SAWING FURNITURE QUALITY DIMENSION FROM SHORT LOG BOLTS

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A B S T R A C T

The supply of large trees from Michigan's original old-growth forests has long been exhausted. Sixty percent of all growing stock of desirable commercial species is in small trees 7 to 15 inches diameter breast height. Hardwoods make up 74 percent of this growing stock volume. The principle species are aspen and hard maple, each of which constitutes 15 percent of the total volume.

Michigan's pallet industry relies heavily on this supply of domestic hardwoods. A production survey taken during 1973 concluded that 80 percent of the bolts used by these mills were of low quality and were best suited for use as pallet stock. On the other hand, this same study estimated that 20 percent of the material being used was from bolts of significantly higher quality. The material obtained from these quality bolts could be redirected to the furniture industry in the form of square dimension stock. Furniture squares and other dimension hardwoods are in demand. The short bolt user has the opportunity to meet this demand and increase his own profits by perhaps as much as 300 percent.

This paper identifies those quality bolts, and provides the users with some facts pertaining to their conversion into furniture dimension stock.

SAWING FURNITURE QUALITY DIMENSION FROM SHORT LOG BOLTS

By

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INTRODUCTION

WOOD SUPPLY

Accelerated inflationary trends in our industrialized economy have made us all aware of the impending problem of material shortages. U.S. News (29) recently wrote, "In one line of business after another, you hear this growing complaint - Shortages of key materials are getting worse, spreading from factories to distributors and on to retail customers." Business Week (4) states that "Shortages are hitting plastics, synthetic fibers and other textiles, steel, aluminum, copper, lumber, and paper products." One industry in particular which is experiencing challenges in obtaining material is the furniture industry in Michigan. Particularly those manufacturers using exposed and solid core domestic hardwoods in their production lines are finding themselves forced into using available substitutes that are less expensive and at times less attractive. This shortage of hardwoods is especially acute for grade oaks, yellow birch, hard maple, white ash, black cherry, black walnut, sweet-gum, and yellow-poplar (3).

The supply of big trees from the original old-growth forests has long been exhausted. Sixty percent of all forest growing stock of desirable commercial species is in small trees 7 to 15 inches in diameter breast height (27). Hardwoods make up 74 percent of Michigan's growing stock volume. The principle species are aspen and hard maple (mostly sugar maple), each of which constitutes 15 percent of the total volume. Hard maple is a valuable species, and present demand for high-quality logs and bolts exceeds the current estimate of allowable cut for this species (6).

One way to cope with the increased demand for lumber is to make better use of small logs. Greater use of bolts will play an important role in attaining this goal. A bolt is defined as tree sections eight foot and smaller. By using bolts, loggers can utilize tree sections considered unmerchantable under present harvesting practices (21). Hardwood stands can also be substantially improved by removing trees that can produce bolts of shorter length and lower quality than would otherwise be permissible for sawlog production.

Gill and Phelps (8) suggest that the use of bolt wood by manufacturing industries increased 61 percent from 1960 to 1965. Manufacturers of wood products have realized that the cutting pattern required for their production lines can often be satisfied better economically by the short lumber from bolts than by cross-cutting and ripping longer lumber. Johnson (13) states that converting hardwood lumber to dimensioned pieces wastes 34 to 40 percent of the original volume. This does not include waste in producing lumber from logs. In addition, the user of dimension stock cut from standard lengths of hardwood lumber has to pay freight, handling, and overhead costs on that portion of the lumber that is wasted in producing short dimension stock. Also, he must be concerned with the disposal of this waste and its associated environmental consequences (13). If short dimension stock can be furnished to the user directly from short length bolts, he should achieve substantial savings because he will be utilizing practically all of the material shipped into his mill.

BOLTER SAWS

Short length bolts are most frequently converted into squares or flat stock by the use of bolter saws. The short-log bolters originated in the New England States over 75 years ago and were used to saw square stock for the wood turning and dowel industries (2). They still serve as producers of squares, but their use is growing for production of flat stock for pallet and furniture manufactures.

Two types of short-log bolter are manufactured: the table bolter and the carriage bolter, or short-log carriage. The carriage and table are powered through a set of conical iron and fiber independent frictions. These are placed beneath the carriage and engaged by either foot pedals or a lever. A top saw is also used in some locations where bolts of larger diameter are sawn (2).

Bell and Calvert (2) state that two distinct possibilities for improving the utilization of both small and defective hardwood trees are provided by the use of short-log bolters as compared to conventional saws. First, since the bolter is a relatively flexible machine, and as the operator has close control of the sawing, greater care could be taken in sawing for grade and in obtaining the greatest yield from the log. Second, the bolter handles short length material, and trees could be bucked into short lengths with the consequent elimination or reduction of defective material and crook.

Three points of economic significance which have stimulated interest in bolter operations are first, the low production requirements, second, the low cost of bolter machines, auxiliary equipment, and plant, and third, it's portability. For these three basic reasons together with the States abundance of bolt type materials, bolter operations have received their greatest acceptance in Michigan's pallet industry.

PALLET INDUSTRY

Pallet manufacture is the fastest growing lumber consuming industry in the United States. Nationally it consumes more than two and one-half billion board feet of lumber annually - over 6 percent of our domestic production (10). The pallet which had its birth in the mid-1930's, achieved major use when the military services began to use it to speed the warehousing, handling, and delivery of supplies during World War II. The fork-lift truck and the wooden pallet combination created the "cubic concept" of modern warehousing, which permits the use of air space as well as floor space in storage areas and transportation vehicles (23).

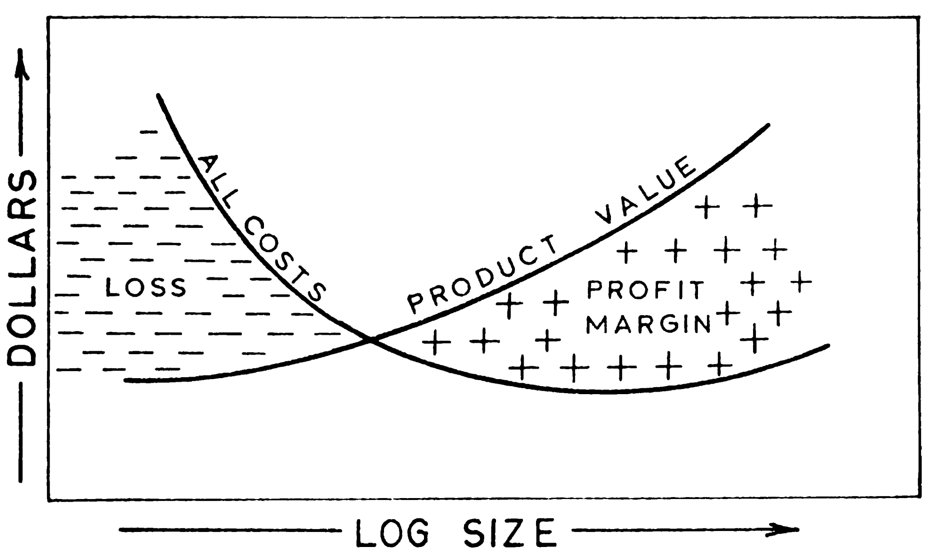
Today, the wooden pallet is a basic tool of modern materials handling and automation. It's use can be seen in the automotive, masonry, food and many other industries. In conjunction with the flat pallets are the pallet containers. Pallet containers are being used to good advantage to increase the efficiency and lower costs of storage, handling, transportation, and harvesting of various agricultural as well as industrial products (1).

In spite of the optimistic picture regarding economic growth of this industry, it does have its drawbacks. The main problem of the wooden pallet industry is that it has the lowest profit margin of all the lumber and wood products industries. It also has the highest financial mortality rate of all of these same industries (1). It is a business that one can enter with a small investment in equipment and physical assets. This often leads to persons of little or no financial responsibility becoming wooden pallet manufactures. Financial success can come quickly for the energetic business entrepreneur with the proper technical and managerial mixture but financial mortality in this industry might likewise be termed quick.

Much of the economic difficulties experienced by operating pallet mills stems from milling substantial quantities of logs whose total handling costs exceed the value of the products derived from them. Another source of economic difficulty is that the higher grade materials are sold as low quality pallet stock. These two problems cause a narrow profit margin which has lead to financial instability for the industry as a whole.

Knowing ones costs from the standing tree, to the final disposal of the product, and increasing the value of the primary product is important in order to establish a desirable profit margin. Specific publications (2), (9), (10), (12), (25), and (26) can aid the short-log producer in reducing his costs and increasing his product value. This idea illustrated simply by use of cost-product value curves as seen in Figure 1. Lowering the cost curve through application of modern conversion techniques or raising the product value curve by means of increasing lumber grade yield will widen the profit margin.

FIGURE 1. COST-PRODUCT VALUE CURVE OF PRIMARY PRODUCER



Reasons for the poor profit performance of the pallet industry in Michigan is that the typical pallet plant lacks the capital and managerial ability to expedite cost reduction. Another limitation is that pallet material is used in a low-value product with minor restriction as to quality or species requirements. Thus to raise the product value curve would require finding other markets for the higher quality material.

POTENTIAL USE OF BOLT LUMBER

One possible market for this quality material is the furniture industry. As previously stated, increased demands for grade oaks, maples, ash and other species of lumber could be obtained from short dimension stock derived from bolts. It would seem most logical that the largest users of bolts would try to satisfy this market if profitable.

There are two possible alternatives for marketing lumber cut from bolts. One is to sort out the number one common and better lumber grades produced at the pallet plant and sell it direct to the furniture industry. This often requires modification of existing hardwood lumber standards for which most pallet stock does not qualify. Also, a sizing problem exists in that the furniture industry requires a majority of 4/4 inch stock. Most pallets are made from other thicknesses such as 5/16 inch, 3/4 inch deck boards and 6/4 inch runners. The second alternative solution is to custom cut squares or 4/4 inch lumber from selected bolts for use in higher grade products.

The first requirement for success in the recovery of the optimum potential, in terms of product or value yield of a log, is to be able to recognize the potential of the log. Prior to 1930 there was no generally accepted concept of timber quality. From 1930 on, interest in the field mounted, and the researchers began to examine the relationship between log characteristics and products or value yields. It was then possible to write a set of specifications which grouped the logs by similar characteristics or grades. The Hardwood Log Grades for Standard Lumber are the first of these grades recognized and used by the Forest Service (9). Since the late 1950's the Forest Service has established a program for developing grades of this type for all species (28). With the advent of high speed computers, complex relationships in infinite combinations can make the task of grade formulation possible.

SURFACE DEFECTS AND TIMBER QUALITY

The need for understanding the factors affecting timber quality are essential for grade formulation. Volume per acre is lower and trees are smaller than in the past. Changing utilization patterns require new interpretations of defects for grading.

In regard to bolt quality, factors such as height of bolts above ground, rate of growth, age and number of clear faces all directly affect its quality. Stayton and Marden (24) conducted a study on sugar maple defects and found that the percentage of bark distortions and surface rises that had associated interior defects increased as height of indicator above the stump increased. The interior defects associated with surface rises and bark distortions are closer to the tree surface with increased height above stump, and thus more likely to be in the quality sapwood zone (24). Thus, knowing how the percentage of associated interior defects in the quality sapwood zone increases with height would permit better segregation of tree stem sections into product-use classes.

The percentages of bark distortions, flutes, and overgrown seams that had interior defects were significantly correlated with tree age. As tree age increased, the percentage of bark distortions and flutes associated with interior defect increased but the percentage of overgrown seams associated with interior defect decreased. The number of epicormic branches and surfaces rises per tree increased as tree age decreased while the number of overgrown seams increased as tree age increased. Growth rate also plays its role in timber quality in that the number of bark distortions and flutes per tree increased as growth rate increased.

