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A COMPARATIVE ANALYSIS OF
TWO LUMBER PRODUCTION SYSTEMS: THRASHER THIN BLADE
VERSUS A CONVENTIONAL MILL OPERATION

By

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B.S., University of Montana, 1972

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for the degree of Master of Science
In Business Administration

UNIVERSITY OF MONTANA
1973

Approved by:

[Signatures]

Date June 1, 1973
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CHAPTER I
INTRODUCTION

In Western Montana, the forest products industry supports 43 per cent of the population, either directly or indirectly, and generates 51 per cent of the personal income (Johnson, 1972).

Just as Western Montana is dependent on the timber industry, the timber industry is dependent on the availability of timber. The volume of timber that can be cut in any year is dependent on the number of acres available for harvesting (at a fixed level of management) and any reduction in acreage will have a corresponding effect on timber production and thus on the economy of Western Montana.

The individual mill owner faces stumpage prices that are rising faster than the market value of lumber. The mill owner must become more efficient, and the Thrasher system of thin-blade precision sawing may offer an opportunity to increase efficiency and profitability of the sawmill (Thrasher 1972).

Until recently, the woods products industry and the
Forest Service were primarily concerned with the harvesting of timber in the most economical way for the short run. The logging pressure on the national forests has increased substantially during the past 25 years. Between 1952 and 1969, total timber harvested in the Western states showed an increase of 35 per cent. During the same period, timber cutting on Western National forests increased from 3,855 million board feet to 9,798 million board feet, or 154 per cent (Wikstrom and Hutchison, 1971). Sixty per cent of the wood harvested in Montana comes from the national forests (Johnson, 1972).

During the past decade, changes in attitudes by the American public have resulted in legislation and directives that may have serious repercussions for many in the forest products industry. The Multiple Use Act recognizes that our national forests have important uses other than timber. (1960). The American public has increased its demands for more recreation land, more wilderness areas, better harvesting methods, and a reduction or total elimination of clearcutting on the national forests. The end result is an estimated reduction in the allowable cut by the Forest Service of 22 per cent. (M. Johnson, 1972).

In 1963, the allowable cut for the lands comprising the Ninth District Federal Reserve system was approximately
455 million cubic feet with an estimated growth rate of 320 million cubic feet and a reservoir of 17 billion cubic feet of standing timber (Nelson, 1963). The allowable cuts exceeded the current growth rate by 135 million cubic feet.

The figures quoted by Nelson are not actual but estimated volumes. With estimates such as the current annual growth of 320 million cubic feet, it must be remembered that changes in the intensity of management can alter the figures drastically. If the apparent level of overharvesting continues, the timber reservoir will be completely depleted in 126 years. When Edgar T. Ensign conducted the first survey of Western Montana Forests in 1887 for the United States Department of Agriculture, he was appalled at the amount of timber being harvested in the Missoula area and felt certain the supply would be exhausted in 15 years (1888).

An interesting figure developed by Nelson is the estimated 155 million cubic feet of logging and mill residue. One-hundred fifty-five million cubic feet of solid wood could be processed into approximately 900 million board feet of lumber by a conventional mill operation (155 MMCF x 12 BF/Cubic Foot). 

\[
\frac{155 \text{ MMCF} \times 12 \text{ BF/Cubic Foot}}{2(\text{avg. recovery})}
\]

of the 1963 allowable cut would remove 100 million cubic feet of standing lumber and 600 million board feet of lumber from the economy of the Ninth Federal Reserve District.
The projected 22 per cent reduction in timber to be harvested is expected to drive the stumpage value of timber higher. The mill owners can be expected to try to continue to operate their miles at the present or higher levels of production. With a smaller supply of logs, the increased competition for the available logs will drive the stumpage prices higher (Johnson, 1972). The higher stumpage prices will make the selling and harvesting of timber more attractive to small woodlot owners (Bolle, 1960). However, the total board foot volume available from private woodlots cannot compensate for the volume of timber to be removed from the market by the Forest Service (Setzer and Wilson, 1970). In the Rocky Mountain States, national forests accounted for 500 million of the 800 million cubic foot volume of round wood products in 1966 (includes posts, poles, veneer, lumber, etc.). In Montana, national forests accounted for 59.4 per cent of the round wood usage in 1966. Non-industrial private resources contributed less than 10 per cent for the Rocky Mountain region and 15 per cent for Montana (Setzer and Wilson, 1970).

