considered:

1. The effect of log size on quality of the lumber that can be cut from the log.

2. The feasibility of using log grades as a basis of purchasing logs.

3. The relationship of time of manufacture to the size of logs.

4. The relationship of lumber value to the various scaling rules used in measuring logs.

5. The determination of the smallest log that can be cut into lumber at a profit.

6. The relationship of lumber prices to the grade of lumber cut from the log.

Procedures

The data for this study were collected at the L. L. Johnson Lumber Company of Charlotte, Michigan in November and December of 1948, and in January of 1949. Logs were scaled and graded in groups of eight or ten on the log-deck. Then, the mill tally and lumber grade of the actual lumber sawed from the log were determined at the trimmer. The time of manufacture to the nearest one-quarter minute was recorded for each log. The period of time spent on one log is considered to be from the time the last board is cut on the previous log, until the last board is sawed from the log being timed. All delays due to break-downs and saw changes were recorded separately.

SAMPLE DATA CARD

Log No. 145 Species H. MAPLE Date 12/16/48

d.i.b. 12 Length 12 Grade 1 Sawing time: 4 1/2

to 11-26-45

Doyle Scale 48 Defects — from 11-22-15

SM	GR	TH	BM	SM	GR	TH	BM	SM	GR	TH	BM*	Totals
3	1	4	3	4	1	4	4					* SM-Surface Measure
7	2	5	9	6	F	4	6					GR-Grade
6	1	4	6	6	2	4	6					TH-Thickness in ¼ Inches
8	1	5	10	6	3	8	12					BM-Board Measure
5	1	4	5									
6	F	5	8									
6	3	4	6									
6	3	4	6									

Figure A

The lumber was graded according to the National Hardwood Lumber Association rules. For ease in grading, and because lumber is often sold that way, the select grade was combined with the #1 common grade. Prices used are those of air-dried lumber, f.o.b. mill, as published by the "Hardwood Market Report" for January 29, 1949.[1]

All lumber values are on a thousand board feet basis measured immediately after sawing with an allowance of ten percent for shrinkage and degrade due to air drying.

All log diameters were measured at the small end of the log to the nearest inch. Lengths were dropped to the nearest foot, allowing about three inches for trim. Lumber thicknesses were recorded in quarter-inches except in the case of five-eighths inch stock. Scale for five-eighths lumber was adjusted to one inch thickness to make possible mill tally on the board-foot basis.

A total of 372 logs were graded and scaled. The average log was approximately 15" in diameter at the small end, and slightly longer than 12 feet. Hard maple and American elm comprised 60 percent of the logs cut. The red and white oak groups, beech, basswood, soft maple, and white ash made up the bulk of the other 40 percent.

The log grading rules used in this study are explained in Appendix II. Also, the method used in determining the mill tally curve formula and summary of

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[1] "Hardwood Market Report", published weekly at Memphis, Tennessee.

basic data are contained in Appendix I and III respectively, at the end of this paper.

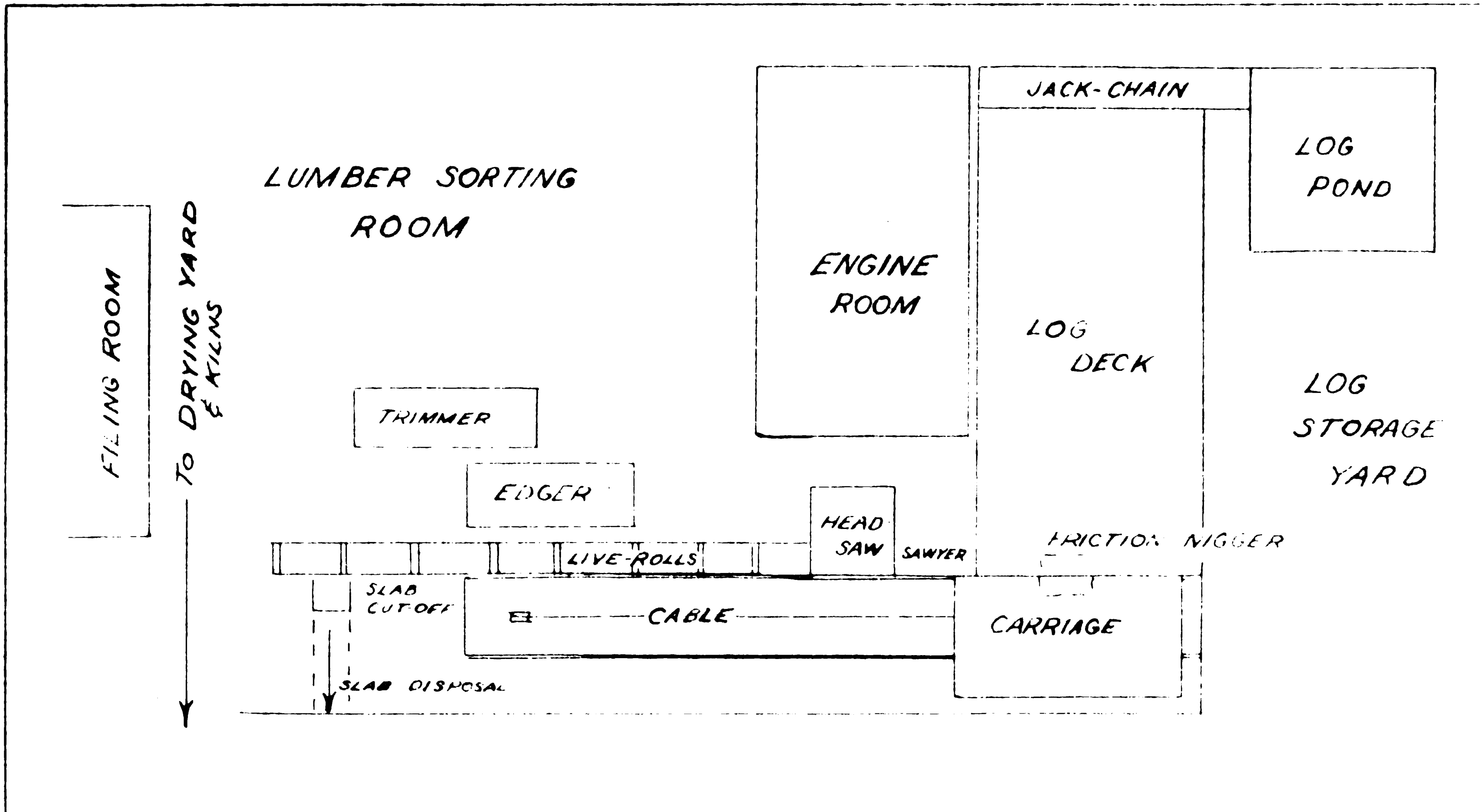
Equipment Used(Description of the Johnson Mill)

The L. L. Johnson Company has a steam powered band mill, producing about 9,000 board-feet per nine hour day. In conjunction with the sawmill the company operates three Standard dry-kilns, a drying yard, a dimension and planing mill, and complete logging and hauling equipment.

Logs are purchased from the area around Charlotte, Michigan. The finished lumber is sold wholesale to local wood users and to the furniture trade in the Grand Rapids area. The mill also does some custom sawing. A layout of the mill is shown in Figure B.

The sawyer at the Johnson mill is considered to be better than average. Quality lumber is given the first consideration and quantity next. Lumber is not scaled or graded until it is kiln-dried or sold, except that there is some sorting of the low and high grades before kiln-drying. Generally, low grades are only air-seasoned.

The operation of the Johnson mill is very much like that of other mills of its type, with the exception of the use of air-dogs on the carriage. The carriage-dogs were originally of the hand-operated type. Air-dogs were mounted on the number one and number three knees and are operated by the block-setter from his position. Use



LAY OUT OF THE JOHNSON BAND-MILL, CHARLOTTE, MICHIGAN

CREW — LOG STORAGE & LOG POND (2), LOG DECK (1), BLOCK-SETTER (1), SAWYER (1), EDGER (1), TRIMMER (1), SLAB CUT-OFF (1) SORTING (1), FILING (1), STACKING & SCALING (2 5)

Figure B

of the air-dogs is limited by their position on the carriage; logs under twelve feet cannot be held with both dogs and some logs are too large for effective use of the dogs. The principle advantages of the air-operated dogs are an increased rate of cut and easier work for the block-setter.

Explanation of Abbreviations Used in the Manuscript

The National Hardwood Lumber Association Hardwood Lumber Grades are abbreviated as follows:

First and Seconds	FAS
#1 Common and Select	#1C&S
#2 Common	#2C
#3 Common	#3C

Other abbreviations commonly used throughout this paper are:

Diameter inside bark, small end	d.i.b.
1000 board feet	M
Board feet	b.f.
Air-dried	AD

FACTORS AFFECTING LUMBER VALUES

Prices

Lumber prices vary with the seasons, years, and with business cycles. The relationship between prices for various grades remains fairly constant, except that difference in price between FAS lumber and the lower grades tends to increase in periods of business depressions and to decrease in periods of prosperity.[1]

Explanation of the above is simple. In times of prosperity, when demand is high, lumber buyers cannot obtain all the best grades they may desire, so they compete with each other in purchasing lower grades, causing the price of lower grades to rise. When business is at low ebb, and demand for lumber is low, buyers will buy only the best grades. Low grades are then difficult to sell at any price.

Herrick[2], in his study of grade yields and overrun for Indiana hardwood sawlogs, places the relative value of each grade as:

FAS(First and Seconds)	100 %
#1C&S(#1 Common and Selects)	70
#2C(#2 Common)	50
#3C(#3 Common)	30

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[1] Brown, N. C., "Lumber", John Wiley & Sons, New York, 1947

[2] Herrick, A., "Grade Yields and Overrun from Indiana Hardwood Sawlogs", Agriculture Experiment Station, Purdue University, Bulletin 516, 1946

TABLE I
GRADE-PRICE RELATIONSHIPS FOR DIFFERENT PERIODS*

Lumber Grade	Forest Products Study of[1] NE Hardwoods--1936 Prices		Herrick's Study[2] OPA Prices--1945		Hardwood Market Report[3] Weighted Prices, January 1949	
	Relationship %	Range %	Relationship %	Range %	Relationship %	Range %
FAS	100	--	100	--	100	--
#1C&S	72	69 to 77	68	59 to 74	73	66 to 80
#2C	47	40 to 52	48	40 to 53	47	40 to 58
#3C	28	24 to 31	28	22 to 33	24	21 to 32

*The price of each grade is expressed in percent of the price of FAS lumber.

[1]U. S. Forest Products Laboratory, "Woods and Mill Studies of the Manufacture of Birch, Beech, and Maple Lumber in the Northeast", Report No. R1217, 1939

[2]Herrick, A., "Grade Yields and Overrun from Indiana Hardwood Sawlogs", Agricultural Experiment Station, Bulletin 516, Purdue University, 1946

[3]"Hardwood Market Report", published weekly at Memphis, Tennessee. Prices are for AD lumber, f.o.b. mill, Wausau, Wisconsin area.

According to the U.S. Forest Products Laboratory[1], the following relationship exists between FAS and #1 Common grades:

FAS	1.50 (or 100 %)
#1 Common	1.00 (or 67 %)

Prices in Table I refer to species cut in this area. The prices from the "Hardwood Market Report" are adjusted to thicknesses cut in the L. L. Johnson mill.

It was found that the price relationships used by Herrick will apply to most situations and can, therefore, be used to compare relative values of logs of different diameters or of different log grades.

<u>Size of Logs</u>

Grade yield of lumber from logs is very variable. In general, the quality of lumber increases with an increase in diameter of the log. Figure C shows the grade distribution of 372 logs of all diameters, of all species cut at the mill. The freehand curves were plotted from the means for each diameter class. The data in diameters above 18" d.i.b. were grouped and averaged so that all points were based on a minimum of seven samples. The standard error of estimate of the means was 5.2 percent, which means that the average logs of a given diameter will contain the percentage distribution of grades shown by Figure C within 5.2 percent of the curved value 68 percent of the time.