Surface features such as knots, birdpecks, insect signs, adventitious bud clusters, and limbs also serve as defect indicators. Various publications describe exterior defects and there associated interior defects, (17) and (24). On trees 7 to 15 inches d.b.h. these defects will limit the length of clear cuttings in lumber sawed from most merchantable sawlogs or bolts (3). A literature review of previous articles written on bolt grading systems showed that the number of clear faces in a bolt provides a highly significant indication of lumber quality attained from bolts (7), (13), and (21). Johnson (13) stated that "as the number of clear faces increased, the yield of clear and select squares increased and the yield of common and number 2 decreased." He continues, "the largest recovery of clear and select squares can be obtained by utilizing bolts with two, three, and four clear faces."

It is important to note at this time that the presence of most defects in merchantable logs usually is signified by bark distortions and other surface indicators. "But bark grows, so indicators lose their usefulness progressively; and in time the indicators may become buried under normal bark growth. It is not always possible to predict the loss of an indicator, the entrance or emergence of a grub, the growth of a new branch or the feeding of a sapsucker (3)."

The study of surface indicators and their associated relationship to interior defects is of vital importance and its application will simplify the future task of bolt grade formulation.

P U R P O S E   A N D   O B J E C T I V E S

The purpose of this study was to gather research in the area of bolt grades, and examine, in a practical manner, it's application to the bolter mill operations in Michigan's pallet industry. Inherent in the purpose, are the following objectives:

1. Identify those quality bolts procured by pallet manufacturers, that could be converted into furniture dimension.

2. Determine the lumber dimension grade yield from those quality bolts using National Hardwood Lumber Association grade rules.

3. Predict the dimension recovery from bolts based on predicted yields using the International 1/4 Inch Log Rule.

4. Establish the time necessary to convert quality bolts into furniture dimension.

PROCEDURE

SPECIES SELECTION

Hard maple is a "universal" industrial specialty wood. For any purpose where hardness, strength, wearing ability, and good finish are required, it is very desirable (11). The close-grained wood can be bleached and stained to look like cherry. It also is well adapted for bending purposes as in chair legs and backs and also is well suited for turnings.

The Hardwood Market Report (16) ranks hard maple second only to birch as one of the most valuable Northern Hardwoods. With these facts along with Michigan's abundance of bolts, hard maple was selected for use in this study.

MILL SELECTION

The mill selected for this study is located in LeRoy, Michigan, 10 miles south of Cadillac, owned and managed by Mr. David Dyer. The primary product of this mill is a standard industrial flat pallet using both hard and soft woods in its construction.

The mill purchases both stumpage and cordwood from privately owned woodlots in the area and relies on independent loggers to fell and haul the raw material to the mill. At the mill, the logs are unloaded with a tractor unit equiped with a front end hydraulic loader, and bunched in an adjacent storage yard. The logs are then bucked into pallet length bolts and transported to the mill for conversion.

Several factors were influential in determining the selection of this mill for the study. Among the most important were the simplicity of the mill operation, the availability of required species, and the expressed interest of the owner to participate in the study.

The simplicity of the mill was important in order to obtain an accurate tally from each individual bolt. Other plants were excluded because of numerous resaws and rip saws which result in the dispersion of material from one bolt to several different machines, this would greatly increase the difficulty of getting an accurate count from any one bolt.

This mill also had the required species in quantity and quality. Various production samples taken during the year showed as much as 34% maple, 12% beech, 8% basswood, and the remaining species consisting of disproportionate units of pine, oak, ash, elm and cherry. Appendix C lists species and grade distribution as obtained from a random survey conducted by the author during the summer.

The Forest Products Laboratory suggests other factors that should be considered, as listed below:

1) The log supply should be great enough to allow adequate

time for diagramming the logs without slowing down the normal production of the mill.

2) The log deck or holding yard should be large enough to allow adequate diagramming space and time.

3) Logs should not be covered with mud that obscures defects on end or bark surfaces nor should the bark be absent.

MILL LAYOUT

This pallet mill is a garage-like structure approximately 20 feet x 50 feet with a poured concrete slab as the floor base. All equipment is secured to this base (see Appendix A). The mill contains three major pieces of equipment - a head-saw, trim-saw, and slat saw. The head-saw, located perpendicular to the loading deck, is a 40-inch diameter - 945 r.p.m. Brettrager bolter saw. Its primary function is to break the bolts down into 3 1/2 inch or 5 1/2 inch thick x random width cants. The cants are then sent to a swing cut-off saw where they are trimmed to the length required to fill the order. The cut to length cants are then carried over to a Brettrager slat saw equiped with a 36-inch diameter saw - 1,050 r.p.m. and sliced into deck boards or runner stock whichever may be the case. The cut stock is then carried to the nailing room and nailed into the flat pallets by using pressurized air-nail guns.

At full capacity, this mill is capable of producing 3.4 M board feet of pallet cut-stock each eight hour shift. It requires a minimum of 5 people to operate the mill with an additional supervisor to control log supplies and other managerial duties. (See Appendix B for production data.)

DATA COLLECTION

For this study 3.2 M board feet International 1/4 inch rule, 12 foot hard maple logs were selected. Each log was bucked into 48-inch or 72-inch length bolts then scaled, diagramed and graded. (See Table 1.) Net bolt scale was obtained by subtracting the amount of defective material from the gross scale. Defective material includes bolts with decay and wind shake; bolts with crook and twist were also eliminated. Each bolt was diagramed using standard Forest Service forms. Bolts were theoretically quartered; each quarter representing a face and defects recorded on the diagram forms using appropriate defect symbols (18). End defects were also inspected and recorded when visible. Each bolt was then numbered at the ends so recovery data could be collected from individual bolts. Appendix D shows the diagram form used in this study.

The sawing pattern used in this study was that of sawing around. The first slab was removed from the face containing the most defects. After its removal, the bolt was turned down 90° so that the defective side faced the table. The bolt was then alligned parallel to the fence and another slab removed in order to expose a 3 to 4 inch face. Sawing parallel to the bark maximizes the yield of straight-grained stock,

TABLE 1. DISTRIBUTION OF 167 SUGAR MAPLE BOLTS BY DIAMETER CLASS, BOLT LENGTH, AND NUMBER OF CLEAR FACES.

DIAMETER CLASS (INCHES)	BOLT LENGTH AND NUMBER OF CLEAR FACES										
	4 FEET					6 FEET					
	0	1	2	3	4	0	1	2	3	4	TOTAL
6											0
7											0
8								1			1
9					2	1		1	1	1	6
10			2	5	1	1	2	4	4		19
11		3	4	5	9		3	2	4	1	31
12		1	3	9	13	1	2	3	2	2	36
13		5	3	3	18			2	2	1	34
14	1		1	4	7	1					14
15	1			3	4				1	1	10
16				2	4						6
17		1	1	2	3						7
18			1								1
19					2						2
TOTAL	2	10	15	33	63	4	7	13	14	6	167

which is an important criterion for furniture dimension (18). Two and one-quarter inch cants were then removed consecutively until an apparent loss of grade occurred at which time the bolt was turned down and the process completed until total bolt conversion.

Each cant removed from the bolt was then carried to the slat saw where it was squared. The squares were then recorded by bolt number and graded following generally the grading standards established by the National Hardwood Dimension Manufactures Association. (See Appendix E.) The squares were then self-stickered and banded for transportation. Self-stickered squares facilitates faster air drying thus thought to reduce possible blue stain degrade.

R E S U L T S   A N D   A N A L Y S I S

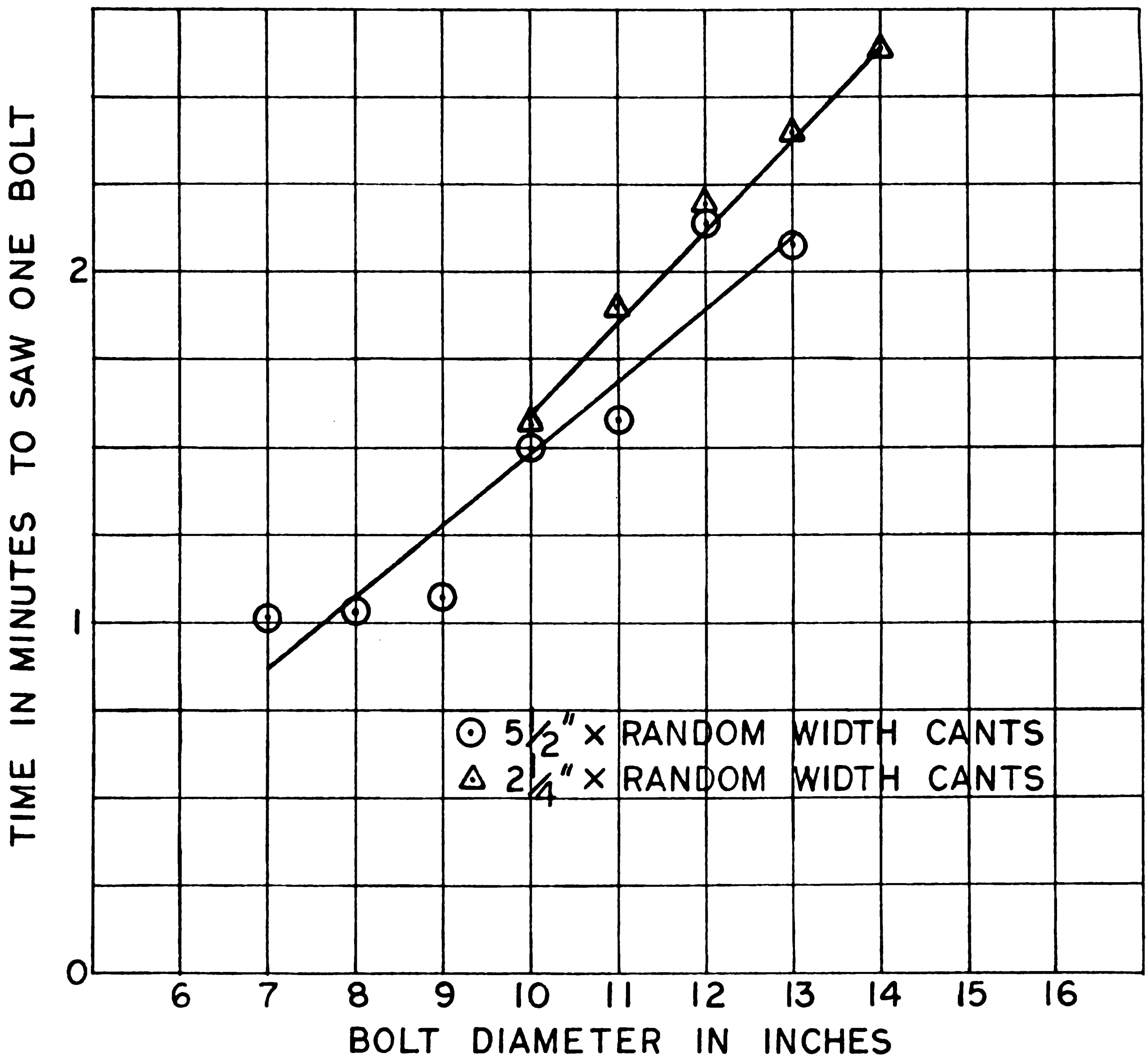
SAWING TIME FOR BOLT BREAKDOWN

During this study, time values were recorded for bolt conversion whenever possible. The unit time measured was the actual minutes required to convert the bolt into 2 1/4 inch x random width cants. Variations in time were observed within each diameter class due to sawing various grade bolts. The sawyer was asked to turn the bolt down when there was an apparent loss in grade. Thus bolts in the lower grade classes required more turning while clear bolts were converted the quickest.

Sawing time increased as a linear function of bolt diameter up to 14-inch diameter bolts. Data points were best fitted to the equation $\bar{y} = -1.00 + .2620\ (x)$ where $\bar{y}$ equals the minutes required to convert the four foot bolt and x equals the bolt diameter. The correlation coefficient was calculated to be .9957. (See Appendix F.) Bolts 15 inches - 20 inches exceeded the bolter saw capacity and required additional sawing time for slab removal. However, other bolter saws such as the J.W. Penny Model E are equipped with an overhead saw which is designed to handle the larger bolts.