The price paid for stumpage by the mills has increased drastically over the past decade. In 1961, the national average was $27.60 for Douglas fir (Pseudotsuga menziesii) and $12.10 for ponderosa pine (Pinus ponderosa) per thousand board feet (MBF). In 1969, the national average for Douglas fir was $82.20 MBF and $71.00 MBF for ponderosa pine (1971

The difference between the price changes for lumber and stumpage have been just as dramatic in Western Montana. The wholesale price increase for ponderosa pine lumber was 26 per cent from the 1954-55-56 base to August of 1971. The Douglas fir-larch price in August of 1970 was 20 per cent lower than the 1957-58-59-60 base price. By November, 1972, Douglas fir-larch was 31.47 per cent above the base price and ponderosa pine was 57.42 per cent higher than the base price (WWPA, December, 1972). Stumpage prices increased 250 per cent for Douglas fir and 500 per cent for ponderosa pine between 1960 and 1970.

While the prices for stumpage were rising faster than the prices for lumber in the Rocky Mountain States, the number of active mills was rapidly declining. From 1962 to 1966, the number of active mills decreased 24 per cent (864 to 657) in the Rocky Mountain States (Setzer and Wilson, 1970). In Montana, 333 mills were active in 1956 (Wilson, 1958); by 1966, only 148 mills remained (Setzer and Wilson, 1970). Large mills increased in number by 11
(10 MMBF or more per year), while small mills (less than 1 MMBF per year) decreased by 143 and medium-size mills decreased by 53 (Setzer and Wilson, 1970). While the total number of mills in Montana decreased 56 per cent between 1956 and 1966, total lumber production increased 8.6 MMCF, an increase of 33 per cent (Setzer and Wilson, 1970). Round wood products increased 79 per cent in Montana between 1953 and 1966 (Setzer and Wilson, 1970).

It is evident from the above data that the small and medium-size mills are rapidly being forced out of the industry. Several of the small mills still active have been purchased by larger firms. The December, 1969, issue of Forest Industries magazine listed some 200 mergers and acquisitions, all related to the forest products industry, that occurred during the previous 24 months. Many of the mergers were large firms diversifying into other fields. However, many others were large firms acquiring smaller firms. Holmes believes that the motivating forces behind the acquisitions were a combination of the need for more timber (timbered lands and timber cutting contracts bought with the mill) and the increase in the acquiring firm's stock price by absorbing the small firm's profits (1970). The more efficient, profitable, and successful the small mill, the better candidate the small mill is for a merger.

The close correlation between the increase in stumpage
price and reduction in the number of active mills leads to
the conclusion that the smaller, less efficient, marginal
operator tends to be forced out of the industry when a
raise in stumpage price occurs. Many of the more success­
ful small mills are absorbed by large firms, tending to
increase the pressure on the remaining small and medium­
size mills. The smaller mills are at a definite disadvan­
tage when trying to compete with the large firms, especially
in a declining market. The large mills have economies of
scale, better credit sources, more and better channels for
selling finished products, and capital of sufficient quantity
to diversify (Holmes, 1970). The large mills can make better
use of waste material and can better afford large deposits
on Forest Service logging contracts (Bolle, 1960).

If the reduction in U. S. Forest Service timber sales
occurs as expected, the medium-size and small mill owners
have four choices as to future courses of action. These
are:

1. The mill owner can sell his mill to a larger
company complete with stumpage contracts and
possible commercial forest land and remove
himself from the industry.

2. The mill owner can close his mill until
conditions become more favorable.

3. The mill owner can continue to operate at present or higher levels of production and try to minimize losses until conditions improve.

4. The mill owner can change his production process to a more efficient operation in order to increase his margin or sell his mill (as in alternative #1) and build a more efficient mill.

This paper concerns itself with the last alternative, developing a more efficient mill. The Thrasher system of thin-blade precision sawing is analyzed and compared to a conventional mill now operating in Western Montana (Thrasher, 1972).