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[1]U. S. Forest Products Laboratory, "Hardwood Log Grades for Standard Lumber-Proposals and Results", D1737, 1949

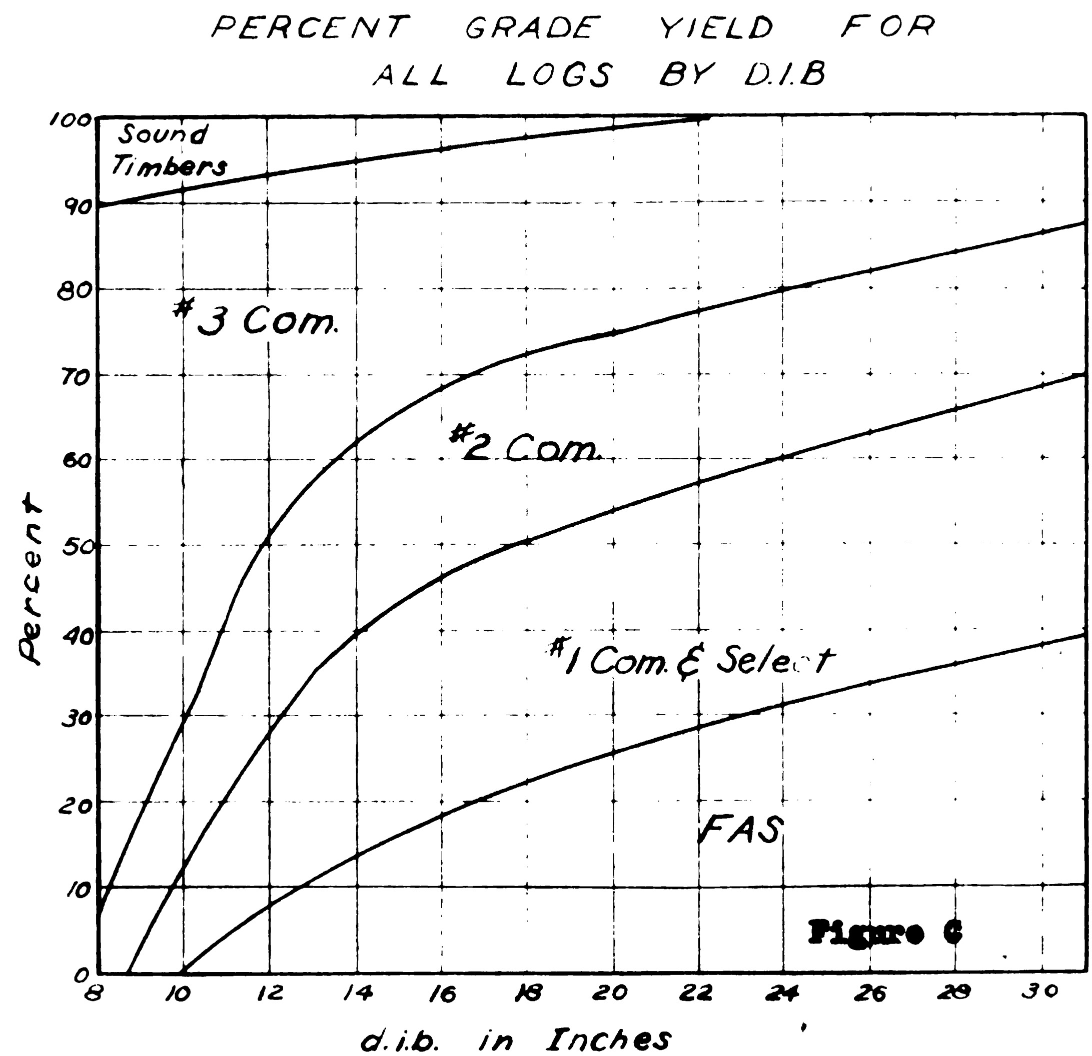

Figure D shows the average value per M of lumber expressed in percent of FAS lumber for each diameter of log. The curve was plotted from the grade distribution in Figure C. Actual percentages and adjusted values per M may be found in Appendix III.

It is interesting to note that in Figure D, the most rapid increase in the value of lumber is in diameters up to 18" d.i.b. This gives a rough indication of the minimum cutting size of logs. An 18 inch log, measured

LUMBER VALUE PER M
IN PERCENT OF FAS PRICE

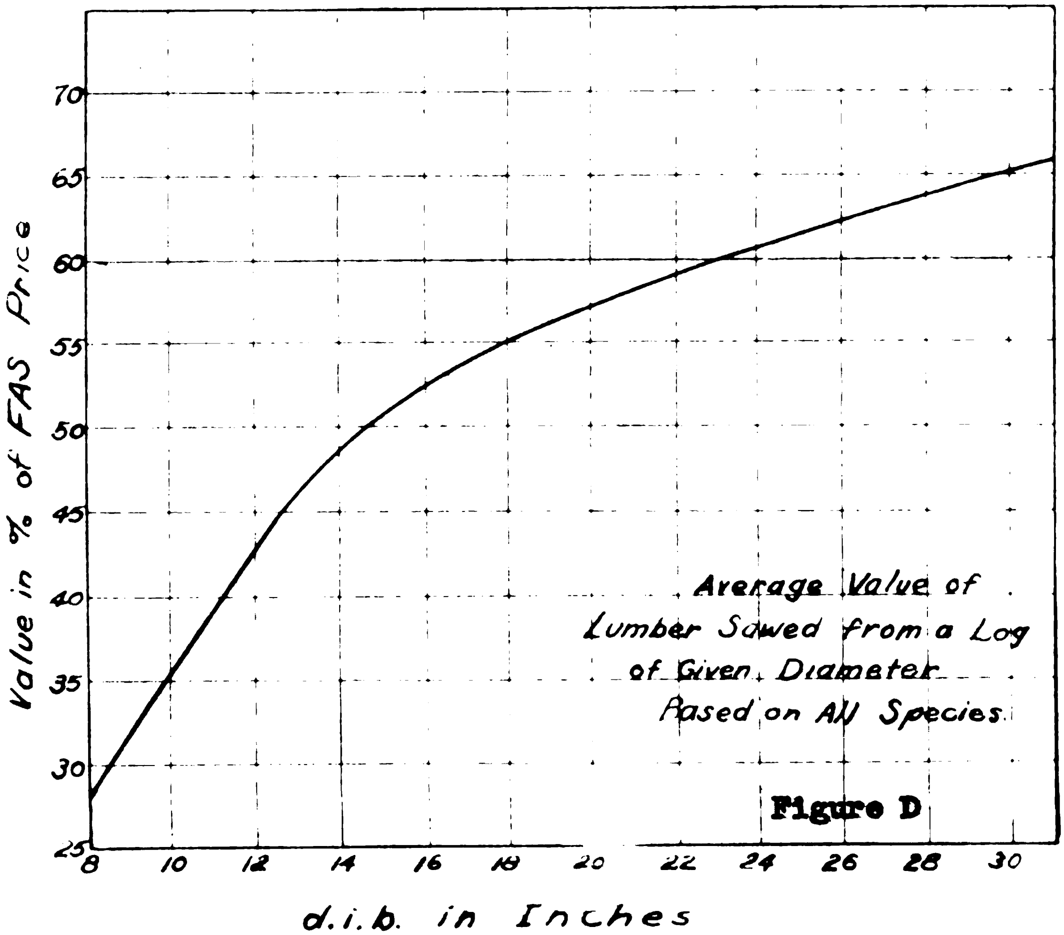

Figure D

at the small end, with a length of 12 feet would be about 20 to 22 inches dbh if measured in the standing tree. The lumber from a 20 inch log will have approximately twice the value per M of the lumber sawed from an 8 inch log of the same species.

Of 372 logs sawed during this study, the grade distribution was as follows:(from Appendix III)

FAS.......19.2%	#3C.......28.6
#1C&S.....25.8	Timbers....4.0
#2C.......22.4	

Giving the above data a value of FAS = 100%; #1C&S = 70%; #2C = 50%; #3C and Timbers = 30%; the following values are obtained:

FAS	19.2	x	1.00	=	19.20
#1C&S	25.8	x	.70	=	18.06
#2C	22.4	x	.50	=	11.20
#3C	28.6	x	.30	=	8.60
Timbers	4.0	x	.30	=	1.20
Totals	100.0				58.25 %

Less 10% due to degrade and shrinkage = 52.4 %

This total indicates that mill-run lumber has approximately 52.4 percent of the value of FAS lumber.

Using actual prices for January, 1949 for the various species, the following relationships were found:

TABLE II
ACTUAL VALUES OF MILL-RUN LUMBER

Species	Weighted AD Value/M of FAS Lumber	Average Value/M of Lumber	Value in % of FAS Lumber
Elm	$112	$66.40	59%
H. Maple	184	89.40	49
S. Maple	139	70.00	50
Beech	148	62.50	42
W. Ash	137	68.30	50
Basswood	164	93.60	57
Red Oak	158	75.00	48
Average	142	71.75	50.5

The actual percentage of 50.5 percent is less than the percentage found by using the average price relationships, because actual #3C values were about 25 percent of the FAS prices, whereas 30 percent was used in computing the average. Actual prices were for lumber shipped by car-load, f.o.b. mill. Low grades, such as #3C, can often be sold at slightly higher prices locally or by cutting it into hardwood dimension.

Table III shows the percentage of #1 Common and Better lumber by length, for all logs of all species.

TABLE III
PERCENTAGE OF #1 COMMON AND BETTER
LUMBER BY LENGTH FOR ALL SPECIES

Length of Log	Number of Logs	Average d.i.b. in Inches	% #1C&Btr. from Figure B for Average d.i.b.	Actual % #1C&Btr.	% Error
8'	29	12.0	27	6.6	20.4
10'	72	14.6	42	44.9	2.9
12'	138	15.4	44	47.1	3.1
14'	73	14.9	43	46.8	3.8
16'	52	15.0	43	43.8	.8

Quality of lumber sawed from logs does not vary greatly in logs 10 feet and over. Logs 8' long definitely have a lower output of the better grades. Figure B does not give a good estimate of the grade output of 8' logs but is very close in predicting the output for an average diameter for lengths over 8'.

<u>Effect of Thickness of Stock on Quality of Lumber</u>

The current market requirements determine the thicknesses into which lumber is cut. The mill owner will attempt to have best grades sawed into thicknesses that will net the greatest profit. Production of the better grades in desired thicknesses is an indication of the skill of the sawyer.

In the case of hard maple the best market for the better grades is in 5/4 stock for the furniture trade. Lower grades of maple are more salable as 4/4 stock or as planks or timbers to the local trade.

TABLE IV
DISTRIBUTION OF THICKNESSES BY GRADES FOR*
HARD MAPLE

Thick-ness	Distribution by Percentage				
	FAS	#1C&S	#2C	#3C	Totals
4/4	28	51	68	59	49.6
5/4	72	49	25	4	35.5
6/4	--	--	3	9	2.7
8/4	--	--	4	28	7.5
Timbers	--	--	-	-	4.7

*Based on 11,981 board feet
Average thickness: 1.318"

TABLE V
DISTRIBUTION OF THICKNESSES BY GRADES FOR ELM**

Thick-ness	Distribution by Percentage				
	FAS	#1C&S	#2C	#3C	Totals
4/4	8	26	42	78	38.7
5/4	16	15	10	5	11.1
6/4	10	20	18	9	13.8
8/4	57	32	23	7	28.3
10/4	9	7	7	1	5.6
Timbers	-	-	-	-	2.5

**Based on 20,590 board feet
Average thickness: 1.539"

Relationship Between Rate of Lumber Cut and Quality of Lumber

Of great importance to the mill operator is the time of manufacture of lumber from logs of various sizes. The board-foot rate of cut is affected by the following factors:

1. Skill of sawyer and block-setter.
2. Capacity and type of equipment.
3. Log size and amount of defect.
4. Species of log.
5. Quality of lumber cut.

Of the above factors, skill of sawyer and block-setter, and capacity and type of equipment are concerned with the efficiency of the mill and shall not be considered in this study. The last three factors are dependent on the quality and size of the logs.

The quality of lumber to be cut from the log varies inversely to the rate of cut. If a sawyer is to cut for quality, he will sacrifice time to get higher grades. He will do this by turning the log more often, and more thoroughly utilizing the taper and by reducing waste. This closely correlated with species. The sawyer will be more particular in sawing hard maple because of its high market value. Elm will be sawed at a more rapid rate because of the lower value of the lumber. Logs of low grade of any species will be rushed rapidly through the sawing process, since, regardless of the skill of the sawyer, only lumber of low grade can be produced.

Size of log is the most important factor in sawing rate. Rate of cut varies directly with length of log.

TABLE VI
RATE OF LUMBER CUT AS AFFECTED BY LENGTH OF LOG

Length	Average b.f. per Minute	Mill Tally in Logs of Each Length	Average d.i.b.
8'	9.8 b.f./min.	1460	12.0
10'	18.0 " "	7860	14.6
12'	18.4 " "	20250	15.4
14'	20.1 " "	11570	14.9
16'	21.2 " "	9620	15.0

The above figures are based on all logs. The differences are not great, but there is evidence of a faster rate of cut for longer logs.

Rate of cut varies with diameter. Figure E shows the rate of cut per minute of 372 logs of all species sawed in the mill. The form of the curve is parabolic and has the general formula:

$$Y = A + BX + CX^2$$

where Y is the rate of cut per minute and X is the diameter of the log in inches; A, B, and C are the unknown coefficients. The formula for the parabolic curve in Figure E is:

$$Y = 17.5 + 1.245X - .052X^2$$

Standard error of estimate of the means is 1.14 board feet per minute.