In another part of this study, time values were taken for converting bolts into 5 1/2 inch thick x random width cants. As was expected, more sawing time was required to produce 2 1/4 inch cants than was required for cutting 5 1/2 inch cants. The regression equation $\bar{y} = -.6243 + .2114\ (x)$ was calculated with a correlation coefficient of .8997. Results from these two studies are shown in Figure 2.

FIGURE 2. TIME REQUIRED TO SAW 2 1/4 INCH THICK CANTS AND 5 1/2 INCH THICK CANTS FROM 4 FOOT BOLTS.



PERCENT LUMBER RECOVERY

Recovery data was obtained directly from the mill tally record sheets. The squares from each individual bolt were counted, and actual board footage calculated. Percent recovery equals the actual board footage in the squares divided by the volume of wood in the bolts as measured by the International 1/4 Inch Log Rule. Table 2 contains the percent recovery for four-foot bolts.

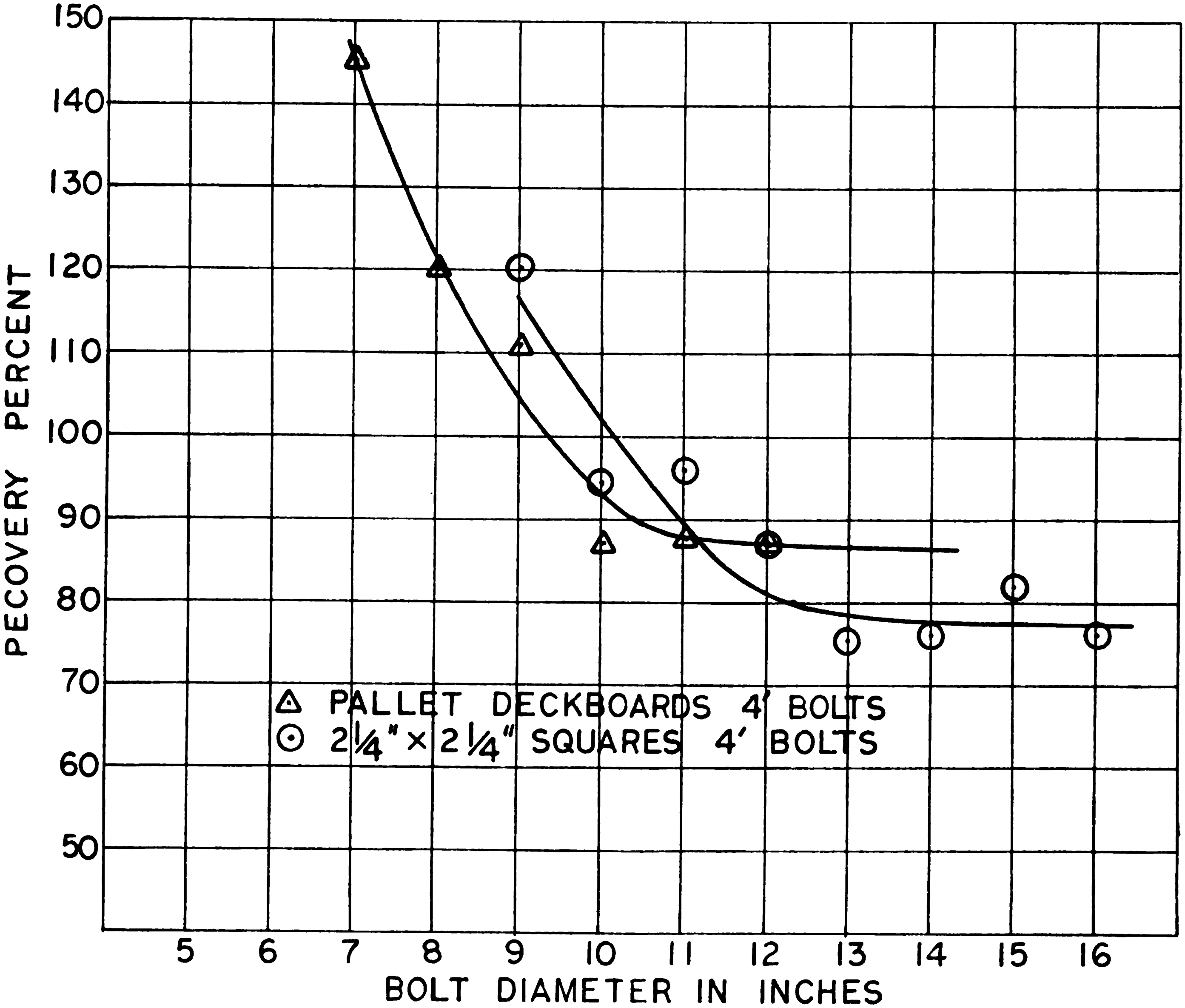
TABLE 2. SQUARE RECOVERY OF 2 1/4 INCH SQUARES FROM FOUR-FOOT SUGAR MAPLE BOLTS

1 Diameter Class Inches	2 Predicted Volume (Int. 1/4") Bd. Ft.	3 Actual Mill Tally Bd. Ft.	4 % Recovery Col. 3 ÷ Col. 2	5 Ave. Number of 2 1/4" Squares per Log
9	10	12	120%	5
10	15	16	94%	7
11	18	17	95%	9
12	23	20	87%	10
13	28	21	75%	11
14	33	25	76%	13
15	38	31	82%	17
16	43	33	76%	17
17	48	34	71%	18
MEAN			86%	

As the diameter of the bolts increased, the total yield decreased when measured as a percentage of the predicted yield. The recovery data from 2 1/4 inch cants was plotted by bolt diameter and percent recovery for bolts 9-14 inches. The results showed that one could expect a square recovery of 86 percent based on the predicted Int. 1/4 Inch Log Rule.

Once the bolt diameter approached 13 inches however, recovery leveled off at approximately 78 percent. (See Figure 3.)

FIGURE 3. PERCENT RECOVERY BASED ON PREDICTED YIELD (Int. 1/4 Inch Log Rule) BY BOLT DIAMETER.



This was the case in similar studies by Redman and Willard (22), Johnson (13), Bell and Calvert (2). Redman and Willard (22) also investigated the yield of usable furniture dimension cut from logs 26, 35, 43, 51, and 72 inches long. They found that the length of the bolt had no effect upon yield except in the percentage of usable dimension that was full length of the bolt.

In another related study conducted as a part of this project, recovery data was collected from bolts which were processed into pallet material. Instead of slicing the bolts into 2 1/4 inch cants, as was done with the hard maple, these were processed into 5 1/2 inch cants. Deckboards 3/4 inch x 5 1/2 inch x 48 inches were then removed from the cants and recorded by individual bolt number. The results were tabulated (Appendix G) for bolts 7-13 inches giving an overall mean of 106% recovery based on International 1/4 Inch Log Rule. As the bolt diameter approaches 11 inches, recovery percent will level off at approximately 85 percent as shown in Figure 3. The difference in overrun is inherent to the log rule and could also be the result of grade sawing. The sawyer turned the bolts around, removing the outer-quality material. The waste was in the outside slabs, the sawdust, a wedge-shaped center, which contained the pith and usually mineral stain. On the other hand, the waste incurred in producing the deckboards was in the sawdust and the outside slabs only. The defective centers went into pallet dimension.

GRADE RECOVERY FROM BOLTS

Grade recovery data was analyzed by using the bolt diagram forms and mill tally sheets. Preliminary examination of the diagram forms indicated a correlation between usable square material and the number of clear quarter faces on a bolt. Bolts with four clear faces had a higher percentage of clear square material than those with three, two, or one clear faces.

Lumber grade recovery was analyzed as a function of clear faces. An increase in the number of clear faces resulted in a higher percentage of clear and select squares. A reduction in the number of clear faces resulted in an increase in Common and No. 2 squares (Appendix H). Bolts with four clear faces had an average of 60 percent clear, 14 percent select, 7 percent Common, and 18 percent No. 2. (See Table 3.) There was no observed percentage increase in the number of clear squares with an increase in diameter for bolts with four clear faces. For bolts with three clear faces, the number of squares reduced to 43 percent clear, 22 percent select, and increased to 10 percent common, and 23 percent No. 2. Bolts having three clear faces with diameters 14 inches to 17 inches had more clear squares than bolts 10 inches to 13 inches. Those bolts having two clear faces showed 25 percent clear, 20 percent select, 13 percent common, and a sharp increase to 39 percent No. 2. Here again, those bolts ranging between 10 inches to 13 inches had a lower percentage of clear squares than those 14 inches and larger. When the number of clear faces was reduced to one and zero, the percentage clear squares was only 5 percent, select 20 percent, common 25 percent and 41 percent No. 2. (See Figure 4 for graphed results.)

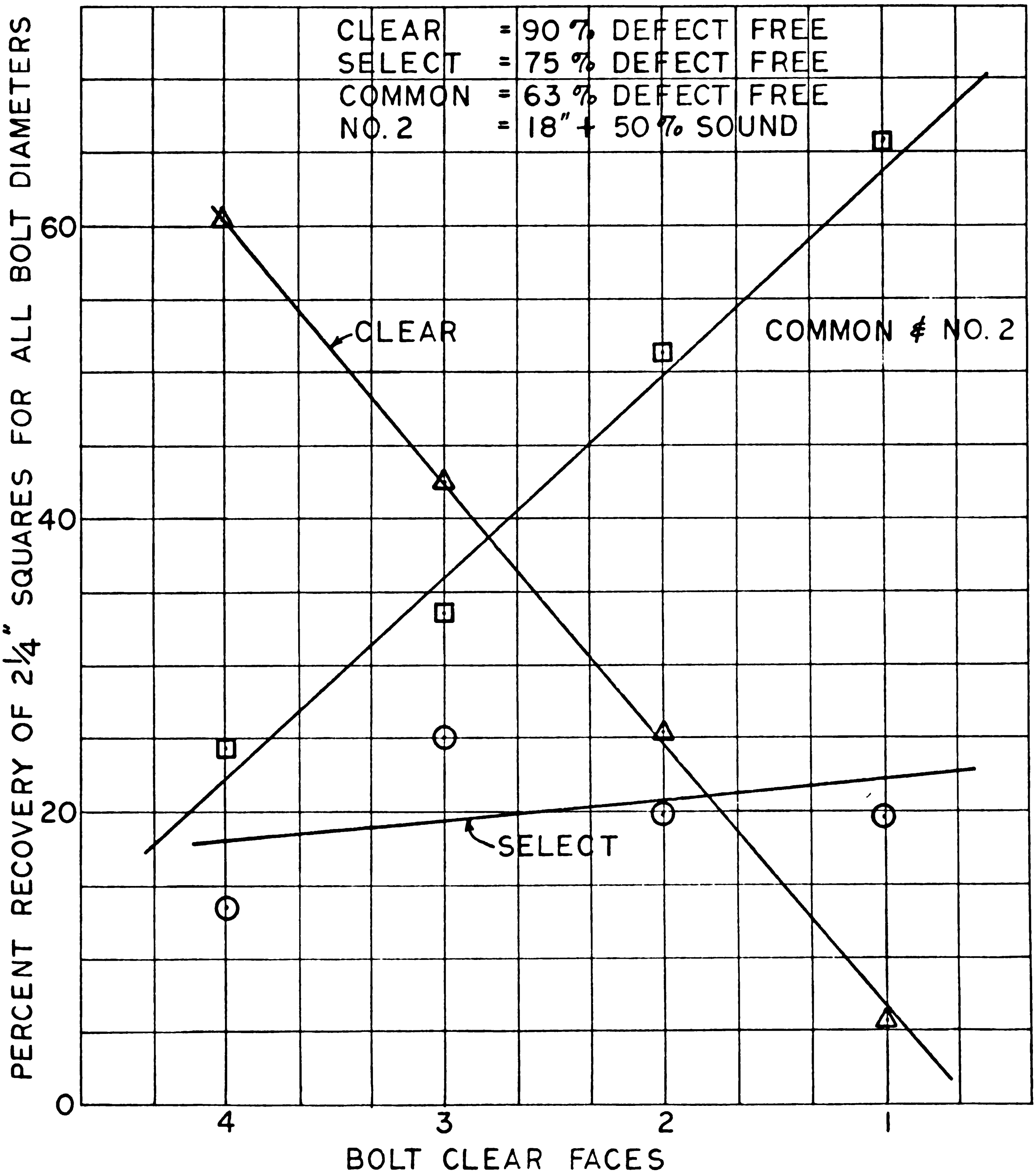
Overgrown knots, seams, and heavy bark distortions had a serious degrading influence on bolts up to 14 inches. Bolts 14 inches and larger were able to grow enough wood over the defects so it was possible to produce some clear and select squares before the defects became apparent on the exposed surface of the bolt.