The problem facing the mill owner is a simple one: survival. The small operator can neither afford short periods of unprofitable operation nor the equipment necessary for efficient use of waste material to help maintain profits in periods of rising stumpage costs or falling lumber prices. The smaller independent operator's higher cost of capital, smaller resources, limited sources of funds,
etc., will force him to close if he cannot remain as efficient as the larger firms.

In Chapter Two the Thrasher system of manufacturing is briefly explained along with other efforts at reducing the waste produced by sawing logs into lumber. The question concerning the Thrasher system is not whether the system will reduce waste, but how much of the saved material will be in the form of lumber rather than chips in order to justify the additional expense of converting to this method of production.

In order to compare and estimate the value of the Thrasher system, a conventional mill was first evaluated. The conventional mill is representative of mill operations in the Western Montana area. The total costs, production levels, name and location of the mill have been altered at the request of the owner(s). However, the per unit costs have not been changed. Chapter Three describes the conventional mill and some of the problems facing the mill owner(s).

Two identical mills receiving the same log mix can generally be expected to operate at different levels of productivity and efficiency. The variations are due to the large number of judgments necessary by the head sawyer,
graders, and resaw operators, not to mention the effect of different management personnel on production.

If the human element leads to different results in the manufacturing of lumber for identical production processes, then comparing two dissimilar systems requires a vehicle that can eliminate the human element if only the equipment is to be evaluated. A computer model that makes the decisions of the head sawyer while holding lumber grade constant would reflect the efficiency of the production system. Such a model is described in Chapter Four along with other models and current research being conducted in the fields of computer science and operations research as applied to the forest products industry.

The results of the simulation of the Thrasher and conventional production systems are discussed in Chapter Five. Since the model is designed to maximize the value of the lumber produced rather than the amount of lumber produced, the results are expressed in dollar figures. This feature of the model enables a direct comparison of the two production systems.

Chapter Six is a summary of the paper and the conclusions and recommendations of the author.
CHAPTER II

DESCRIPTION OF THE THRASHER SYSTEM:
AN EFFORT TO REDUCE WASTE

Since the beginning of the forest products industry, efforts have continuously been made to make the manufacturing process more productive and efficient. The first sawmills in the United States were reportedly built at Jamestown, Virginia, in 1625, and at Berwick, Maine, in 1631 (Brown & Bethel, 1958). Sawmills used the water wheel as a source of power for almost two hundred years, switching to steam in the early nineteenth century. The change to steam enabled mills to become more productive and created a need for better equipment. Prior to the invention of the steam engine, most sawing was done by hand using pit saws. Water wheels were primarily used to drive gang saws and sash saws. The steam engine provided a steady source of power that enabled the mills to employ a circular saw with a great deal of success (Brown & Bethel, 1958).

The band saw was invented in England in 1808. Band saws reduced waste by allowing a narrower kerf and facilitated the cutting of larger diameter logs. Early band saws created serious maintenance problems until the tech-
nology of welding and the development of better metals provided a more dependable saw.

Recent attempts at improving production and reducing waste have met with varying degrees of success. E. L. Bryan experimented with both high energy water jets and a laser beam in order to reduce waste. (1963). Neither proved effective. Difficulties encountered in developing equipment capable of producing water jets of sufficient force to cut wood hampered an evaluation of the potential of such a system. The laser beam used by Bryan could not penetrate more than 0.060 inches of wood due to a relatively low-power source (1963). However, the kerf was narrow, 0.012 inches, and the cut was extremely smooth with little discolorization of the wood. McMillin and Harry had far better success with the laser (1971). Among the advantages McMillin and Harry found when using the laser were: no sawdust was created; complicated patterns were easily cut; cut surfaces were very smooth; noise was minimal; there was no tool wear; and no reaction forces were exerted on the work piece (1971). However, the laser could only be used on one-inch boards. Also, McMillin and Harry deemed this process too expensive to operate except on specialty items needing highly accurate cuts (McMillin and Harry, 1971).