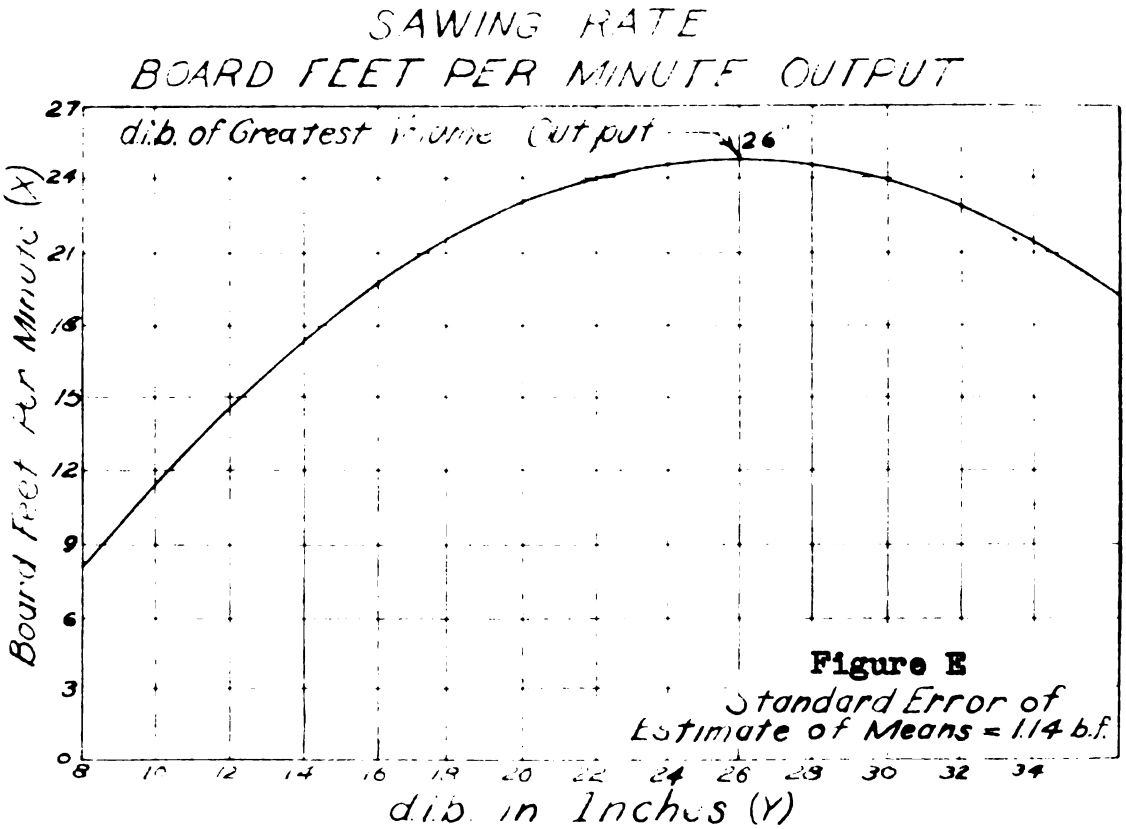

Figure E

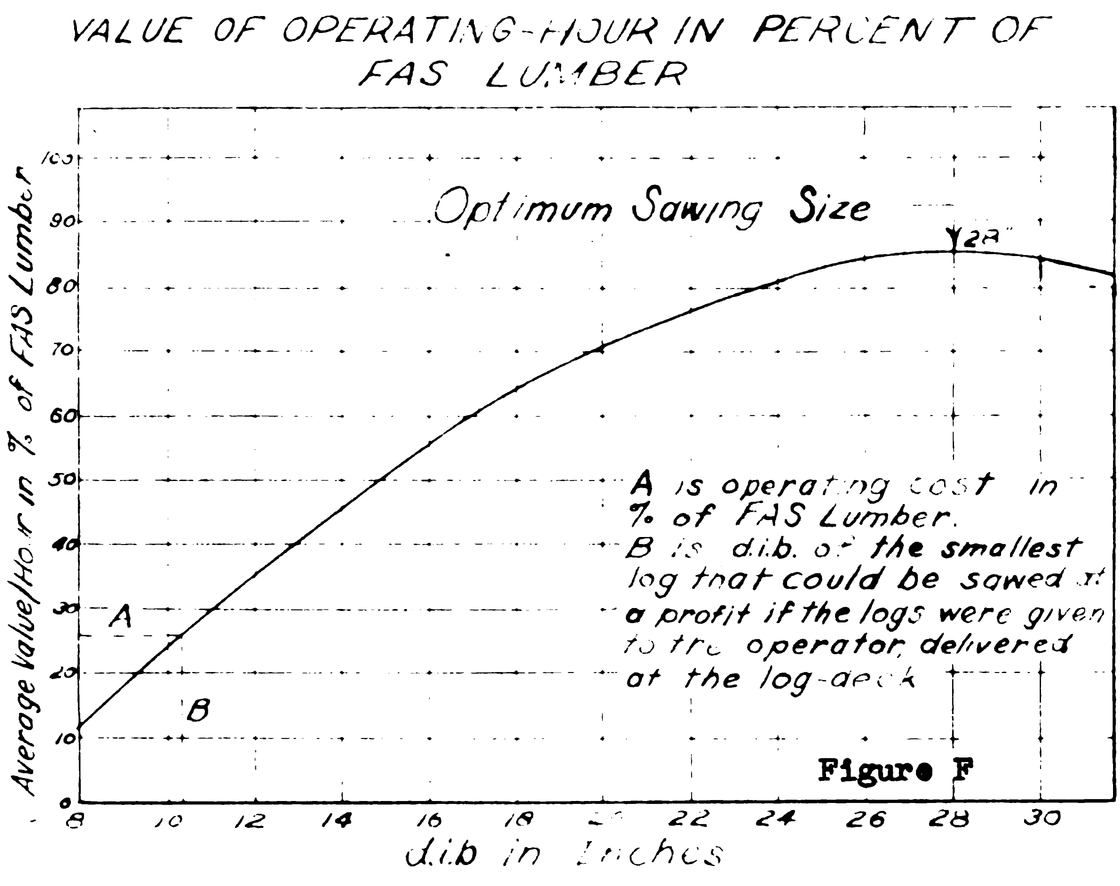

Figure F

The optimum cut of lumber, when expressed in board feet of lumber produced per one minute of operation, is for logs between 22" and 30" d.i.b. Logs larger than this have a slower rate of cut for the following reasons:

1. Presence of heartrot and other defects in larger logs.

2. Time required to turn and handle very large logs with inadequate equipment.

If we consider quality of the log and time of cut, the relationship takes the form shown in Figure F. The curve in this chart was calculated by taking the average value by diameter from Figure D and the volume from logs of each diameter that can be cut in one hour. (Delay time included) The actual percentage relationships of Figure F is shown in Table VII.

The optimum size of log, considering time of cut and value of lumber, is about 28" d.i.b. That is, the average 28" log is most valuable to the mill operator. This is the average for all species and may vary either way, although it is definite that logs over 30" are too large for most efficient operation.

Figure F may be used as follows. If the average diameter of a group of logs is 14", the average value of an hour's operation will be about 46.5 percent of the value of FAS lumber for the species concerned. If hard maple is valued at $180 per M for FAS, f.o.b. mill, AD, then the value of output for one hour will be about $84(for 14" logs). The rate of cut for one hour is 950 board feet. Dividing $84 by .95 M b.f. gives the value per M of lumber as about $88 for AD mill-run lumber.

TABLE VII
VALUE OF LUMBER CUT PER HOUR IN PERCENT OF FAS LUMBER FOR DIAMETER CLASS

d.i.b. Class	% of FAS Value Per M	Rate of Cut Per Hour Delays Included	% of FAS Value Per Hour	% FAS Value/Hour with Logging and Hauling Costs Excluded*
8	28.30	425 b.f.	12.00	6.50
10	35.50	625	22.20	14.10
12	43.60	800	34.80	24.40
14	49.00	950	46.50	34.20
16	52.80	1075	56.80	42.80
18	55.10	1175	64.80	49.50
20	57.20	1250	71.50	55.20
22	58.70	1300	76.30	59.40
24	60.40	1325	80.00	62.80
26	62.30	1350	84.10	66.50
28	63.50	1325	84.20	67.00

*An arbitrary figure of $25 per M Doyle scale is used as the logging and hauling costs. No definite amount can be placed on these costs because they vary with each operation. Also, logging and hauling costs vary with diameter. In Table VII, an average overrun of 35 percent was used making the hauling and logging costs equal to $18.50 per M for actual mill tally. This is equal to about 13 percent of the average FAS price of lumber at the present time.

THE MARGINAL LOG

The cost of operation of a mill includes labor, depreciation on equipment, insurance, taxes, selling and buying costs, supervisory and clerical help, interest on indebtedness and capital, miscellaneous mill expenses, and a normal profit. A decision as to the smallest log that can be sawed at a profit(the marginal log) can be reached by application of costs to the value of lumber sawed per hour.

Total costs for this band mill are estimated to be about 60 cents per minute or 36 dollars per hour of operation. This figure was arrived at in the following way for all logs cut during this study:*

Total value of lumber cut................	$3,696.99
Less amount paid for logs at log-deck.... (Includes stumpage, logging, and hauling)	1,842.92
Gross operating margin....................	$1,854.07

$$\frac{\text{Gross Operating Margin}}{\text{Time of Manufacture (including all delays)}} = \frac{\$1,854.07}{3,101.9 \text{ Minutes}} = \$0.598/\text{Minute},$$

or approximately 60 cents per minute or 36 dollars per hour. This figure includes profit.

The average weighted value of FAS lumber was $142 per M. Average rate of cut was 980 board feet per hour. Multiplying $142 by .98 M b.f., an average value of FAS lumber as $139 per hour of operation is obtained. With costs at $36 per hour, the relative cost of operating

*From Appendix III

one hour is $\frac{\$36}{\$139}$, or 26 percent of the value of FAS lumber. This means that the operating costs at the time of this study were about 26 percent of the selling price of FAS lumber. By reference to Figure F, we find that 26 percent exceeds the value of all logs under 11" d.i.b. Therefore, any log under 11" d.i.b. will not have an average value great enough to cover costs even if the logs were given to the operator free, delivered at the mill.

Logging and hauling costs vary with each operation and no definite figure can be set. A Doyle scale price of $25 per M is not excessive to use as an average figure for this area. With an average overrun of 35 percent for all logs, this would make logging and hauling costs about $18.50 per M, when applied to actual mill-tally. Dividing $18.50 by $142 (the average price of FAS lumber at this time) we find that logging and hauling costs are about 13 percent of the average value of FAS lumber.

Figure G shows the value per hour in percent of the FAS value of lumber for each average diameter after logging and hauling costs have been paid.

The break-even point is just below a 13" log. This means that a log must be at least 13" before the mill owner can pay any stumpage price whatsoever and still meet costs. Figure G is slightly in error for some species because of:

CHART FOR DETERMINATION OF THE MARGINAL LOG—ALL SPECIES

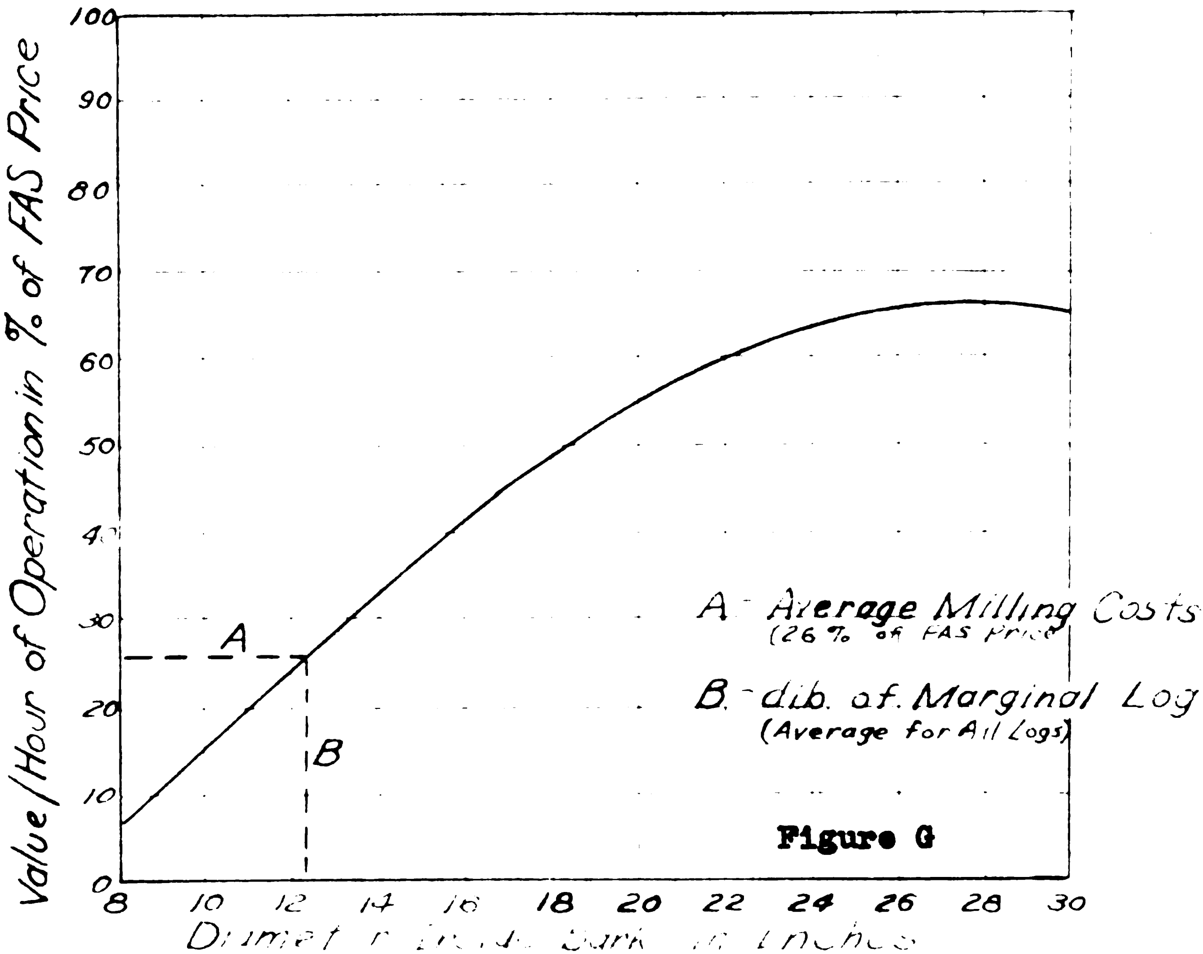

Figure G

1. Higher value of some species.

2. Variance in rate of cut between species.

3. Thicknesses into which various species are sawed.

However, Figure G is fairly accurate in prediction of the marginal log and may be used as illustrated in the following example:

Example

The curve in Figure G is based on a band mill sawing about 9800 board feet per nine hour day, or 1100 board feet per hour. The average log is between 14" and 16" d.i.b., and 12' in length. To find the marginal log for a given species, the following steps are necessary:

Assuming a price for FAS hard maple lumber as \$184 per M and milling costs as \$36 per hour, then,

$\frac{\$36}{\$184}$ = 19.5 percent (Costs are 19.5% of FAS price)

In Figure G, find 19.5 on the left-hand margin. Follow to the right, straight across to the curve. From the point of intersection with the curve read straight down to the bottom margin. The reading is the diameter inside bark at the small end of the marginal log for hard maple; it is very close to a 11" log.

For elm logs: $\frac{\$36}{\$112}$ = 32%, or the marginal log is about 14" d.i.b. To saw 10" elm logs and break even, the costs of operation would have to be 14 percent of the value of FAS lumber or approximately $16 per hour of operation.

Figures H and I are break-even charts for hard maple and elm respectively. Curves are based on actual prices and costs at the time of this study. Additional curves are included for a range of logging and hauling costs. The results check closely with those obtained by using the break-even chart for all species(Figure G).

The optimum logs for hard maple and elm are lower than the 28" d.i.b. predicted from Figure G. This is due to the slower rate of cut for large logs and the high amount of defect in large logs of both species.

The break-even point or the marginal log may be used interchangeably in expressing the diameter of the smallest log for which the mill operator can afford to pay a stumpage price, and from which he may expect to realize a normal profit.

THE MARGINAL LOG-HARD MAPLE

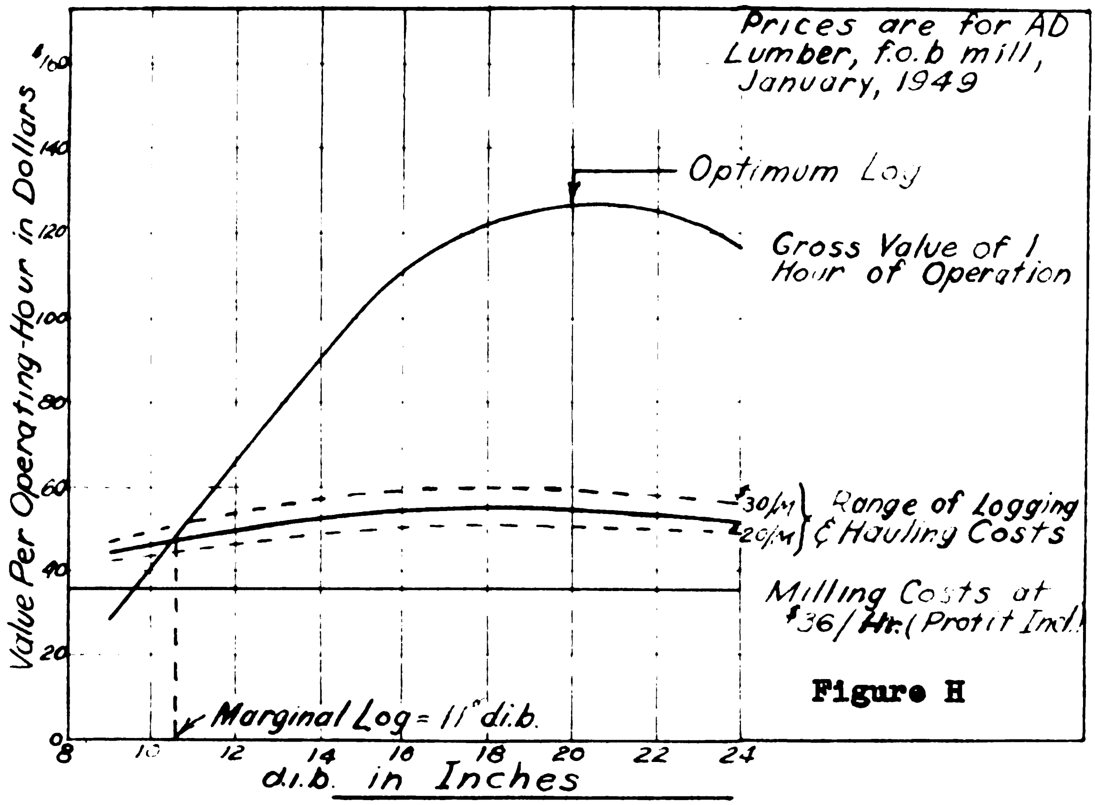

Figure H

THE MARGINAL LOG - ELM

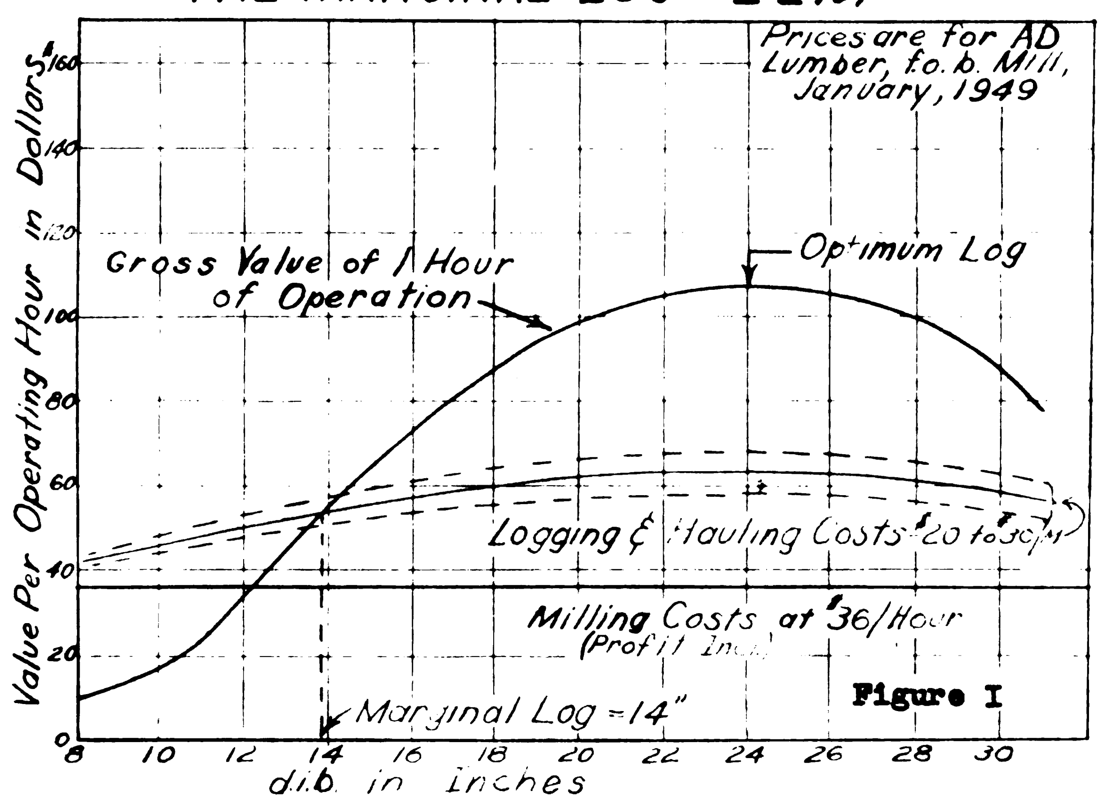

Figure I

LOG SCALING RULES

The Doyle rule is used almost exclusively in this section of Michigan as the basis for measurement in log purchases. There are two main reasons for its continued use, although the International ¼" rule is the official rule of Michigan:

1. The Doyle rule is a deeply rooted custom, and both buyer and seller are adverse to change. (The Doyle rule price seems higher to sellers of logs who do not understand the difference in rules.)

2. The Doyle rule is very close to a value rule.

The second statement needs further elaboration. The merits of the Doyle rule have long been a matter of contention between foresters and millmen. The rule was developed by formula and great errors in actual board-foot measurement are encountered, particularly in small logs.

However, when logs are purchased, the buyer is interested in quality as well as in quantity. If a rule that measures quantity, such as the International rule, is used with a single price, the amount paid for small logs(of low quality) will be more than what the logs are actually worth in terms of value of lumber that can be sawed from them. Likewise, large logs that have high quality of lumber will be underpriced.

Both the Doyle rule and the International ¼" rule have approximately the same board-foot scale for 12' logs of 28" d.i.b. Giving the 28" log a value of 100 percent and using the average values found in Figure D, relative values of logs of each diameter can be computed.[1] (Column B, Table VIII) For example, the average 10" log has 6.2 percent of the value of a 28" log. Column C in Table VIII shows the relative value of logs of each two-inch diameter class in terms of a 28", 12' log with a volume of 432 board feet by either scale. For a 10" log the relative value was computed by taking 6.2 percent of 432. (.062 x 432 = 27) The figures in Column C can be considered a value scale.

The correlation between the value scale in Column C and the Doyle rule in Column D is very close. The International ¼" rule in Column E overscales the average values up to about 24" d.i.b. Above 24" d.i.b., both rules show little error. This correlation is calculated for second-growth Michigan hardwoods and may or may not be applicable to logs from other areas, or to softwoods.

Figure J shows the percentage overrun found for various diameters for all species sawed at the mill. Overrun varies with species, thickness of lumber cut, width of saw-kerf, and with the efficiency of the mill operation.