The large number of common and No. 2 squares is a result of the mineral stain and decay found in hard maple. Unsound knots, overgrown knots, and large bumps seemed to contain a large amount of decay which caused staining in the longitudinal directions. This stain is undesirable for exposed solids and turnings causing a reduction in grade, usually to No. 2 or common.

TABLE 3. GRADE RECOVERY OF 2 1/4 INCH x 2 1/4 INCH SQUARES BY NUMBER OF CLEAR FACES

NUMBER OF CLEAR FACES	NUMBER OF OBSERVATIONS	PERCENT SQUARE YIELD BY DIMENSION GRADE				
		CLEAR	SELECT	COMMON	NO. 2	NO. 3
4	64	60.27	13.53	6.45	17.81	1.95
3	43	42.83	21.64	10.38	23.18	1.97
2	36	25.16	19.76	12.58	38.76	3.74
1	5	7.14	18.41	20.32	47.38	6.75
0	2	-	22.62	36.91	23.81	16.67

FIGURE 4. DIMENSION GRADE RECOVERY OF 2 1/4 INCH SQUARES BY NUMBER OF CLEAR FACES FOR ALL BOLT DIAMETERS



APPLICATION OF BOLT GRADES

There is no generally accepted bolt grading system in use. Not until the late fifties did the Forest Service publish methods for developing bolt grades. Research in this field is still of an "exploratory nature" dealing with a wide range of diverse problems. One problem area is the limited research in the science of defect indicators. Various publications have been written explaining how surface defects degrade lumber quality. Defects have also been classified as to their degree of severity, but no statistical varification is available that can quantifiably determine the absolute significance of defect indicators.

It may not be possible to develop a bolt grading system over its entire range. Topographical and geographical variations along with site index, stand density and species variety, all influence variations in timber quality within a species.

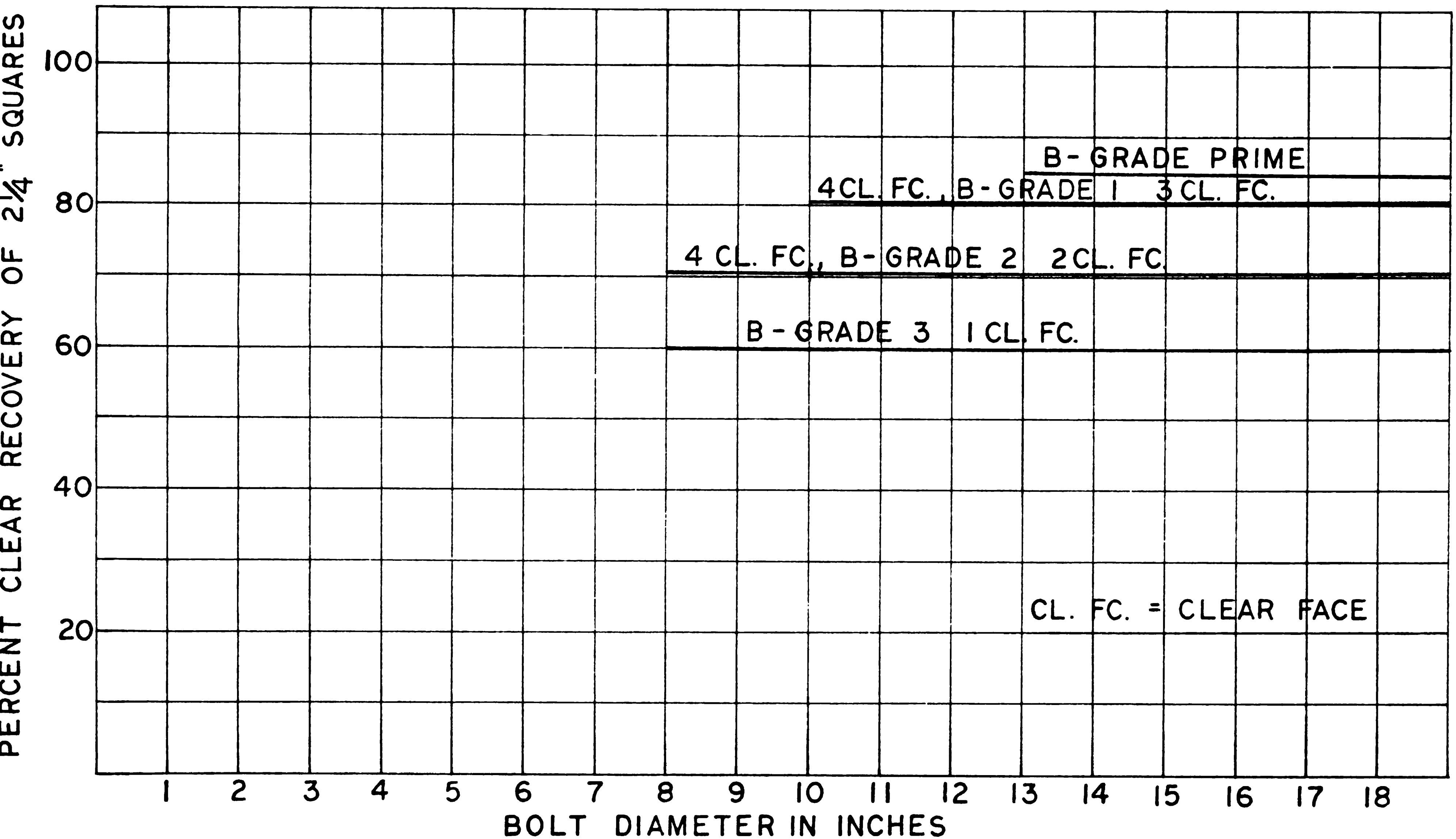
Much sampling is required to formulate bolt grades. The Forest Service recommends a minimum of 10 observations for each diameter class within that grade. This would be a minimum of 375-400 bolts to formulate a four grade system. Mill check tests are later required for varification of the hypothetical grading systems.

Requirements of product end use should be reflected in grade too. Variety of end-products can make log grading a difficult assignment. One bolt grading system which was formulated by the Northeastern Area

Forest Service under the supervision of Mr. Daniel Dunmire (7), classifies bolt quality on the basis of diameter and clear faces. When data from the hard maple study was sorted, using his "PA Bolt System", there was an observed segregation as to quality and value for each grade within the system (Appendix I). Graphed results for the four foot bolts, can be seen in Figure 5. Bolts 8 inches in diameter and larger, having only one clear face, were graded as B-Grade 3. The cummulative percent recovery of clear material was calculated to be 60 percent for the grade. Clear material was determined from adding clear sections 18 inches and larger at intervals of two inches. Bolts 10 inches and larger, with two clear faces, or bolts 8 and 9 inches with four clear faces, were graded as B-Grade 2. The total percent recovery of clear material was approximately 70 percent for B-Grade 2. Bolts graded as B-Grade 1 had three clear faces, 12 inches and larger or bolts 10 and 11 inches with four clear faces were included in the grade. They had a cummulative clear recovery of 81 percent. Those bolts classified as prime had a cummulative clear recovery of 85 percent. (See Appendix J.) Variations within each grade are to be expected due to natural phenomenon. Increased sample size and additional practice in cutting squares may also reduce the variation about the mean within each grade.

Lumber recovery and dimension grade recovery for the graded bolts can be obtained directly from Tables 2 and 3, respectively. With this information, the pallet manufacture or other short bolt users can predict the yield of 2 1/4 inch graded squares obtainable from a bolt given the diameter and number of clear faces.

FIGURE 5. PERCENT GRADE RECOVERY BY BOLT DIAMETER, 4 FOOT BOLTS, AND PA BOLT GRADES



CONCLUSION AND RECOMMENDATIONS

Research on hard maple bolts procured for pallet manufacture in Michigan indicated the following:

1) Grade yield from four-foot and six-foot bolts can be determined from the number of clear quarter faces on the bolts.

   a) Defect indicators on bolts include adventitious bud clusters, sound and unsound knots, limbs, seams, bird pecks and flutes. Many of these defects occur in the form of bark distortions which decrease in severity with an increase in bolt diameter. End defects on bolts, such as wind shake, grub holes, double pith, decay and mineral stain will also reduce lumber dimension grade.

   b) The greater the number of clear faces (ones without defect indicators) the higher the grade yield. Bolts with four clear faces had a cummulative total of 73 percent clear and select squares. Those with three and two clear faces had 65 percent and 45 percent respectively. Clear and select squares are more valuable than Common and No. 2's. They require less machining per thousand board foot, and less waste is involved in their use at the furniture plant. The value per thousand, for a load of squares, is contingent upon the number of clear and select squares. If the number of Common and No. 2 squares increases, the value per thousand, will decrease. It is the responsibility of the user to specify the percentage of clear and select squares required in a load of furniture dimension. Once an agreement has been made, the producer can select those bolts which will yield the required furniture dimension grade, by using the information in Tables 2 and 3.

c) Bolt diameter also influences grade yield in that the larger diameter bolts will have more clear material than the smaller diameter bolts with the same number of clear faces.

d) To segregate bolts into the highest product value groups, it is necessary to consider both diameter and the number of clear faces. These two variables will influence furniture dimension grades obtainable from any one bolt.

e) The PA-Bolt System incorporates diameter and the number of clear faces into a four grade system. Each grade in the system represents bolts with similar characteristics and value per M.

2) The volume yield of 2 1/4 inch squares can be predicted from bolt diameter.

a) The International 1/4 Inch Log Rule underestimates yields for bolts under 10 inches in diameter. Actual yield compared to estimated yield decreases with an increase in bolt diameter. For bolts 13 inches and larger in diameter actual yields may be 20 percent less than predicted by the Log Rule.

3) The volume yield of pallet dimension can also be predicted as a function of bolt diameter.

   a) The International 1/4 Inch Log Rule underestimates yields for bolts 9 inches and smaller in diameter.

   b) The volume yield of pallet deckboards 3/4 inch x 5 1/2 inch x 48 inches was up to 6 percent greater than that of 2 1/4 inch squares for logs 12 inches or more in diameter. Sawyer inexperience in cutting squares may account for part of this difference.

4) The time necessary to convert bolts into squares versus pallet dimension can be estimated.

   a) The time study comparison of conversion times for 5 1/2 inch versus 2 1/4 inch cants indicates an additional 0.30 minutes per 13 inch bolt, is necessary for square conversion. Assuming 13 inches would represent the average diameter for graded bolts we could enumerate a 13 percent reduction in total daily footage. (Figure 2.) For this mill total pallet production is estimated to be 3,500 board feet per 8 hour shift (5 man crew). A 13 percent reduction would place the daily production of

2 1/4 inch square material at approximately 3,000 board feet per 8 hour shift. As the sawyer's confidence increases, one could expect a significant increase in daily footage.