Henry Huber linked a punch press operation to a com-
puter to obtain maximum utilization of boards while stamping out furniture patterns (1971). The computer gave a 12 percent increase in recovery, enough to pay for the computer at high lumber and furniture prices (Huber, 1971). No value judgment was made by Huber regarding the punch press equipment.

E.W. Thrasher has developed a system that closely follows current production processes (1972). Unlike the other attempts cited above, Thrasher has adopted present methods of production and has applied technological advances in engineering to develop thin radial saws and more accurate guides for the saws, along with improved methods of positioning and holding the logs in place on the head rig (1972).

The primary advantages of the Thrasher system are a reduction in the kerf, smaller allowances for planing, and virtual elimination of the need to allow for rough cuts and the variation of cut (See Exhibits 1 and 2). Another, and probably equally important factor, is the close similarity between the Thrasher system and the conventional types of operations. The Thrasher system does not require a radical change in procedure, personnel, or in management. Indeed, segments of the Thrasher system can be easily integrated into any existing mill. For example, the Thrasher gang saws can be placed behind any type of head-rig and
COMMOM INDUSTRY PRACTICE
NOMINAL  
3" X 4"

function properly. Or, the Thrasher head rig can be employed without any other changes being necessary. This "modular" feature of the Thrasher system enables a mill owner to improve his operation one step at a time. A total commitment is not necessary and the smaller operator can convert gradually if finances are limiting. The mill owner can also convert the most inefficient segment of his mill first and wait until the conversion generates enough savings to finance the next step in conversion.

It must be noted that the thin radial saw is limited to cuts of 10 inches in depth. When larger cuts are required on the head rig, the Thrasher system employs band saws. Thrasher refers to his band saw system as a "Rapid Response, Low Inertia, Strain and Guide System" (Thrasher, 1972). The band saw differs little from other types of band saws now on the market. The chief advantage of Thrasher's band saw head rig is in the set works that holds the log in position while the log is being cut.

The Thrasher system employing radial saws directly reduces the volume of sawdust and planer shavings produced when manufacturing logs into lumber. Sawdust has little economic value, and until recently was disposed of by burning. At present sawdust has some value as fuel and, in integrated forest products' operations, as raw material
for pulp and paper manufacturing. Many other low value uses for sawdust have been developed, such as bedding for cattle and production of Presto Logs. However, the value of sawdust does not approach the value the same volume of material would have in the form of lumber (Cummins, 1972, Hollack, 1968).

Thrasher estimates the average kerf used in the United States is between 5/16 (0.3125 inches) and 11/32 (0.3438 inches) of an inch. (1972). Hollack estimates that on a national basis circular saw kerfs will average about 5/16 of an inch and band kerfs average perhaps 5/32 of an inch, with about half of all saws being band saws (1972, 1968). Hollack goes on to state:

Sawdust production in the United States is in excess of 15 million tons per year. This is equivalent to a single pile, triangular in cross-section and 50 feet in height, 100 feet in width at the base, and nearly 200 miles in length.

Another way of viewing the volume of sawdust produced yearly in the United States is that one per cent of the sawdust salvaged and converted into softwood lumber would supply enough lumber to build 7,500 homes by 1968 FHA specifications (Cummins and Culbertson, 1972).

It would be wrong to assume that all savings in saw-
dust resulting from reducing the size of the kerf would end up as lumber. Cutting a log into lumber is, in essence, removing rectangular objects from a circle. Fitting a number of rectangles in a circle results in areas of the circle that are not covered. These unused areas of a log are converted into wood chips. Wood chips are currently selling for approximately $4.61 per unit (220 cubic feet) and cost roughly $2.78 to manufacture (Forest Service Manual, pp. 2423.31-2423.52, Feb., 1973).

In order to determine the volume of sawdust that will become chips and the volume that will become lumber by converting to the Thrasher system, a computer model was employed. The model calculates the volume of sawdust, chips and lumber produced by each kerf size and for each log diameter. The model is more fully explained in the section entitled "The Evaluation of Kerf Reduction."