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[1] Mill tally from Appendix I

TABLE VIII
COMPARISON OF RELATIVE VALUES OF 12 FOOT LOGS SCALED BY DOYLE AND INTERNATIONAL ¼" RULES

d.i.b. in Inches	Relative Curved Value Per M*	12' Mill Tally	A Average Value of 12' Log*	B Relative Value 28"Log 100%	C Value Scale 28"Log 432	D Doyle Scale	E International ¼" Scale
8	28.30	33	.93	3.1	13	12	25
10	34.60	54	1.87	6.2	27	27	45
12	43.60	79	3.44	11.3	49	48	70
14	49.00	109	5.34	17.5	76	75	100
16	52.80	145	7.65	25	108	108	130
18	55.10	186	10.24	34	147	147	170
20	57.20	233	13.30	44	190	192	210
22	58.70	285	16.70	55	237	243	260
24	60.40	342	20.60	68	293	300	310
26	62.30	407	25.27	84	363	363	370
28	63.50	476	30.20	100	432	432	430
30	65.30	550	35.90	119	513	507	495

*Average values in percent of FAS lumber

PERCENT OVERRUN FROM DOYLE & INTERNATIONAL LOG SCALES

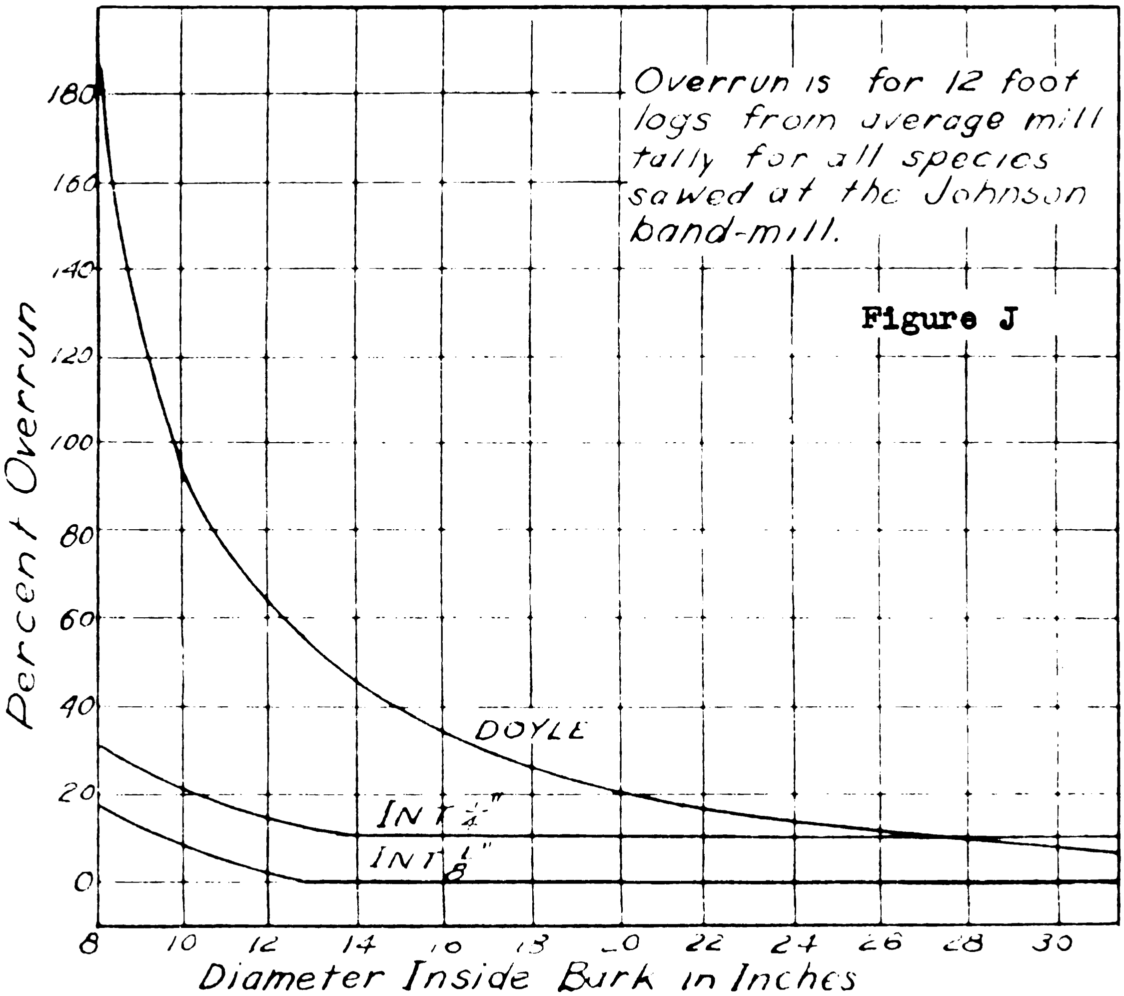

Figure J

An important feature of Figure J is the accuracy of the International 1/8" rule in regard to actual board-foot volume sawed by Johnson's mill. (International 1/8" was estimated by adding ten percent to the International 1/4" rule.) It can be used by band mill operators as a close estimate of the actual mill tally for logs over 12" d.i.b.

LOG GRADES

Prediction of Log Values

Use of log grades by buyer and seller is not a common practice in this area. In general, lack of acceptance of standard hardwood log grading rules is due to:

1. Lack of necessary information on which to base log grades.

2. Lack of a concerted effort by the industry to standardize log grades.

3. Failure to convince the buyers and sellers of logs that log grades are applicable for use in log sales.

4. Many of the log grading systems developed have been too complicated for use by the average small buyer.

At present, the log grading rules developed in an extensive study by the Forest Products Laboratory of Madison, Wisconsin[1] appear to have the best possibility of being accepted as a standard. The basic principles of these rules follow closely the rules used in grading hardwood lumber.

The log grades used in this study are a modification of the rules used by the Northern Hemlock and Hardwood Manufacturers Association and follow closely the rules developed by the Forest Products Laboratory

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[1] Report Number D1737, "Hardwood Log Grades for Standard Lumber-Proposals and Results", March, 1949

study published in March, 1949, after this study had been started. Description of log grades used herein are found in Appendix II.

The test of a set of log grades is the ability to separate the logs into definite value groups, with a minimum of overlapping of values of each grade. Two factors, the quality of the log and the rate of cut, influence the value of a log to the mill operator. In comparing the value of each log grade, relative values were used. Number 1 logs were given the value of 100 percent for both the rate of cut and the quality of the lumber cut from the log. Number 2 and number 3 logs were compared to number 1 logs with values as shown in Table IX.

Table IX, Column E, represents the absolute relationship of value of each log grade and can be used as a key of the price to be paid for the logs delivered at the log-deck.(See Table XIII) Column G, Table IX, shows that when both time of manufacture and quality of logs are considered, there is no overlapping of log grades where groups of more than 5 logs were graded.

Use of Log Grades in Scaling Logs

Quality of the log increases with diameter within each log grade. Figure K shows the curved value per M in percent of FAS lumber for each diameter for each log grade. Values were computed from grade output for each log grade from Appendix III.

That the Doyle rule follows very closely the

TABLE IX
RELATIVE VALUES OF LUMBER SAWED FROM EACH LOG GRADE

Log Grade	Value in % of FAS Price of Lumber Cut from Log Grade	Relative Value #1 Logs 100%	Rate of Cut-b.f. Per Min.	Relative Rate of Cut--#1 Logs = 100%	Relative Value to Mill Operator (Col.B x Col.D) / 100	Range of Relative Values of Various Species
	Column A	Column B	Column C	Column D	Column E	Column F
#1	61.60	100	19.2	100	100	100
#2	49.80	80.7	17.9	93.3	75.2	60 to 80
#3	39.50	64.1	13.1	67.2	43.0	30 to 47

Column A was calculated by using the grade output for each log grade(from Appendix III) and giving each grade the following values: FAS=100%; #1C&S=70%; #2C=50%; #3C=30%.

Column B compares the percentages in Column A, giving #1 logs a value of 100%.

Column C is calculated by dividing the total board-foot mill tally of each grade by the time required to cut the logs in that grade.(Appendix III)

Column D compares the rate of cut in Column C, giving #1 logs a value of 100%.

Column E is a composite relative value combining both the rate of cut and the value of the lumber sawed from the logs of that grade.

Column F was calculated as Column E, except that the rate of cut and the actual values were used for the various species where there were more than five logs represented in each log grade.

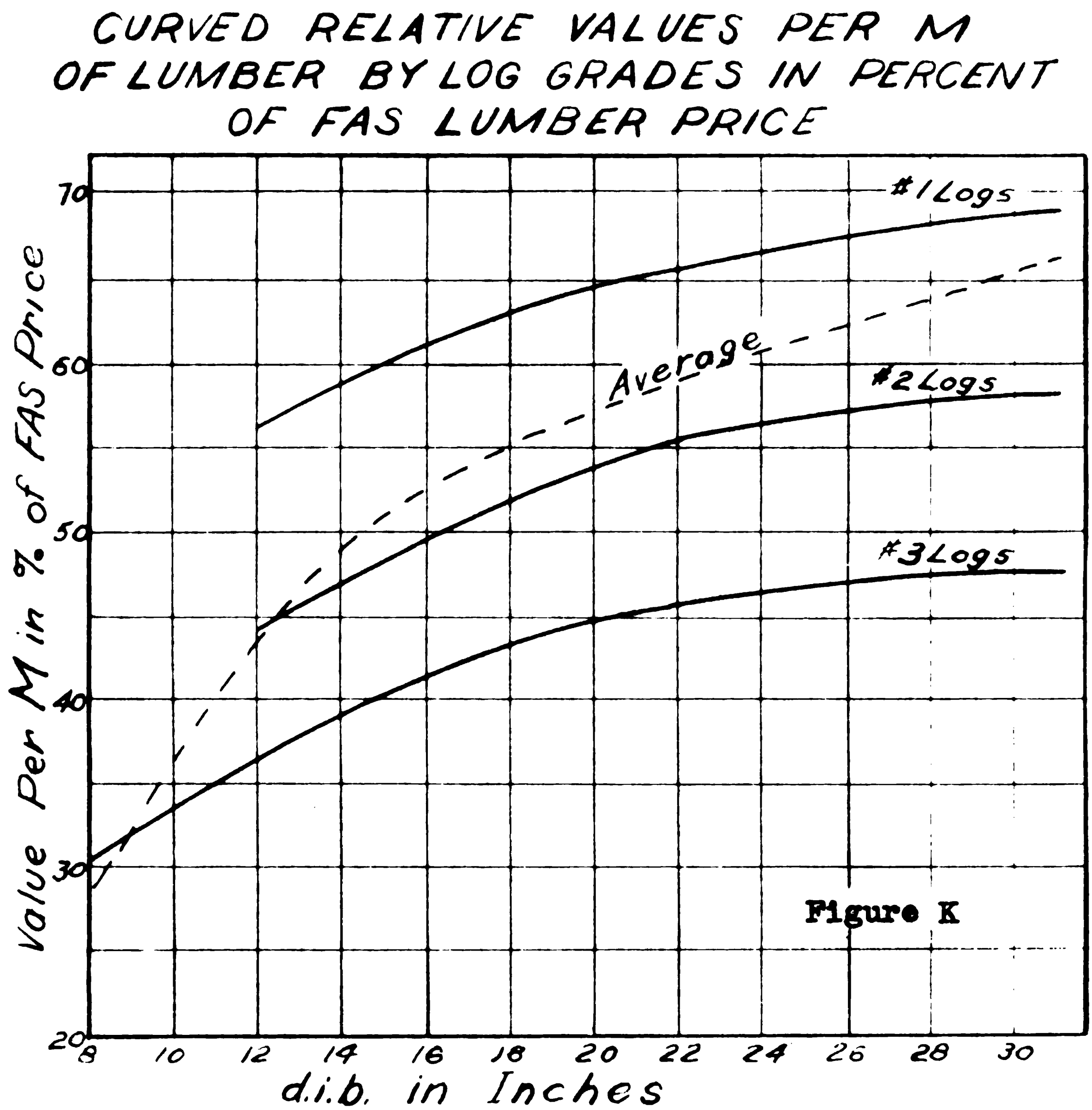

Figure K

increase in value of logs with an increase in diameter, was shown in Table VIII. Tables X, XI, and XII show the development of a value scale for each log grade using the curved values per M of lumber from Figure K. The same method used in Table VIII was employed. Values of each diameter class of 12' logs were calculated in percent of the value of a 28" log. A value scale was then computed by multiplying the board-foot scale of a 28" log(432 b.f.) by the percentage value of each diameter class. The value

TABLE X
RELATIVE VALUES OF #1 LOGS BY DIAMETER CLASS

d.i.b. in Inches	Curved Value Per M in % of FAS Price	12'* Mill Tally	Value of 12' Log	% of 28" Log Value	Value Scale 28"Log=432	Doyle Rule	International ¼" Rule	Scribner Dec. C Rule
12	56.00	79	4.42	14	59	48	70	60
14	59.00	109	6.44	20	86	75	100	90
16	61.60	145	8.94	27	119	108	130	120
18	63.00	186	11.70	36	156	147	170	160
20	64.40	233	15.00	46	200	192	210	210
22	65.50	285	18.65	58	249	243	260	250
24	66.50	342	22.70	70	302	300	310	300
26	67.30	407	27.35	85	365	363	370	370
28	68.10	476	32.40	100	432	432	430	440
30	68.70	550	37.80	117	505	507	495	490

*Mill tally from Appendix I

TABLE XI
RELATIVE VALUES OF #2 LOGS BY DIAMETER CLASS

d.i.b. in Inches	Curved Value Per M in % of FAS Price	12'* Mill Tally	Value of 12' Log	% of 28" Log Value	Value Scale 28"Log=432	Doyle Rule	International ¼" Rule	Scribner Dec. C Rule
12	44.00	79	3.47	13	55	48	70	60
14	47.00	109	5.12	19	81	75	100	90
16	49.60	145	7.20	27	116	108	130	120
18	51.70	186	9.60	36	155	147	170	160
20	53.80	233	12.53	47	203	192	210	210
22	55.30	285	15.75	59	254	243	260	250
24	56.40	342	19.27	72	311	300	310	300
26	57.10	407	23.20	86	371	363	370	370
28	57.60	476	26.80	100	432	432	430	440
30	58.00	550	31.80	119	513	507	495	490

*Mill tally from Appendix I

TABLE XII
RELATIVE VALUES OF #3 LOGS BY DIAMETER CLASS

d.i.b. in Inches	Curved Value Per M in % of FAS Price	12'* Mill Tally	Value of 12' Log	% of 28" Log Value	Value Scale 28"Log=432	Doyle Rule	International ¼" Rule	Scribner Dec. C Rule
8	30.20	33	.99	4	19	12	25	20
10	33.50	53	1.77	8	34	27	45	30
12	36.50	79	2.88	13	56	48	70	60
14	39.10	109	4.26	19	83	75	100	90
16	41.40	145	6.00	27	116	108	130	120
18	43.30	186	8.05	36	155	147	170	160
20	44.60	233	10.37	46	199	192	210	210
22	45.60	285	13.00	58	250	243	260	250
24	46.30	342	15.80	70	303	300	310	300
26	46.80	407	19.00	84	365	363	370	370
28	47.30	476	22.50	100	432	432	430	440
30	47.50	550	26.10	116	498	507	495	490

*Mill tally from Appendix I

scale developed in this way gives each diameter of log a scale that is relative to the value of a 28" log. (The common log rules are approximately equal at this diameter.)