5) Recommendations for future research:

a) An area that should be explored more carefully to assume optimum lumber recovery from graded bolts is further research in the area of sawing patterns. The method used in this study was sawing around, otherwise known as grade sawing. This method has traditionally been used in this country to "optimize" National Hardwood Lumber Association lumber grade recovery. In reality it produces less lumber than could otherwise be achieved through live sawing, which is sawing through and through requiring limited turning of the log. Two articles published in the Forest Products Journal 1972, (15) and (19) studied various hardwood sawing methods. The article by Kersavage found that "Live sawing resulted in a considerable increase in lumber output per man-hour, ..." And that "sawmill productivity expressed on the basis of lumber value per hour of operation, increased significantly with live sawing." Pnevmaticos and Bousquet stated in their study that "the highest value and surface area yields of furniture components were produced from live-sawn, unedged boards." "For F-3 logs there was no significant difference in lumber value yield. In processing F-2 logs into furniture components via unedged boards, live sawing yielded more dimension stock than did around or taper sawing." Such a study applied to bolt grades might recommend live sawing to be used on bolts with three and four clear faces and around sawing for bolts with two clear faces.

b) Another alternative for utilizing bolts with two clear faces and less is to convert the bolts into 5 1/2 inch x random width cants. Grade the cants on the basis of visible defects, and then proceed to cut furniture dimension from the clear cants. Defective cants will be processed into pallet stock. Thus optimum utilization of bolt material could be achieved if dimensions are compatible for furniture use.

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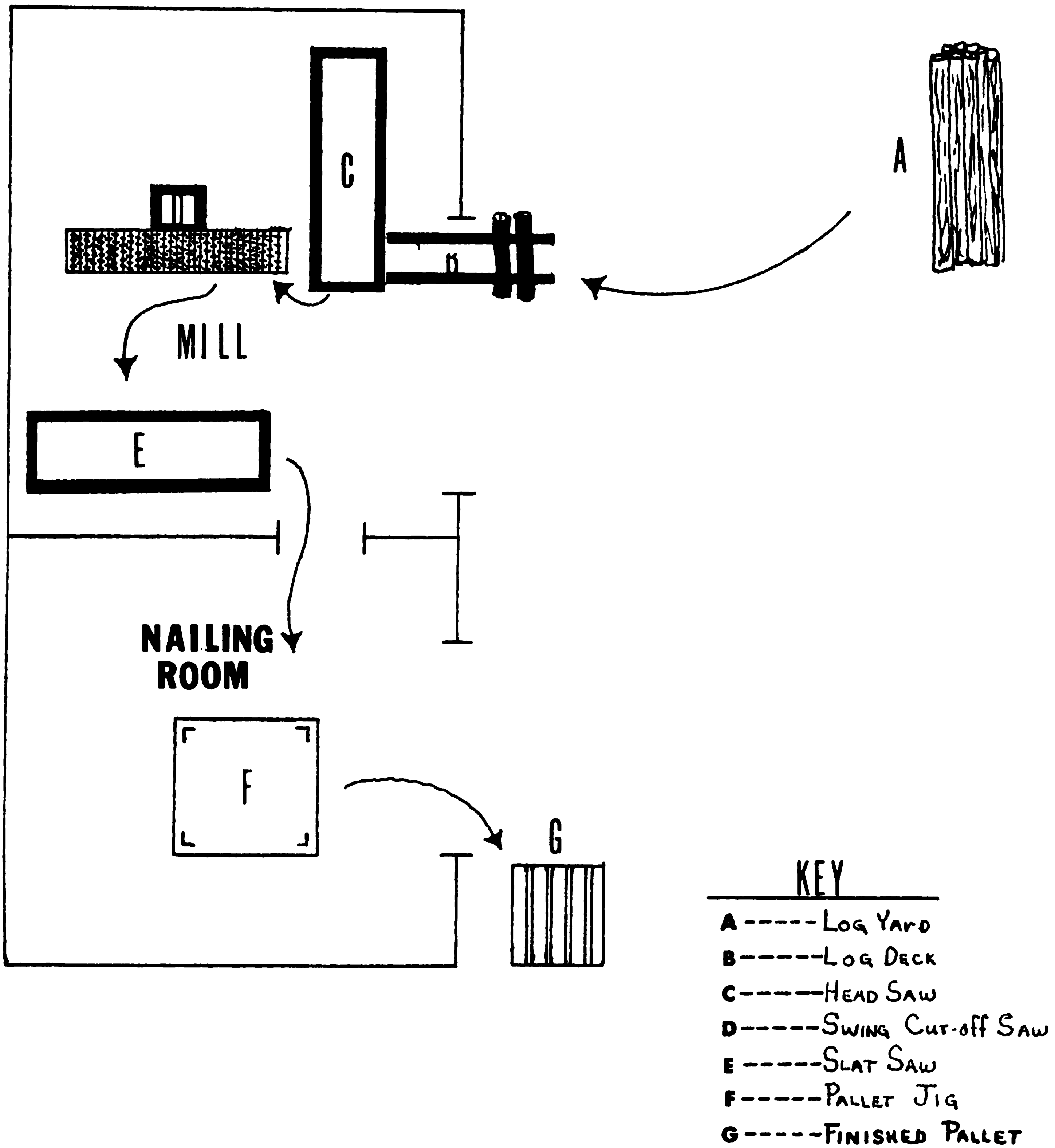
APPENDIX A. HARD MAPLE BOLT STUDY FLOOR PLAN OF PALLET MILL USED IN THIS STUDY.



APPENDIX B. PRODUCTION SURVEY TAKEN AT PALLET MILL, SUMMER 1973, MR. DAVID DYER, OWNER

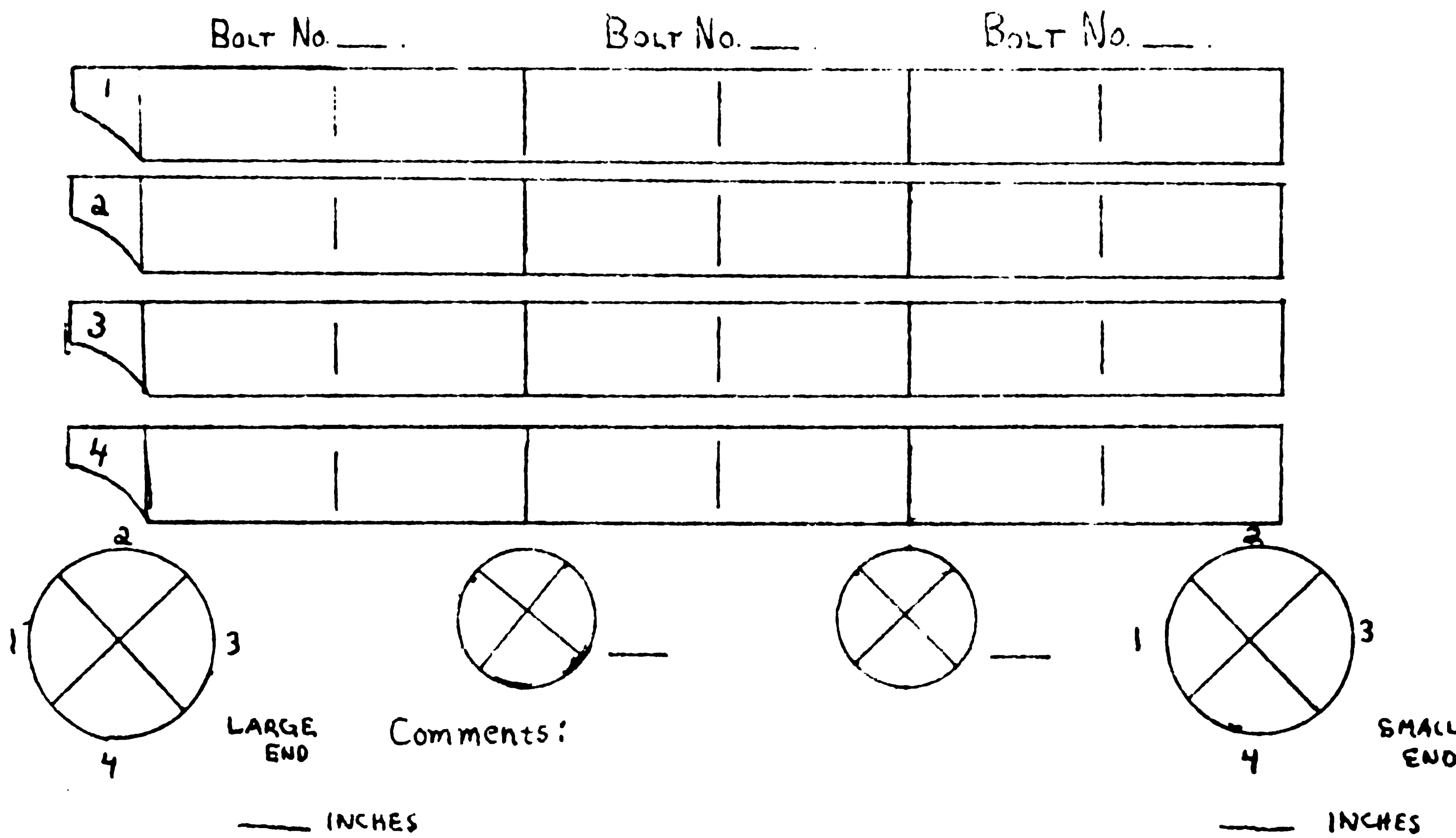
DATE	INT. 1/4 TOTAL PRODUCTION	LAPSED TIME PER HR	LAPSED PRODUCTION RATE	MACHINE TIME	MACHINE PRODUCTION RATE	TALLY OF PALLET MATERIAL
	Board Feet		Bd. Ft./HR		Bd. Ft./HR	Board Feet
7/09/73	293.13	.75	390.84	.64	458.02	304.72
8/06/73	1,477.50	3.08	479.71	2.77	533.39	1,536.60
7/13/73	602.09	2.25	267.60	1.50	401.39	626.73
7/19/73	1,007.50	3.00	335.83	2.42	416.32	1,037.73
8/03/73	742.50	2.83	262.37	2.08	356.97	934.56
8/23/73	1,334.39	3.50	381.25	3.18	419.62	1,500.77
TOTAL	5,457.11	15.41	2,117.60	12.59	2,585.71	5,941.11
AVERAGE			353.90		433.11	

APPENDIX C. TABLE OF SPECIES AND GRADE COMPOSITION (INPUT) CU. FT.

SPECIES AND GRADE[1]	SAMPLE DATES											
	7/09/73		8/06/73		8/13/73		8/19/73		8/23/73		9/03/73	
	PV[2] cu. ft.	%TPV[3]	PV cu. ft.	%TPV	PV cu. ft.	%TPV	PV cu. ft.	%TPV	PV cu. ft.	%TPV	PV cu. ft.	%TPV
ASH------Grade 1	-	-	-	-	-	-	-	-	-	-	-	-
Grade 2	-	-	11.85	4.7	-	-	-	-	25.19	12.2	-	-
Grade 3	-	-	1.58	.6	-	-	-	-	30.12	14.5	-	-
ASPEN----Grade 1	-	-	-	-	-	-	4.28	2.5	-	-	-	-
Grade 2	-	-	-	-	12.51	12.9	-	-	-	-	21.64	16.6
Grade 3	-	-	-	-	27.60	28.5	31.41	18.2	10.70	5.2	109.60	83.5
BASSWOOD-Grade 1	-	-	-	-	-	-	-	-	-	-	-	-
Grade 2	-	-	-	-	-	-	58.22	33.7	-	-	-	-
Grade 3	-	-	-	-	-	-	69.32	40.2	-	-	-	-
BEECH----Grade 1	-	-	-	-	-	-	-	-	-	-	-	-
Grade 2	5.65	10.3	46.31	4.99	-	-	-	-	4.22	2.0	-	-
Grade 3	19.30	35.3	18.4	2.0	-	-	-	-	27.74	13.4	-	-
CHERRY---Grade 1	-	-	-	-	-	-	-	-	-	-	-	-
Grade 2	-	-	-	-	-	-	-	-	9.99	4.8	-	-
Grade 3	-	-	-	-	-	-	-	-	.69	.3	-	-
ELM------Grade 1	-	-	-	-	-	-	-	-	-	-	-	-
Grade 2	-	-	-	-	-	-	-	-	4.66	2.2	-	-
Grade 3	-	-	-	-	-	-	-	-	14.58	7.0	-	-
MAPLE----Grade 1	7.48	13.7	4.28	1.7	-	-	-	-	-	-	-	-
Grade 2	-	-	46.12	18.4	14.33	14.8	-	-	11.59	5.6	-	-
Grade 3	22.18	40.6	121.51	48.4	7.39	7.6	9.29	5.4	67.74	32.7	-	-
OAK------Grade 1	-	-	4.28	1.7	-	-	-	-	-	-	-	-
Grade 2	-	-	10.19	4.1	-	-	-	-	-	-	-	-
Grade 3	-	-	-	-	-	-	-	-	-	-	-	-
PINE-----Grade 1	-	-	-	-	-	-	-	-	-	-	-	-
Grade 2	-	-	-	-	13.83	21.08	-	-	-	-	-	-
Grade 3	-	-	-	-	14.3	21.8	-	-	-	-	-	-
T O T A L	54.61	100%	251.11	100%	96.74	100%	172.52	100%	207.22	100%	131.27	100%