By comparing the Doyle, International ¼", and the Scribner Decimal C rules in Tables X, XI, and XII, it is found that the Scribner rule more nearly indicates the value of the log than the other two rules. The International ¼" rule overscales the value and the Doyle rule underscales the value, when log grades are used. However, it is believed that the errors in the use of the Doyle rule when buying by log grades is not great when the mill operator considers that small logs require more than the average sawing time per thousand board feet of lumber.

Since the Johnson mill buys on the Doyle rule, the approximate prices this mill should pay for logs of each grade can be estimated. An average price paid for logs at the mill was used in this study. Lumber from #2 logs was actually 49.8 percent of the value of FAS lumber for all species(Table IX). The lumber from the average mill-run log had a value of 52.4 percent of FAS lumber (See page 13). Lumber from #2 logs has a value very close to the mill-run value, so the average price paid at the mill for #2 logs should be approximately equal to the average price paid for all logs.

Using the relative values from Table IX, Column E, the price to pay for logs of grades 1 and 3 can be estimated from the following proportion:

$$\frac{\text{Relative Value \#2 Logs}}{\text{Average Doyle Price}} = \frac{\text{Relative Value \#3(or \#1) Logs}}{\text{(X) Doyle price for \#3(or \#1) Logs}}$$

Example(using above proportion)

Average price paid for hard maple = $60/M Doyle.

then,

$$\frac{75.2}{60} = \frac{100}{X}$$

$$75.2\ X = 6000$$

X = $80/M Doyle, the price to pay for #1 hard maple logs delivered at the log-deck.

Table XIII shows the estimated Doyle price that should be paid for logs of each log grade for various average delivered log prices.

TABLE XIII
ESTIMATE OF DELIVERED DOYLE PRICE
FOR EACH LOG GRADE IF AVERAGE PRICE IS KNOWN

Average Log Price*	#1 Log Price	#2 Log Price	#3 Log Price
$65/M	$86/M	$65/M	$37/M
60	80	60	34
55	73	55	31
50	67	50	29
45	60	45	26
40	53	40	23
35	47	35	20

*Average prices used in this study can be found in Appendix III.

CONCLUSIONS

Small Logs Are Undesirable

Logs under 13" d.i.b. cannot be sawed into lumber at a profit in a mill of the size covered by this study, even if no stumpage is paid for them. The mill operator cannot expect to cut all large logs, because some small logs must be taken from the tops. However, he should control his purchases to the extent of buying the least number of small logs possible. To offset the losses from cutting small logs it is necessary for mill operators to make a greater profit on the larger logs. Greater profit to the mill owner and increased stumpage prices will result if the small trees are not cut.

Log Grades Can Be Used to Predict Log Values

Log grades, based on the amount of clear surface and the location of defects in the log, provide an acceptable method of predicting log values. When both the time consumed in manufacture and the quality of each log grade is considered, there is a minimum of overlapping of values between log grades. There was no overlapping of values in this study when at least five logs were present in each grade.

The major difference between the log grading rules used in this study and those proposed by the U.S. Forest Products Laboratory* is in the amount of cull

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*Report Number D1737, "Hardwood Log Grades for Standard Lumber-Proposals and Results", March, 1949 allowed in #1 and #2 log grades. From the results of this study, it is believed that cull should be allowed in large diameter logs where the amount of clear surface meets the requirements for the grade concerned.

The prime requisites of a system of log grading rules are the simplicity of use and the accuracy of estimation. The rules developed by the U.S. Forest Products Laboratory meet these qualifications.

The Doyle Rule is a Close Estimate of Value

The Doyle rule is very close to a value rule and may be used as a measure of average quality of the log as the log diameters increase. The overrun gained by use of the Doyle rule decreases, as quality increases. The Doyle rule may be used with or without log grades with a single price. There is nothing in the use of the Doyle rule that should encourage the practice of cutting small logs. The fact that the Doyle rule gives such low values for small logs should tend to discourage cutting of trees of small diameter. The International ¼" rule overscales the value of small logs. With a single price for a group of logs, it would overvalue the small logs. On the other hand, if the price were lowered because of these small logs, the large logs would be undervalued.

Log Quality Varies with Length and Diameter

The length into which logs are cut makes little difference in the quality of lumber, if the logs are 10' or over. Logs under 10' tend to have a greater percentage of lower grades. Quality of lumber increases directly with diameter of the log. A log smaller than 12" d.i.b. has very little clear lumber. The value of a log increases rapidly up to 18" d.i.b., and then increases at a slower rate above this diameter. Logs above 25" d.i.b. tend to have a larger amount of defect and more cull. Quality of each diameter-size of log varies with species. Twelve inch maple logs averaged 40 percent of the volume in #1 Common and better lumber. Twelve inch elm logs averaged 24 percent of the volume in #1 Common and better lumber.

Rate of Cut Increases Directly With Diameter

The rate of cut increases with diameter up to about 28" d.i.b. Above this diameter, the handling and turning time causes the rate of cut to decrease. Logs between 22" and 28" d.i.b. are the optimum size for the Johnson Mill. The rate of cut for larger logs is affected by the log-turning equipment.

Prices of Each Lumber Grade Have a Definite Relationship

Lumber prices are relative. That is, the value of each grade remains approximately proportional to the value of the FAS market price. The value ratio is also approximately equal to the minimum clear lumber requirements for each grade. Number 1 Common lumber* requires 67 percent in clear cuttings, while the value of Number 1

*National Hardwood Lumber Association Grading Rules

Common averages close to 70 percent of the value of FAS lumber. Number 2 Common lumber requires 50 percent of the area in clear cuttings and the average value of Number 2 Common lumber is about 50 percent of the value of FAS lumber. Number 3A and 3B Common require 33 1/3 and 25 percent of the area of the board in clear cuttings; the average value of Number 3 Common lumber is approximately 30 percent of the FAS value.

Prices for Each Log Grade Can be Estimated if the Average Price is Known

Mill-run lumber will have a value approximately 50 percent of the value of FAS lumber. Number 2 logs will produce lumber approximately equal in value to mill-run lumber. Therefore, if the value of mill-run lumber is known, prices that can be paid for logs of grades 1 and 3 can be estimated.

APPENDIX I

DERIVATION OF A MILL TALLY FORMULA

Mill tally is the actual board-foot volume that is cut from a log at the sawmill. In determining a curve for mill tally, three variables are involved: length <u>(L)</u>, diameter inside the bark at the small end of the log <u>(D)</u>, and the actual board-foot volume sawed from the log <u>(V)</u>. Length and diameter are measured values and become the independent variables, while volume becomes the dependent variable(dependent on <u>L</u> and <u>D</u>).

If a log is considered as a cylinder the board-foot volume would be:

$$V = \frac{\pi}{4(12)} D^2L, \text{ or } V = .06545\ D^2L \qquad (1)$$

where <u>D</u> is in inches and <u>L</u> is in feet, and no allowance is made for saw kerf or waste.

However, in a log, <u>V</u> does not increase as to the square of <u>D</u> or directly as to <u>L</u>. Usable taper will cause <u>V</u> to increase at an increasing rate. Therefore, <u>V</u> will increase at some power of <u>L</u>. The proportion lost in slabs, edgings, and kerf will decrease as diameter is increased. This will cause <u>D</u> to have an exponent greater than two. The constant(.06545) will be reduced because a certain proportion of every log is lost in saw kerf, edgings, and slabs. The reduced constant shall be designated <u>K</u>. We now have the correct formula for <u>V</u> as:

$$V = KD^bL^c \qquad (2)$$

where <u>b</u> and <u>c</u> are the unknown exponents and <u>K</u> is the

unknown constant.

Changing the above formula (2) to logarithms we have:

$$\log V = b(\log D) + c(\log L) + \log K \qquad (3)$$

The exponents, b and c, can now be determined by the method of least squares by use of the following normal equations:

$$\left[\Sigma(X)^2 - \frac{(\Sigma X)^2}{N}\right]b + \left[\Sigma(XZ) - \frac{(\Sigma X)(\Sigma Z)}{N}\right]c = \left[\Sigma(XY) - \frac{(\Sigma X)(\Sigma Y)}{N}\right] \qquad (4)$$

$$\left[\Sigma(XZ) - \frac{(\Sigma X)(\Sigma Z)}{N}\right]b + \left[\Sigma(Z)^2 - \frac{(\Sigma Z)^2}{N}\right]c = \left[\Sigma(ZY) - \frac{(\Sigma Z)(\Sigma Y)}{N}\right] \qquad (5)$$

N = number of samples
b and c = unknown exponents of D and L
X, Y, and Z = the logarithms of L, V, and D
Σ = the sum of

then,

$$\log K = \overline{\log V} - b\,\overline{\log D} - c\,\overline{\log L}\,^* \qquad (6)$$

To test the linearity of the logarithmic volume equation, the logarithms of V and D, and of V and L, were plotted. Results of the plotting of averages for hard maple logs are shown in Figures a and b.

From Figures a and b, it is evident that the relationship of the logarithms of board-foot volume to the logarithms of diameter inside bark, and the relationship of the logarithms of board-foot volume to logarithms of length, is linear. Calculation of a formula(and curve) by the least squares method eliminates all errors due to free-hand curve fitting. Curves derived by this method

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* Bar over term indicates the average for all samples.

GRAPHIC TEST FOR LINEARITY

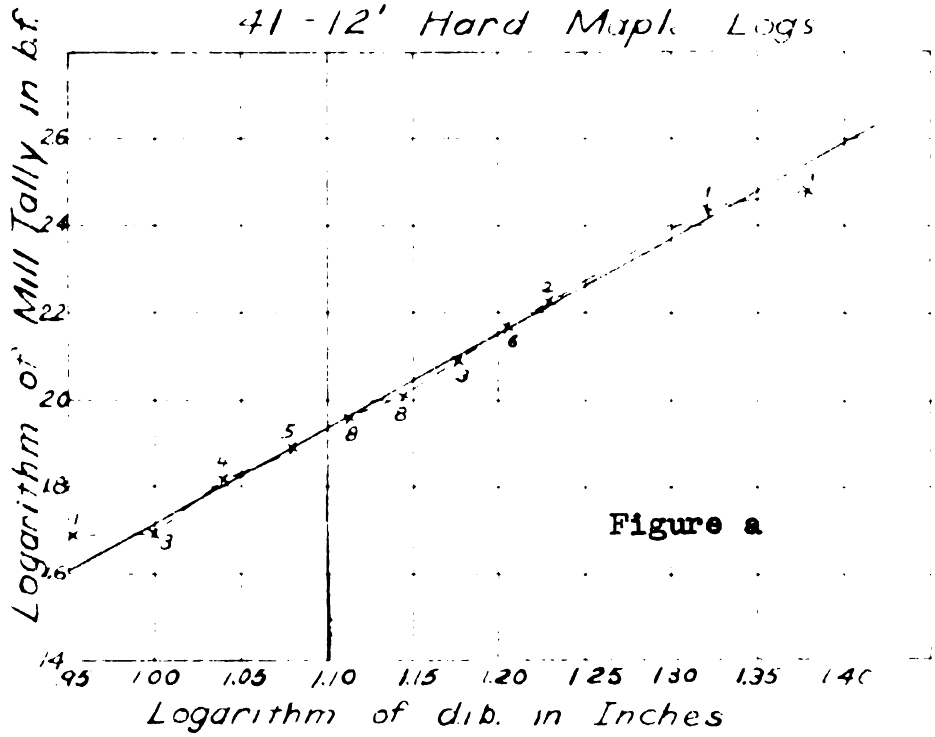

Figure a

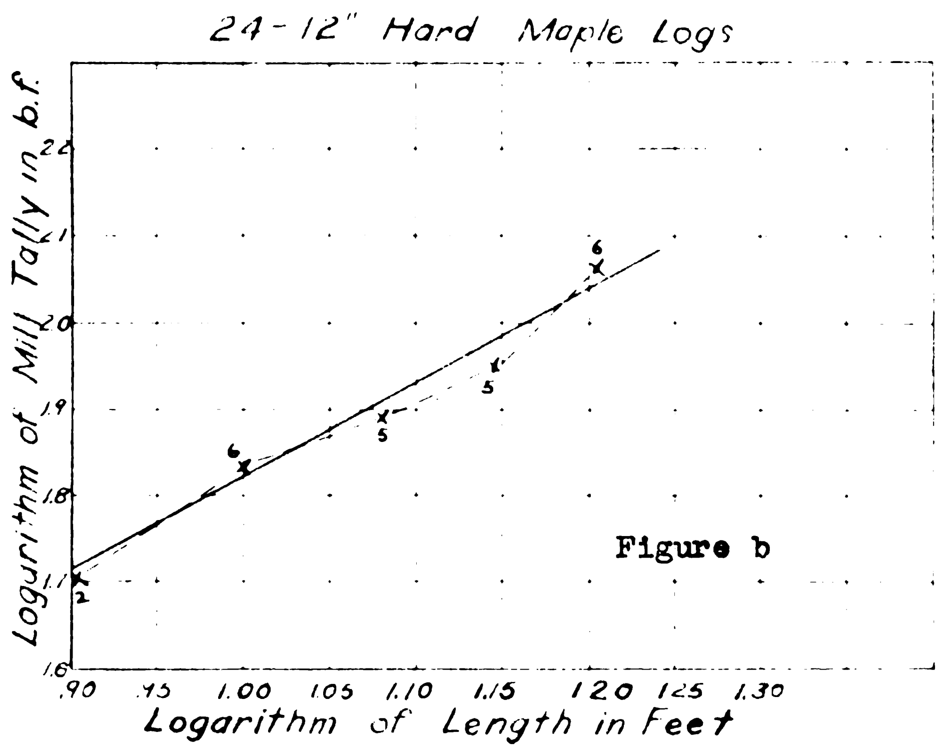

Figure b

are objective and comparisons between species or groups of logs of the same species are possible.

Computation of Standard Error of Estimate

The standard error of estimate for a group of data indicates the accuracy of the formula. One standard error of estimate means that about 68 percent of the cases will fall within one standard error of estimate of the predicted values, 95 percent will fall within two standard errors of estimate, and 99.73 percent of all cases will fall within three standard errors of estimate of the values predicted by the curve.

The simplest method of calculating the standard error of estimate is to take the square root of:

$$\frac{\text{the sum of (actual values - predicted values)}^2}{\text{Number of samples}}$$

or in the case of formula (2),

$$S_e = \sqrt{\frac{(V - V')^2}{N}} \qquad (7)$$

where V' is the value obtained from the formula or curve for any given value of D and L.

The standard error of estimate increases in direct proportion to diameter. For example, in maple and elm the standard error of estimate averaged approximately 12 to 14 percent of the actual mill tally for all diameters.

Mill Tally for Hard Maple

The formula for mill tally of 104 sound hard maple logs was found to be:

$$V = .03396\ D^{2.0236}\ L^{1.1041} \qquad (8)$$

In logs 12" d.i.b. and under, the standard error of estimate was 9.8 board feet based on 46 logs, and 15.9 board feet for 62 logs over 12" d.i.b. The standard error of estimate for all logs(104) was 13.8 board feet. In other words, about 68 percent of the logs of a given diameter and length will have a board-foot volume within 13.8 board feet of the value given by the formula.

This standard error of estimate is not great considering that all diameter measurements were made to the nearest inch. The increase in board-foot volume due to a one inch increase in diameter is about 15 board feet for a 12"-12' log and about 25 board feet for a 21"-12' log.

<u>Mill Tally for Elm</u>

The mill tally formula for elm is quite different from hard maple. It was necessary to divide the curve into two parts: logs 13" and smaller, and logs larger than 13". The basis for this division is that elm logs larger than 13" were cut in thicknesses averaging better than 1.5", while logs smaller than 14" were cut mostly into 1" boards; that is, the two divisions were of different populations and were not comparable.

The formula for elm logs 13" d.i.b. and under was:

$$V = .00846\ D^{2.6788}\ L^{.9777} \qquad (9)$$

The standard error of estimate for the above formula, based on 40 logs, was 9.5 board feet. From this, the following conclusions can be drawn:

1. Loss due to kerf, slabs, and edgings is greater in elm than in maple, as evidenced by the low value of K.

2. The exponent of D is larger, indicating a more rapid rate of increase in volume with an increase in diameter.

3. Low utilization of taper and lack of usable taper is indicated because the exponent of L is less than 1. Smaller diameter elm logs may have slight crook making impossible higher output from longer logs.

The formula for elm logs over 13" d.i.b. was:

$$V = .02846\ D^{2.0817}\ L^{1.1232} \qquad (10)$$

The standard error of estimate for the above formula, based on 57 logs, was 23.4 board feet. From the formulas for elm and hard maple the following may be noted:

1. Hard maple has a higher constant (K). This indicates greater utilization of the log and more careful manufacture.

2. The exponent of D is larger in elm. This is attributable to greater average thicknesses and wider boards sawed from elm logs.

3. The exponent of L is larger in elm, indicating more taper in larger elm logs. Most butt logs of elm have a buttress base in which usable lumber is cut. This is not prevalent in maple.

4. Elm has a higher standard error of estimate

(maple-13.8 b.f., elm-18.8 b.f.). This is due to a larger average diameter for the elm logs sawed. The standard error of estimate for maple was 12.9 percent of mill tally while the standard error of estimate for elm was 12.0 percent of the mill tally. That is, the standard error of estimate increases with an increase in diameter.

A general formula for logs cut at this mill, based on 318 sound logs, is as follows:

$$V = .0261\ D^{2.1298}\ L^{1.0939} \qquad (11)$$

TABLE 1
CURVED MILL TALLY TABLE FOR ALL LOGS

d.i.b. Class	Length of Log in Feet				
	8'	10'	12'	14'	16'
8	22	27	33	39	45
10	34	43	53	63	73
12	51	64	79	93	108
14	70	89	109	129	150
16	93	118	145	172	199
18	120	153	186	220	256
20	150	191	233	277	321
22	184	235	285	340	397
24	220	283	342	408	472
26	262	338	407	482	560
28	307	394	476	565	656

APPENDIX II

TABLE 2
BRIEF OUTLINE OF HARDWOOD LOG GRADES USED IN THIS STUDY

Grade Factors	#1 Logs	#2 Logs	#3 Logs
Diameter(minimum)	12"	12"	8"
Length(minimum)	10'	10'	8'
Clear Cuttings(on best 3 faces)			
Length(minimum)	5'	3'	no restrictions
Number per face(maximum)	2	3	" "
Yield in clear face(minimum)	5/6 or 83%	2/3 or 67%	" "
Sweep Allowable	1" in 4'	1" in 3'	Up to 50% of gross scale allowed for any cull deduction
Cull deductions	None except where cull is slight and included in first foot of the end of the log.	Cull allowed in inner ¼ of diameter of log.	
Defects(shake, dote, wormholes, unsound heart, birdpecks, double-heart, and stains)	Not allowed except as above.	Allowed as above.	

Faces are determined visually by squaring the log with each of 4 faces considered separately. Clear cuttings are areas on each face that are free of visual defects such as knots. Grade of log is determined by lowest grade of 3 best faces.

APPENDIX III
SUMMARY OF BASIC DATA

PERCENT DISTRIBUTION OF THE NUMBER OF LOGS AND MILL SCALE VOLUME BY SPECIES

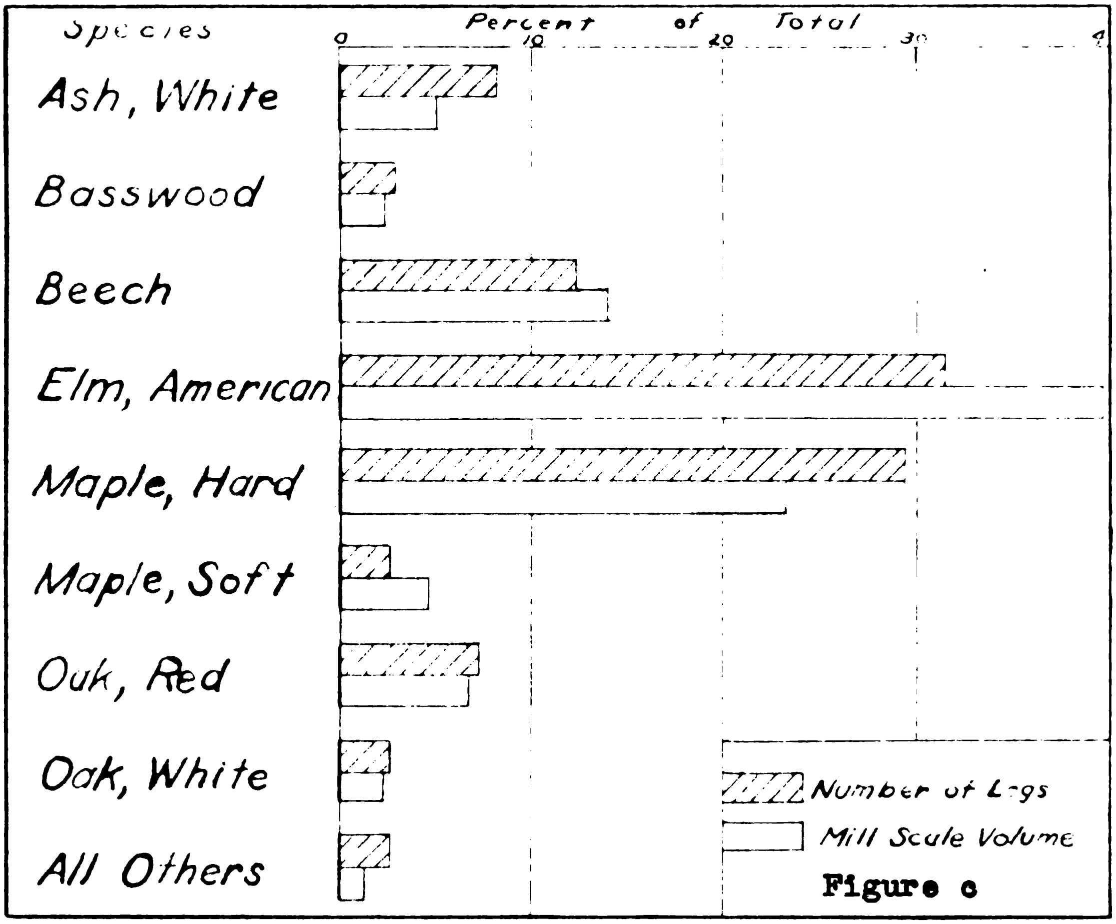

Figure c

PERCENT DISTRIBUTION OF DIAMETERS BY ONE-INCH CLASSES—ALL LOGS

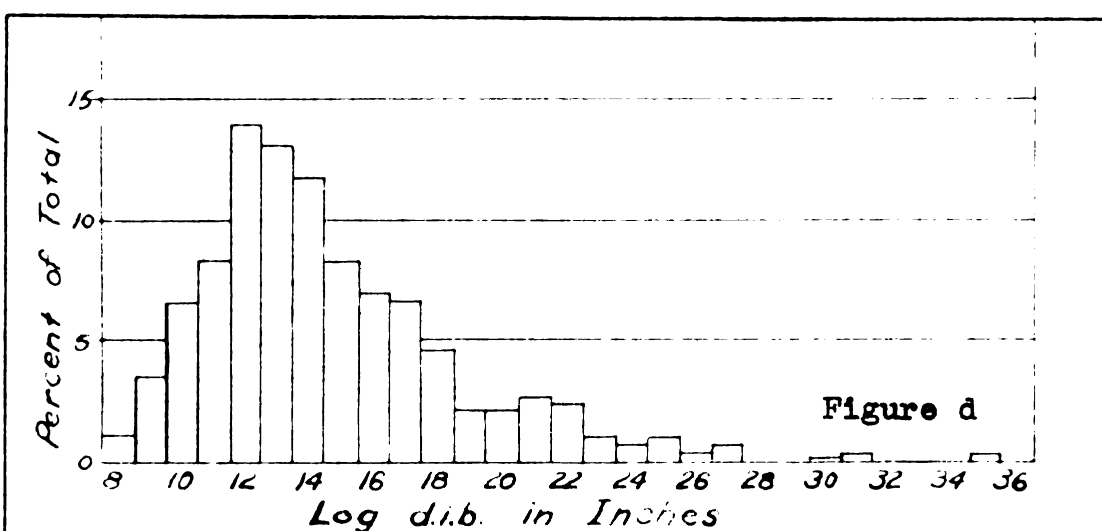

Figure d

TABLE 3
DISTRIBUTION OF LENGTHS BY SPECIES--ALL LOGS

Species	No. of Logs in Each Length Class						Totals
	8'	10'	12'	14'	16'	Odd Lgths.	
White Ash	2	11	8	5	3	1	30
Basswood	0	3	5	1	2	0	11
Beech	1	7	20	12	5	1	46
Black Cherry	0	0	1	0	0	0	1
Cottonwood	0	0	0	1	0	0	1
Elm	11	18	43	22	20	4	118
Hickory	3	1	2	0	1	1	8
Hard Maple	4	22	44	25	15	0	110
Soft Maple	0	3	5	1	1	0	10
Red Oak	5	6	7	4	5	0	27
White Oak	3	1	3	2	0	1	10
Totals	29	72	138	73	52	8	372
Percent	7.8	19.4	37.1	19.6	14.0	2.1	100.0

TABLE 4
MISCELLANEOUS DATA ON MILL OPERATING TIME

Total Operating Time During Study........3,777.0 Min.