GRADE[1] = PA Bolt System PV[2] = Production Volume Sampled %TPV[3] = Percent Total Production Volume

APPENDIX D. LOG DIAGRAM FORM USED IN SUGAR MAPLE STUDY



Piece No.	Total Clear	Grade

APPENDIX E. MILL TALLY SUMMARY SHEET

BOLT NO.	DIA. CLASS INCHES	LENGTH CLASS INCHES	BD.FT. VOLUME INT. 1/4 INCH SCALE	BD.FT. ACTUAL VOLUME TALLY	BD.FT. CLASS VOLUME TALLY	NUMBER OF CLEAR FACES	NUMBER OF SQUARES	SQUARE YIELD BE DIMENSION GRADE					
								CLEAR	SELECT	COMMON	NO.2	NO.3	GRADE
1	12	72	30	36.56	23.52	2	13	3	5	-	1	4	2
2	13	72	40	40.32	25.32	2	14	5	3	-	3	3	2
3	15	48	38	36.48	32.44	3	19	15	2	-	-	2	1
4	17	48	47	38.40	29.12	3	20	9	6	-	4	1	1
5	12	72	30	14.40	11.84	0	5	2	2	1	-	-	4
6	13	72	40	28.80	20.52	3	10	3	2	-	5	-	1
7	9	72	15	17.25	7.04	0	6	-	1	1	2	2	4
8	10	72	20	17.28	11.16	2	6	-	-	1	5	-	2
9	15	72	55	57.60	45.80	3	20	10	3	3	4	-	1
10	14	72	45	43.20	28.80	0	15	6	2	3	2	2	4
11	12	72	30	31.68	23.04	4	11	2	4	2	3	-	1
12	13	72	40	48.96	37.52	3	17	8	4	1	3	1	1
13	12	72	30	20.16	16.80	3	7	3	2	1	1	-	1
14	10	72	20	17.28	13.36	1	6	3	1	-	2	-	3
15	9	72	15	11.52	6.72	2	4	-	1	2	1	-	3
16	11	72	25	25.92	18.48	2	9	3	2	1	3	-	2
17	10	72	20	23.04	16.64	0	8	-	5	1	2	-	4
18	12	72	30	23.04	14.56	1	8	2	1	1	4	-	3
19	11	72	25	20.16	9.44	1	7	-	1	3	2	1	3
20	12	72	30	23.04	18.32	1	8	4	2	1	1	-	3
21	13	72	40	37.44	31.36	3	13	7	3	2	1	-	1
22	11	72	25	14.40	13.04	3	5	3	1	1	-	-	1
23	10	72	20	14.40	9.84	2	5	1	2	-	2	-	2
24	12	72	30	34.56	18.76	0	12	3	1	2	3	3	4
25	11	72	25	23.04	19.68	4	8	3	5	-	-	-	1
26	10	72	30	20.16	18.00	2	7	5	-	2	-	-	2
27	9	72	15	11.52	7.36	3	4	-	1	1	2	-	3
28	10	72	20	11.52	6.00	2	4	-	1	-	3	-	2
						SUBTOTAL	271	100	63	30	59	19	

APPENDIX E. -- Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14
29	10	72	20	17.25	14.08	3	6	3	1	1	1	-	2
30	10	72	20	14.40	11.36	2	5	1	3	-	1	-	2
31	10	72	20	20.16	15.48	1	7	1	5	-	1	-	3
32	11	72	25	25.92	22.88	3	9	6	2	-	1	-	2
33	12	72	30	25.92	23.68	3	9	6	3	-	-	-	1
34	12	72	30	23.04	17.36	2	8	2	2	1	3	-	2
35	11	72	25	23.04	18.48	2	8	4	2	1	1	-	2
36	10	72	20	20.16	14.72	0	7	-	2	4	1	-	4
37	11	72	25	23.04	16.16	1	8	-	4	3	1	-	3
38	11	72	25	25.92	21.44	2	9	4	2	1	2	-	2
39	12	72	30	31.68	24.24	3	11	4	3	-	4	-	1
40	11	72	25	23.04	21.04	3	8	6	-	2	-	-	2
41	13	48	28	19.20	17.04	4	10	8	-	-	2	-	1
42	12	48	23	15.36	12.72	2	8	4	2	1	1	-	2
43	11	48	18	17.28	14.16	4	9	3	5	-	1	-	1
44	13	48	28	24.96	19.28	4	13	4	4	3	2	-	1
45	12	48	23	17.28	12.56	3	9	3	2	1	3	-	1
46	10	48	15	17.28	11.12	2	9	1	2	2	4	-	2
47	14	48	33	26.88	21.28	3	14	8	-	2	4	-	1
48	12	48	23	19.20	15.44	3	10	3	5	-	2	-	1
49	11	48	18	15.36	10.24	2	8	3	-	1	4	-	2
50	10	48	15	15.36	8.64	3	8	1	1	1	4	1	2
51	11	48	18	15.36	11.04	3	8	4	-	2	1	1	2
52	12	48	23	15.36	12.64	4	8	5	1	-	2	-	1
53	10	48	15	15.36	14.56	3	8	6	2	-	-	-	1
54	12	48	23	15.36	12.24	3	8	3	2	1	2	-	1
55	13	48	28	15.36	12.88	4	8	4	3	-	1	-	1
						SUBTOTAL	233	97	58	27	49	2	

APPENDIX E. -- Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14
56	14	48	33	26.88	22.24	3	14	9	1	2	2	-	1
57	13	48	28	17.28	12.08	2	9	4	-	-	5	-	2
58	12	48	23	24.96	15.52	2	13	4	-	4	4	1	2
59	10	48	15	15.36	9.92	3	8	3	-	-	5	-	2
60	11	48	18	15.36	8.72	3	8	2	-	-	6	-	2
61	13	48	28	15.36	14.40	4	8	6	1	1	-	-	1
62	9	48	10	9.60	9.44	4	5	5	-	-	-	-	2
63	9	48	10	13.44	11.52	3	7	5	-	1	1	-	2
64	10	48	15	15.36	8.48	2	8	1	1	-	6	-	2
65	13	48	28	19.20	18.64	4	10	7	2	-	1	-	1
66	14	48	33	30.72	18.40	3	16	6	1	1	6	2	1
67	13	48	28	28.80	25.12	4	15	8	5	1	1	-	P
68	13	48	28	26.88	14.08	1	14	1	2	1	10	-	3
69	13	48	28	23.04	20.32	4	12	8	2	-	2	-	1
70	13	48	28	23.04	17.20	4	12	6	2	-	3	1	1
71	12	48	23	21.12	16.40	3	11	4	4	2	1	-	1
72	10	48	15	17.28	14.00	4	9	7	-	-	1	1	1
73	11	48	18	17.28	13.60	4	9	3	4	-	2	-	1
74	12	48	23	21.12	15.68	3	11	4	3	1	3	-	1
75	13	48	28	23.04	9.76	1	12	-	2	-	9	1	3
76	13	48	28	30.72	18.72	4	16	9	-	-	2	5	1
77	11	48	18	15.36	10.80	3	8	2	2	1	3	-	2
78	12	48	23	24.96	14.32	1	13	3	1	2	5	2	3
79	13	48	28	26.88	15.60	4	14	4	3	-	4	3	1
80	17	48	48	36.48	33.76	4	19	15	2	1	1	-	P
81	16	48	43	38.40	33.20	4	20	13	4	-	3	-	P
82	15	48	37	36.48	30.56	4	19	12	2	1	4	-	P
83	16	48	43	38.40	31.04	3	20	9	7	1	2	1	1
						SUBTOTAL	340	160	51	20	101	17	

APPENDIX E. - Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14
84	18	48	55	46.08	34.48	3	24	9	7	4	1	3	P
85	19	48	63	49.92	30.16	4	26	5	3	3	14	1	P
86	11	48	18	17.28	9.04	2	9	1	1	1	6	-	2
87	11	48	18	19.20	12.80	3	10	3	-	-	7	-	2
88	12	48	23	23.04	21.44	3	12	10	-	2	-	-	1
89	16	48	43	28.80	26.56	4	15	13	-	-	2	-	P
90	12	48	23	11.52	9.28	4	6	2	3	-	1	-	1
91	11	48	18	15.36	10.48	2	8	3	1	-	4	-	2
92	10	48	15	17.28	9.32	2	9	-	1	3	5	-	2
93	12	48	23	21.12	15.84	3	11	4	3	1	3	-	1
94	12	48	23	19.20	13.04	4	10	4	1	-	5	-	1
95	11	48	18	17.28	16.64	4	9	7	2	-	-	-	1
96	14	48	33	24.96	22.40	4	13	10	1	-	2	-	P
97	13	48	28	17.28	14.16	4	9	8	-	-	1	-	1
98	11	48	18	17.28	14.24	4	9	6	-	1	2	-	1
99	17	48	48	30.72	23.92	3	16	7	2	-	7	-	1
100	16	48	43	32.64	30.32	4	17	15	-	-	1	1	P
101	15	48	37	30.72	25.60	3	16	10	1	2	3	-	1
102	14	48	33	21.12	15.84	3	11	6	-	1	4	-	1
103	13	48	28	17.28	10.64	2	9	2	3	-	3	1	2
104	13	48	28	15.36	12.16	2	8	4	2	-	2	-	2
105	11	48	18	17.28	8.96	2	9	-	1	4	3	1	2
106	11	48	18	19.20	12.56	2	10	3	2	1	3	1	2
107	12	48	23	26.88	19.04	3	14	7	-	1	6	-	1
108	11	48	18	17.28	13.84	3	9	6	1	-	1	1	2
109	11	48	18	17.28	12.80	4	9	4	2	1	1	1	1
110	12	48	24	15.36	8.16	3	8	1	-	1	6	-	1
111	11	48	18	17.28	9.44	2	9	1	-	3	5	-	2
						SUBTOTAL	325	151	37	29	98	10	

APPENDIX E. - Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14
112	10	48	15	17.28	11.76	4	9	4	2	-	3	-	1
113	12	48	23	23.04	15.12	3	12	4	1	3	4	-	1
114	13	48	28	19.20	14.32	4	10	5	-	2	3	-	1
115	14	48	33	24.96	21.28	4	13	9	-	2	2	-	P
116	13	48	28	15.36	10.24	3	8	1	2	3	2	-	1
117	12	48	23	23.04	16.16	4	12	4	2	2	4	-	1
118	11	48	18	17.28	9.04	4	9	2	-	-	7	-	1
119	15	48	37	30.72	23.44	4	16	6	2	4	4	-	P
120	13	48	28	21.12	18.96	4	11	7	3	-	1	-	1
121	12	48	23	19.20	15.52	4	10	6	-	2	2	-	1
122	11	48	18	17.28	14.88	4	9	7	-	-	2	-	1
123	13	48	28	17.28	16.08	4	9	8	-	-	1	-	1
124	14	48	33	24.96	22.00	4	13	9	2	-	2	-	P
125	13	48	28	19.20	13.76	4	10	5	-	2	2	1	1
126	12	48	23	17.28	8.64	3	9	1	-	3	4	1	1
127	11	48	18	13.44	9.76	3	7	2	2	1	2	-	1
128	14	48	33	23.04	21.20	3	12	9	2	-	1	-	1
129	13	48	28	17.28	16.08	4	9	8	-	-	1	-	1
130	12	48	23	21.12	14.80	4	11	4	2	2	2	1	1
131	13	48	28	21.12	19.76	4	11	8	2	1	-	-	1
132	13	48	28	23.04	20.80	3	12	9	1	1	1	-	1
133	12	48	23	19.20	14.64	3	10	5	1	1	3	-	1
134	14	48	33	24.96	23.52	4	13	11	-	2	-	-	P
135	11	48	18	17.28	15.44	4	9	7	-	1	1	-	1
136	11	48	18	17.28	13.92	4	9	4	3	-	2	-	1
137	12	48	23	23.04	19.12	4	12	8	1	-	3	-	1
138	15	48	37	28.80	23.04	3	15	9	2	1	2	1	1
139	17	48	48	34.56	28.24	4	18	9	4	-	5	-	P
						SUBTOTAL	308	171	34	33	66	4	

APPENDIX E. - Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14
140	14	48	33	26.88	17.60	2	14	4	-	3	7	0	2
141	13	48	28	26.88	18.32	1	14	3	5	-	6	-	3
142	13	48	28	23.04	17.68	4	12	6	2	-	4	-	1
143	12	48	23	9.60	6.24	2	5	2	-	-	3	-	2
144	12	48	23	21.12	16.88	3	11	5	2	1	3	-	1
145	14	48	33	23.04	19.12	4	12	8	1	-	3	-	P
146	13	48	28	23.04	16.64	1	12	3	3	2	4	-	3
147	12	48	23	15.36	14.40	4	8	5	3	-	-	-	1
148	11	48	18	15.36	12.40	4	8	4	2	1	1	-	1
149	12	48	23	15.36	11.28	4	8	3	2	-	3	-	1
150	13	48	28	19.20	17.20	4	10	7	2	-	1	-	1
151	17	48	48	23.04	21.52	3	12	9	2	1	-	-	1
152	16	48	43	32.64	24.24	4	17	6	2	7	2	-	P
153	15	48	37	26.88	20.80	3	14	5	5	-	4	-	1
154	14	48	33	13.44	7.76	0	7	1	1	1	4	-	3
155	15	48	37	26.88	21.36	4	14	7	2	2	3	-	P
156	16	48	43	28.80	23.60	4	15	8	2	1	4	-	P
157	19	48	63	32.64	30.48	4	17	13	3	-	1	-	P
158	17	48	48	36.48	32.96	4	19	13	3	2	1	-	P
159	15	48	37	28.80	23.84	4	15	11	-	1	3	-	P
					SUBTOTAL		244	123	42	22	57	0	
					TOTAL		1,730	802	285	161	430	52	

APPENDIX F. BOLT CONVERSION TIME STUDY TABLES FOR 5 1/2 INCH AND 2 1/4 INCH CANTS

FIGURE A.

$Y = a + bx$
y = Minutes
x = Diameter

OBSERVATIONS	5 1/2 INCH x RANDOM WIDTH CANTS DIAMETER CLASS FOUR-FOOT BOLTS						
	7"	8"	9"	10"	11"	12"	13"
1	1.80	1.10	.83	1.23	2.08	2.05	2.19
2	1.01	1.21	1.13	2.12	1.24	2.38	2.09
3	.84	.97	1.16	1.56	1.64	2.03	1.84
4	.73	.71	1.17	1.61	1.49	-	2.20
5	.58	1.00	.91	1.38	1.50	-	-
6	.55	.91	1.16	2.08	1.39	-	-
7	1.80	1.13	1.18	1.90	1.40	-	-
8	1.04	1.05	1.11	1.39	1.68	-	-
9	1.01	1.10	1.00	.90	1.97	-	-
10	.75	1.20	1.17	.85	1.30	-	-
MEAN MINUTES	1.01	1.04	1.08	1.50	1.57	2.15	2.08

$\bar{x} = 10$

$\bar{y} = 1.49$

$r = .9485$

$r^2 = .89969$

$a = -.6243$

$b = .2114$

$y = -.6243 + .2114(x)$

FIGURE B.

$Y = a + bx$
y = Minutes
x = Diameter

OBSERVATIONS	2 1/4 INCH x RANDOM WIDTH CANTS DIAMETER CLASS SIX-FOOT BOLTS						
	9"	10"	11"	12"	13"	14"	15"
1	2.55	2.40	2.52	4.12	5.58	3.66	-
2	2.30	2.15	3.11	3.17	2.87	4.77	-
3	2.36	2.79	2.60	3.40	2.92	-	-
4	-	2.58	3.10	2.41	-	-	-
5	-	3.03	2.90	-	-	-	-
6	-	2.59	2.67	-	-	-	-
7	-	2.32	2.76	-	-	-	-
8	-	2.13	-	-	-	-	-
9	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-
MEAN MINUTES	2.40	2.50	2.81	3.53	3.79	4.07	-

$\bar{x} = 12$

$\bar{y} = 3.18$

$r = .9792$

$r^2 = .9589$

$a = 1.068$

$b = .3697$

$\bar{Y} = 1.068 + .3697(x)$

FIGURE C.

$Y = a + bx$
y = Minutes
x = Diameter

OBSERVATIONS	2 1/4 INCH x RANDOM WIDTH CANTS DIAMETER CLASS FOUR-FOOT BOLTS							
	10"	11"	12"	13"	14"	15"	16"	17"
1	1.99	2.82	1.84	2.88	3.22	3.42	6.03	9.92
2	2.82	2.71	2.51	2.91	2.58	7.62	-	9.32
3	1.08	2.11	2.07	2.48	3.76	3.62	-	-
4	2.29	1.85	1.95	2.15	1.69	6.06	-	-
5	1.04	1.19	2.12	2.64	1.38	2.74	-	-
6	.87	1.25	2.02	2.27	1.90	-	-	-
7	.99	1.34	2.42	2.42	3.97	-	-	-
8	-	-	2.72	1.67	-	-	-	-
9	-	-	-	2.20	-	-	-	-
10	-	-	-	-	-	-	-	-
MEAN MINUTES	1.58	1.90	2.20	2.40	2.64	4.69	6.04	9.62

$\bar{x} = 12$

$\bar{y} = 2.144$

$r = .9957$

$r^2 = .99739$

$a = -1.00$

$b = .2620$

$\bar{Y} = -1.00 + .2620(x)$

APPENDIX G. RECOVERY DATA FOR 2 1/4 INCH x RANDOM WIDTH AND 5 1/2 INCH x RANDOM WIDTH CANTS

BOLT NO.	DIA. CLASS INCHES	BD.FT. VOLUME INT. 1/4 INCHES	BD.FT. TALLY VOLUME INCHES	COL. 4 ÷ COL. 3
89	6	5	9	180
20	7	5	7.6	152
57	7	5	7.1	142
87	7	5	5.4	108
92	7	5	7.1	142
95	7	5	6.0	120
106	7	5	8.8	176
109	7	5	8.5	170
116	7	5	9.6	192
118	7	5	7.4	148
				145%
33	8	8	11	138
49	8	8	6	75
75	8	8	8.8	110
88	8	8	10.1	126
93	8	8	8.8	110
97	8	8	10.1	126
104	8	8	8.8	110
107	8	8	9.9	124
108	8	8	9.9	124
112	8	8	11.5	138
113	8	8	10.1	126
121	8	8	10.4	130
122	8	8	9.9	124
				120%

1	2	3	4	5
17	9	10	9	90
53	9	10	11.5	115
65	9	10	8.5	85
73	9	10	10.1	101
74	9	10	11.5	115
82	9	10	19.8	198
90	9	10	11.8	118
94	9	10	8.8	88
100	9	10	14.5	145
102	9	10	11.5	114
103	9	10	12.9	129
114	9	10	11.8	118
115	9	10	11.5	115
				111%
16	10	15	14.3	95
21	10	15	14.8	99
39	10	15	23.0	153
47	10	15	20.0	133
56	10	15	17.2	115
58	10	15	14.3	95
59	10	15	13.1	87
62	10	15	14.5	97
63	10	15	11.5	77
64	10	15	15.8	105
71	10	15	12.9	86
72	10	15	12.8	57
76	10	15	11.8	79
80	10	15	12.9	86
81	10	15	13.1	87
83	10	15	11.3	75
91	10	15	10.4	69
96	10	15	11.5	77
119	10	15	13.1	87
				87%

APPENDIX G. - Continued

1	2	3	4	5
9	11	18	13.6	76
18	11	18	14.8	82
40	11	18	15.9	88
43	11	18	17.3	96
68	11	18	17.4	97
70	11	18	17.2	96
78	11	18	15.8	88
79	11	18	17.5	97
84	11	18	12.9	72
85	11	18	17.0	94
105	11	18	14.5	81
				88%
42	12	23	14.0	61
44	12	23	21.2	92
48	12	23	22.9	100
54	12	23	18.6	81
77	12	23	23.3	101
				87%
				MEAN = 106
7	9	15	17	113
15	9	15	13	87
27	9	15	12	80
		MEAN	14	93.3%
8	10	20	17	85
14	10	20	17	85
17	10	20	23	115
23	10	20	14	70
26	10	20	20	100
28	10	20	13	65
29	10	20	17	85
30	10	20	15	75
31	10	20	20	100
36	10	20	20	100
		MEAN	18.1	90.6%

APPENDIX G. - Continued

1	2	3	4	5
16	11	25	26	104
19	11	25	20	80
22	11	25	15	60
25	11	25	23	92
32	11	25	26	104
35	11	25	23	92
37	11	25	23	92
38	11	25	26	104
40	11	25	23	92
		MEAN	22.8	91.1%
1	12	30	37	123
5	12	30	15	50r
11	12	30	32	107
33	12	30	26	87
34	12	30	23	77
39	12	30	32	107
		MEAN	27.5	100.2%
6	13	40	29	73
12	13	40	49	122
21	13	40	38	95
		MEAN	38.7	96.7%
10	14	45	43	96
		MEAN	43	96%
9	15	55	58	105
4	17	47	39	83
		MEAN	48.5	94%

1	2	3	4	5
62	9	10	10	100
63	9	10	14	140
		MEAN	12	120
46	10	15	17	113
50	10	15	15	100
53	10	15	15	100
59	10	15	15	100
64	10	15	15	100
72	10	15	17	113
92	10	15	17	113
112	10	15	17	113
		MEAN	16	106.5%
43	11	18	17	94
49	11	18	15	83
51	11	18	15	83
60	11	18	15	83
73	11	18	17	94
77	11	18	15	83
86	11	18	17	94
87	11	18	19	106
91	11	18	15	83
95	11	18	17	94
98	11	18	17	94
105	11	18	17	94
106	11	18	19	106
108	11	18	17	94
106	11	18	17	94
111	11	18	17	94
118	11	18	17	94
122	11	18	17	94
127	11	18	13	72
135	11	18	17	94
136	11	18	17	94
148	11	18	15	83
		MEAN	16.5	91.09%

1	2	3	4	5
42	12	23	15	65
45	12	23	17	74
48	12	23	19	83
52	12	23	15	65
54	12	23	15	65
58	12	23	25	109
71	12	23	21	91
74	12	23	21	91
78	12	23	25	109
88	12	23	23	100
90	12	23	12	52
93	12	23	21	91
94	12	23	19	83
107	12	23	27	117
110	12	23	15	65
113	12	23	23	100
117	12	23	23	100
121	12	23	19	83
126	12	23	17	74
130	12	23	21	91
133	12	23	19	83
137	12	23	23	100
143	12	23	10	43
144	12	23	21	91
147	12	23	15	65
149	12	23	15	65
		MEAN	19.8	85.8%
41	13	28	19	68
44	13	28	25	89
55	13	28	15	54
57	13	28	17	61
61	13	28	15	54
65	13	28	19	68
67	13	28	29	104
68	13	28	27	96
69	13	28	23	82
70	13	28	23	82
75	13	28	23	82