Total Saw-Changing Time..210.2 Min.
All Other Delays.........171.3 Min.

Total Delays..............................381.5 Min.

Net Operating Time......................3,395.5 Min.

Average Time to Change Saw..................13.1 Min.

Percent Delay Time..........................10.1 %

Total Volume Sawed--Doyle Scale.............45 M

Estimated Total Mill Tally..................61 M

Approximate Rate of Cut Per Nine Hour Day...9.8 M

TABLE 5
CURRENT PRICES USED IN THIS STUDY*

Species	Average Delivered Log Prices Doyle Scale	Weighted Lumber Prices Per M Air-Dried, f.o.b. Mill, by Grade FAS	#1C&S	#2C	#3C
White Ash	$50/M	$137.00	$98.00	$66.00	$32.50
Basswood	50/M	164.00	118.50	75.00	35.00
Beech	45/M	148.00	104.50	69.50	33.00
Elm	45/M	112.00	89.50	65.00	35.00
Hard Maple	60/M	184.00	122.50	74.00	40.00
Soft Maple	45/M	139.00	102.00	69.00	33.00
Red Oak	45/M	158.00	118.00	68.00	35.00
White Oak	45/M	157.00	118.00	68.00	35.00
Hickory	45/M	---	70.00	40.00	30.00
Cotton-wood	45/M	---	80.00	50.00	30.00
Cherry	45/M	---	125.00	78.00	35.00

*Source of prices is "Hardwood Market Report", published weekly at Memphis, Tennessee. Prices are for AD, f.o.b. mill, Wausau, Wisconsin or from the Memphis, Tennessee area if the species is not listed on the Northern market. Prices for #3 Common are from a local wholesaler in most cases. Prices are weighted as to the thicknesses sawed in the Johnson mill. All lumber prices are for car-load lots. Log prices are approximately the average delivered price paid for each species at the mill.

TABLE 6
ESTIMATION OF VALUE PER OPERATING MINUTE FOR EACH SPECIES*

Species	Total Board Feet	Sawing Time Including Delays	Gross Value	Estimated Log Costs	Gross Operating Margin	Value of Oper. Min.
White Ash	2744	184.9 Min.	$ 187.38	$ 90.75	$ 96.63	$0.521
Basswood	1304	83.1	122.18	46.50	75.68	0.911
Beech	7262	416.5	454.67	249.20	205.47	0.494
Elm	20590	1158.1	1357.29	724.68	632.61	0.546
Hard Maple	11981	756.6	1070.10	479.58	590.52	0.771
Soft Maple	2421	117.4	170.10	92.60	77.50	0.660
Oak	4690	318.4	310.68	140.70	169.98	0.594
All Others	654	58.1	24.59	18.91	5.68	0.098
Totals	51646	3101.9	$3696.99	$1842.92	$1854.07	0.598

*Prices used are from Table 5, Appendix III.
Volume is actual mill tally.
Lumber values are reduced 10 percent to allow for shrinkage and degrade.

TABLE 7

ACTUAL PERCENT GRADE YIELD BY DIAMETER CLASS FOR ALL SPECIES

d.i.b. Class	Board-foot Volume	Number of Logs	Actual Percent Distribution					Adjusted Relative Value/M FAS Lumber = 100.00 %
			FAS	#1C&S	#2C	#3C	Timbers	
8	145	4	0.0	0.0	6.9	93.1	0.0	28.30
9	485	13	0.0	4.8	11.7	73.6	9.9	31.90
10	1167	24	0.4	7.7	25.1	50.8	16.0	35.50
11	2000	31	4.0	8.0	25.9	54.4	7.7	39.30
12	4042	52	9.9	25.6	23.2	37.7	3.6	43.60
13	4949	49	9.5	23.3	27.8	34.1	5.3	45.80
14	5200	44	18.0	29.4	22.5	22.8	7.3	49.00
15	3906	31	12.9	30.0	24.0	29.3	3.8	50.40
16	3863	26	15.0	24.8	24.1	31.4	4.7	52.80
17	4332	25	22.7	25.8	17.4	29.4	4.7	53.60
18	3378	17	37.6	18.6	21.4	17.0	5.4	55.10
19	1617	8	25.4	39.1	16.8	16.7	2.0	56.10
20	1938	8	8.8	17.4	24.1	49.7	0.0	57.20
21	2930	10	22.3	32.1	21.3	23.7	0.6	58.00
22	2748	9	27.7	30.0	20.0	18.9	3.4	58.70
23	1358	4	28.9	42.4	13.0	15.7	0.0	59.50
24	1122	3	22.5	19.4	35.2	22.9	0,0	60.40
25	1412	4	33.4	33.2	15.7	17.7	0.0	61.30
26	828	2	34.0	15.0	24.1	26.9	0.0	62.30
27	1407	3	47.6	33.8	11.2	7.4	0.0	62.60
30	451	1	11.5	32.4	18.0	35.6	0.5	65.30
31	1124	2	44.2	36.8	9.1	9.9	0.0	65.70
35	1244	2	3.5	25.8	51.5	19.2	0.0	---
Totals	51646	372	19.2	25.8	22.4	28.6	4.0	52.40

TABLE 8
PERCENTAGE DISTRIBUTION OF LUMBER GRADES BY SPECIES AND BY LOG GRADES

Species	Log Grade	# of Logs	Percent Distribution					Rate of Cut b.f./Minute	No. of Board Feet
			FAS	#1C&S	#2C	#3C	Timbers		
Hard Maple	1	50	32.6	33.3	16.3	14.7	3.1	19.1	6858
	2	19	7.8	37.8	21.2	27.7	5.5	17.5	2016
	3	41	3.0	14.2	31.9	43.2	7.7	14.4	3107
	All	110	20.7	29.1	21.2	24.3	4.7	17.4	11981
Elm	1	45	36.2	30.2	17.2	14.1	2.2	24.3	10297
	2	23	12.8	30.2	25.6	27.0	4.4	19.8	4116
	3	50	4.1	17.1	31.6	45.4	1.8	15.1	6177
	All	118	22.0	26.3	23.2	26.0	2.5	19.8	20590
White Ash	1	12	35.9	31.3	12.9	6.3	13.6	18.4	1278
	2	5	8.8	36.5	35.4	19.3	0.0	18.2	491
	3	13	0.7	9.1	33.7	43.8	12.7	14.0	975
	All	30	18.5	24.3	24.3	22.0	10.9	16.5	2744
Basswood	1	5	51.2	24.6	14.6	9.6	0.0	19.6	809
	2	1	0.0	5.6	55.2	39.2	0.0	16.5	107
	3	5	8.0	13.4	30.9	47.7	0.0	14.3	388
	All	11	34.1	19.7	22.8	23.4	0.0	17.5	1304
Beech	1	9	23.8	30.0	12.9	30.6	2.7	21.0	1958
	2	12	13.8	31.7	24.0	27.3	3.2	22.8	2679
	3	16	3.4	10.7	19.9	65.4	0.6	15.5	2625
	All	37	12.8	23.6	19.6	42.1	2.9	19.4	7262
Red Oak	1	8	34.8	34.3	20.9	3.6	7.3	20.6	1407
	2	9	5.6	24.8	31.6	29.9	8.1	17.8	1338
	3	10	0.0	5.3	33.5	54.9	6.3	10.0	753
	All	27	16.2	24.4	27.3	24.7	7.4	16.0	3498
Soft Maple	All	10	16.6	28.5	21.4	30.5	3.0	22.9	2421
White Oak	All	10	3.1	16.0	23.8	45.2	11.9	17.6	1192
All Others	All	10	0.0	10.0	20.3	63.0	6.7	12.5	654

TABLE 9

PERCENT GRADE YIELD FOR #1 LOGS OF ALL SPECIES
BY TWO-INCH DIAMETER CLASS

d.i.b. Class	Board-foot Volume	Number of Logs	Actual Percent Distribution					Adjusted Rel. Value/M FAS Lumber = 100.00 %
			FAS	#1C&S	#2C	#3C	Timbers	
12-13	3150	33	21.9	35.4	19.3	19.5	3.9	56.90
14-15	4239	33	28.4	32.5	17.7	17.4	4.0	59.80
16-17	4155	25	31.2	30.7	17.5	14.8	5.8	62.00
18-19	3716	18	42.2	25.2	14.4	12.9	5.3	63.60
20-21	1844	6	35.6	32.6	15.7	16.1	0.0	65.00
22-23	2827	9	36.4	35.9	15.3	11.1	1.3	66.40
24-25	1033	3	39.6	36.0	12.1	12.3	0.0	67.10
26-27	1119	2	57.8	14.5	20.5	7.2	0.0	67.50
28-29	---	-						68.00
30-31	1074	2	34.4	36.2	10.7	17.6	1.1	68.40
Totals	23157	131	32.9	31.3	16.5	14.9	3.4	61.60

TABLE 10

PERCENT GRADE YIELD FOR #2 LOGS OF ALL SPECIES
BY TWO-INCH DIAMETER CLASS

d.i.b. Class	Board-foot Volume	Number of Logs	Actual Percent Distribution					Adjusted Rel. Value/M FAS Lumber = 100.00 %
			FAS	#1C&S	#2C	#3C	Timbers	
12-13	2683	27	5.8	27.1	26.9	35.0	5.2	44.70
14-15	2947	24	6.0	36.0	23.4	24.3	9.3	47.70
16-17	2040	12	12.1	30.6	22.3	30.9	4.1	50.00
18-19	543	2	5.3	19.2	45.3	30.2	0.0	52.60
20-21	1208	5	1.5	25.6	29.2	42.5	1.2	54.40
22-23	585	2	2.4	46.5	24.8	23.6	2.7	55.80
24-25	1197	3	26.5	16.7	32.9	23.9	0.0	56.70
26-27*	811	2	35.1	50.3	7.9	6.7	0.0	57.10
28-29	---	-						57.60
30-31*	501	1	36.0	34.1	13.6	16.3	0.0	57.80
Totals	12515	78	11.3	31.0	25.4	28.1	4.2	49.80

*These logs were placed in #2 grade because of the presence of heartrot although the quality of lumber is comparable to that of grade #1.

TABLE 11

PERCENT GRADE YIELD FOR #3 LOGS OF ALL SPECIES
BY TWO-INCH DIAMETER CLASS

d.i.b. Class	Board-foot Volume	Number of Logs	Actual Percent Distribution					Adjusted Rel. Value/M FAS Lumber = 100.00 %
			FAS	#1C&S	#2C	#3C	Timbers	
8-9	630	17	0.0	3.7	10.6	78.0	7.7	31.00
10-11	3167	55	2.7	7.9	25.6	53.1	10.7	34.50
12-13	3158	41	0.8	10.7	31.0	52.8	4.7	37.30
14-15	1920	18	3.4	13.8	32.4	46.0	4.4	39.90
16-17	2000	14	1.3	9.0	25.2	61.5	3.0	42.20
18-19	736	5	11.6	29.6	29.0	27.6	2.2	43.70
20-21	1816	7	8.2	20.3	24.8	46.7	0.0	44.80
22-23	694	2	16.0	16.3	21.5	40.2	6.0	45.50
24-25	304	1	0.0	37.5	32.2	30.3	0.0	46.10
26-27	305	1	6.6	9.8	20.9	62.7	0.0	46.60
35	1244	2	3.5	25.8	51.5	19.2	0.0	47.70
Totals	15974	163	3.8	13.9	28.9	48.8	4.6	39.50

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