1	2	3	4	5
76	13	28	38	107
79	13	28	27	96
97	13	28	17	61
103	13	28	17	61
104	13	28	15	54
114	13	28	19	68
116	13	28	15	54
120	13	28	21	75
123	13	28	17	61
125	13	28	19	68
129	13	28	17	61
131	13	28	21	75
132	13	28	23	82
141	13	28	27	96
142	13	28	23	82
146	13	28	23	82
150	13	28	19	68
		MEAN	20.9	74.7%
47	14	33	27	82
56	14	33	27	82
66	14	33	31	94
96	14	33	25	76
102	14	33	21	64
115	14	33	25	76
124	14	33	25	76
128	14	33	23	70
134	14	33	25	76
140	14	33	27	82
145	14	33	23	70
154	14	33	14	42
		MEAN	24.4	73.9%

1	2	3	4	5
3	15	38	37	97
82	15	38	37	97
101	15	38	31	82
119	15	38	31	82
138	15	38	29	76
153	15	38	27	71
155	15	38	27	71
159	15	38	29	76
		MEAN	31	81.5%
81	16	43	38	88
83	16	43	38	88
89	16	43	29	67
100	16	43	33	77
152	16	43	33	77
156	16	43	29	67
		MEAN	33.3	77.3%
4	17	48	38	79
80	17	48	37	77
99	17	48	31	65
139	17	48	35	73
151	17	48	23	48
158	17	48	37	77
		MEAN	33.5	69.8%
84	18	55	46	84
85	19	63	50	79
157	19	63	33	52
		MEAN	43	71.7%

$$\bar{y} = \frac{E9887}{n\ 119} = 83.08$$

APPENDIX H. SUMMARY OF GRADE RECOVERY BY DIAMETER AND NUMBER OF CLEAR FACES

DIA.	NUMBER OF OBSERVATIONS	NUMBER OF CLEAR FACES	% SQUARE YIELD BY DIMENSION GRADE				
			+90% CLEAR	+75% SELECT	+65% COMMON	+18" NO. 2	NO. 3
9	2	4	85.72	-	7.15	7.15	-
10	2	4	61.11	11.11	-	22.22	5.56
11	10	4	55.28	17.78	5.83	20.00	1.11
12	12	4	45.90	17.54	8.16	27.64	.76
13	18	4	61.83	13.78	5.36	14.76	4.27
14	6	4	73.61	8.01	5.13	13.25	-
15	5	4	60.59	9.57	10.24	17.50	2.10
16	5	4	65.71	9.02	9.57	14.53	1.18
17	3	4	65.79	16.18	5.26	12.77	-
19	1	4	76.47	17.65	-	5.88	-
	Weighted Mean		60.27	13.53	6.45	17.81	1.95
10	6	3	29.17	19.45	9.72	39.58	2.08
11	9	3	45.80	24.38	11.99	15.21	2.62
12	15	3	41.67	24.97	11.37	21.24	.74
13	6	3	44.39	21.63	8.81	25.17	-
14	3	3	52.98	4.46	11.61	26.79	4.17
15	2	3	55.00	14.17	10.84	16.67	3.34
17	3	3	54.58	19.72	2.78	21.25	1.67
	Weighted Mean		42.83	21.64	10.38	23.18	1.97

APPENDIX H. -- Continued

DIA.	NUMBER OF OBSERVATIONS	NUMBER OF CLEAR FACES	% SQUARE YIELD BY DIMENSION GRADE				
			+90% CLEAR	+75% SELECT	+65% COMMON	+18" NO. 2	NO. 3
9	2	2	-	25.00	37.50	37.50	-
10	9	2	22.15	28.77	9.35	39.74	-
11	9	2	23.95	12.87	12.84	49.23	1.11
12	9	2	31.19	15.94	14.94	29.17	8.76
13	5	2	26.90	18.81	4.76	43.02	6.51
14	1	2	40.00	13.33	20.00	13.33	13.33
15	1	2	35.71	35.72	-	28.57	-
	Weighted Mean		25.16	19.76	12.58	38.76	3.74
11	1	1	-	14.29	42.86	28.57	14.29
12	1	1	-	11.11	44.44	33.33	11.11
13	1	1	-	16.67	-	75.00	8.33
13	1	1	21.43	35.71	-	42.86	-
14	1	1	14.28	14.29	14.29	57.14	-
9	1	0	-	16.67	16.67	33.33	33.33
10	1	0	-	28.57	57.14	14.29	-
	Weighted Mean		5.10	19.62	25.06	40.65	9.58

APPENDIX I. GRADE RECOVERY BY BOLT GRADE (PA-BOLTS)

DIA. CLASS INCHES	BD.FT. ACTUAL VOLUME	BD.FT. CLEAR VOLUME	CLEAR VOLUME TALLY	PA-BOLT GRADE
14	25	23	92.0	P
14	25	21	84.0	P
14	25	22	88.0	P
14	25	24	96.0	P
14	23	19	82.6	P
MEAN			88.52	P
15	37	31	83.8	P
15	31	23	74.2	P
15	27	21	77.8	P
15	29	24	82.8	P
MEAN			79.65	P
16	33	30	90.9	P
16	29	27	93.1	P
16	38	33	86.8	P
16	33	24	72.7	P
16	29	24	82.8	P
MEAN			85.26	P
17	37	34	91.9	P
17	35	28	80.0	P
17	37	33	89.2	P
MEAN			87.00	P
18	46	35	76.1	P
19	50	30	60.0	P
19	33	31	93.9	P
MEAN			76.67	P

APPENDIX I. - Continued

1	2	3	4	5
10	15	15	100.0	1
10	17	14	82.4	1
10	17	12	70.6	1
MEAN			84.33	1
12	32	23	71.9	1
12	20	17	85.0	1
12	26	24	92.3	1
12	32	24	75.0	1
12	17	13	76.5	1
12	19	15	79.0	1
12	15	13	86.7	1
12	15	12	80.0	1
12	21	16	76.2	1
12	21	16	76.2	1
12	23	21	91.3	1
12	12	9	75.0	1
12	21	16	76.2	1
12	19	13	68.4	1
12	27	19	70.4	1
12	15	8	53.3	1
12	23	15	65.2	1
12	23	16	69.6	1
12	19	16	84.2	1
12	17	9	52.9	1
12	21	15	71.4	1
12	19	15	79.0	1
12	23	19	82.6	1
12	21	17	81.0	1
12	15	14	93.3	1
12	15	11	73.3	1
MEAN			76.38	1

1	2	3	4	5
13	29	21	72.4	1
13	49	38	77.6	1
13	37	31	83.9	1
13	19	17	89.5	1
13	25	19	76.0	1
13	15	13	86.7	1
13	15	14	93.3	1
13	19	19	100.0	1
13	23	20	87.0	1
13	23	17	73.9	1
13	31	19	61.3	1
13	27	16	59.3	1
13	17	14	82.4	1
13	19	14	73.7	1
13	17	16	94.1	1
13	21	20	95.2	1
13	23	21	91.3	1
13	23	18	78.5	1
13	19	17	89.5	1
MEAN			82.40	1
14	27	21	77.8	1
14	27	22	81.5	1
14	31	18	58.1	1
14	21	16	76.2	1
14	23	21	91.3	1
MEAN			76.98	1
15	58	46	79.3	1
15	37	32	86.5	1
15	31	26	83.9	1
15	29	23	79.3	1
15	27	21	77.8	1
MEAN			81.36	1

1	2	3	4	5
16	38	31	81.6	1
17	39	29	74.4	1
17	31	24	77.4	1
17	23	22	95.7	1
MEAN			82.50	1
9	10	9	90.0	2
9	13	12	92.3	2
MEAN			91.15	2
10	17	11	64.7	2
10	14	10	71.4	2
10	20	18	90.0	2
10	12	6	50.0	2
10	17	14	82.4	2
10	14	11	78.6	2
10	17	11	64.7	2
10	15	9	60.0	2
10	15	10	66.7	2
10	15	9	60.0	2
10	17	9	52.9	2
MEAN			67.40	2
11	26	19	73.1	2
11	26	23	88.5	2
11	23	19	82.6	2
11	26	22	84.6	2
11	23	21	91.3	2
11	15	10	66.7	2
11	15	11	73.3	2
11	15	9	60.0	2
11	15	11	73.3	2
11	17	9	52.9	2
11	19	13	68.4	2
11	15	11	73.3	2
11	17	9	52.9	2

1	2	3	4	5
11	19	13	68.4	2
11	17	14	82.4	2
11	17	9	52.9	2
MEAN			71.54	2
12	23	17	73.9	2
12	15	13	86.7	2
12	25	16	64.0	2
12	10	6	60.0	2
MEAN			71.10	2
13	40	25	62.5	2
13	17	12	70.6	2
13	17	11	64.7	2
13	15	12	80.0	2
MEAN			69.45	
14	27	18	66.7	2
9	12	7	41.2	3
9	12	7	53.3	3
9	12	7	58.3	3
MEAN			50.93	3
10	23	17	73.9	3
10	20	15	75.0	3
10	17	13	76.5	3
10	20	16	80.0	3
MEAN			76.35	3

APPENDIX I. - Continued

1	2	3	4	5
11	20	10	50.0	3
11	23	16	69.6	3
MEAN			59.80	3
12	23	15	65.2	3
12	23	18	78.3	3
12	35	19	54.4	3
12	25	14	56.0	3
12	14	12	85.7	3
MEAN			57.90	3
13	27	14	51.9	3
13	23	10	43.5	3
13	27	18	66.7	3
13	23	17	73.9	3
MEAN			59.00	3
14	43	29	67.4	3
14	13	8	61.5	3
MEAN			64.45	3

APPENDIX I. - Continued

STATISTICAL TABLE FOR BOLT GRADES - FOUR-FOOT BOLTS ONLY

GRADE	n	Σy	$\bar{y}$	s^2	$s\bar{y}$	.99 CONF. INTERVAL	
						LOWER	UPPER
Prime	21	1,764.80	84.18	73.80	3.514	82.01	86.35
1	20	1,615.70	80.79	85.65	4.283	78.07	83.51
2	25	1,703.80	68.15	128.22	5.129	65.29	70.01
3	20	1,282.20	64.11	160.52	8.026	59.00	69.22

APPENDIX J. PENNSYLVANIA BOLT GRADES AND PRICES, JUNE 18, 1971

Prime	Clear and free of all visable defects, 14" and larger, except that bolts 18" and larger may have one defect. Not over 10% scale deduction due to rot, sweep, etc.
#1	Three clear faces, 12" and larger, except that 10" and 11" clear bolts will be accepted. Not over 20% scale deduction due to rot, sweep, etc.
#2	Two clear faces, 10" and larger, except that 8" and 9" clear bolts will be accepted. Not over 30% scale deduction due to rot, sweep, etc.
#3	One clear face, 8" and larger, not over 50% scale deduction due to rot, sweep, etc.

All bolts must be cut 64", scaled as 5'.

We use the International 1/4" Log Rule, and scale in accordance with the U.S. Forest Service Scaling Practices.

	PRIME	#1	#2	#3
H. Maple	$150/M	$125/M	$ 80/M	$ 60/M
Ash	$150/M	$125/M	$ 80/M	$ 60/M
S. Maple	$125/M	$100/M	$ 60/M	$ 45/M
Cherry	$125/M	$100/M	$ 60/M	$ 45/M
Birch	$ 80/M	$ 60/M	$ 45/M	$ 30/M
Oak	$ 95/M	$ 65/M	-------	-------
Hickory	$ 80/M	$ 50/M	-------	-------

Prime and #1 Hard Maple bolts must be heavy to sapwood and reasonably free of mineral. #2 and #3 logs will accept unlimited brown heartwood and some mineral.

All grades of Soft Maple will accept unlimited brown heartwood, black heart and mineral scaled out.

Logs may be delivered Manday through Friday, 7:00 A.M. to 2:30 P.M. or anytime if you have your own loader.

Logs delivered Friday through Tuesday will be paid for on the following Friday or by mail.