Most other attempts at reducing the size of the kerf have been centered on the band saw. The only other significant work done on reducing the kerf of circular saws has been conducted by Hiram Hollack (1968). Hollack has developed a "taper-tension saw blade" that is designed for cutting boards only and cannot be used for cutting logs or cants. The saw is primarily used for hardwoods and has a kerf of 6/32 of an inch. The average kerf for this type of radial
saw is 10/32 of an inch. Hollack's saw reduces the allowance for variation as well as the kerf and provides a smoother cut than obtained with other saws (Hollack, 1968).
CHAPTER III

DESCRIPTION OF THE CONVENTIONAL MILL

In order to determine the exact advantages of the Thrasher system, it was first necessary to investigate a typical mill and establish estimates of the cost of manufacturing, volume of wood needed to produce given sizes of lumber, and the possible changes in other parts of the plant by introducing the Thrasher system.

Several mills were visited and one was chosen as representative of the average mill. The head rig kerf is 0.375 of an inch and the edger kerf is 0.190 of an inch (Exhibit 5, Appendix). The allowances for planing, variations and roughness of cut averaged closer to what was assumed "average" than other local mills. This data was used in the simulation model.

The mill studied is located in the South Central part of Western Montana. The mill primarily manufactures studs, occasionally running special orders of boards and rough green dimension lumber.

The mill employs 22 men on each of two shifts on the
green end (saw milling department). The green end includes yarding of logs, log breakdown into lumber, and sorting, stacking, and inventoried lumber in the yard as well as chip manufacturing and sawdust disposal. The planer department includes planing of the lumber, grading and sorting, and shipment of the finished products (including chips). The planer division employes 14 men on each of two shifts. Approximately 75 per cent of the lumber sold is surfaced on four sides, double-end trimmed, and with eased edges. The remainder is sold as rough green lumber.

During the past several years the mill has been faced with sharply rising costs. The elimination of the teepee burner, scheduled for late 1973, will add considerably to the manufacturing cost. No local sawdust market exists for the mill and the mill owner(s) are currently considering some type of burner system similar to the hog fuel burners.

Labor costs have increased from an average of $3.89 per hour, per man in January, 1969, to $5.08 per hour, per man in January, 1973. The employee costs include wages, insurance, taxes, pension contributions, and employee medical insurance plans.

The cost of manufacturing includes all costs from the time logs arrive at the mill (including scaling and un-
loading) until, and including, shipping. The cost figures are derived from company records. A rough sampling of work performance and volume of production was made during two visits to the mill. The calculated yearly production was within 10 per cent of the mill's book figures. Part of the discrepancy (sampling figure was larger than the book figure) was due to the mill having a large percentage of shrinkage. This shrinkage was deemed to be mainly a result of inventory and stacking practices. Each load of lumber stacked at the green chain was supposed to have twenty-three pieces of lumber per tier. The tiers counted while establishing a production figure ranged between twenty-one and twenty-four per tier. Several stacks of green lumber being air dried or awaiting planing collapsed. Such a collapse will result in broken, and possibly, decayed, or stained lumber.

During both visits to the mill the Guidelines for the Study of Sawmill Performance was used as a guide in evaluating the mill (Dobie, 1972). The mill and planer operations satisfactorily met the criteria established by Dobie with the exception of the aforementioned stacking practices and the debarker. The debarker was not functioning properly and left a large amount of bark on the logs.

The average diameter of the logs received by the mill
during 1972 was estimated by the plant manager to be about 13 1/2 inches. The plant manager stated that the average diameter was steadily decreasing and he felt that it would soon level out to an average of approximately 11 inches. The decrease in log size means higher costs. The processing of small logs versus larger logs for the same board foot content increases manufacturing costs due to the larger number of logs that must be handled and the slower production of lumber (Nelson, 1963).

At present, the mill owner is negotiating the purchase of a mill designed by E. W. "Al" Thrasher. The new mill will be located in Western Montana and is currently undergoing final adjustments in California before being shipped to Montana.
CHAPTER IV

THE EVALUATION OF KERF REDUCTION:

THE SAWMILL SIMULATION MODEL

One of the most important and complex jobs in a sawmill is that of the head sawyer. When logs are cut into lumber, the number of decisions regarding each individual cut is enormous. The head sawyer must decide where to open the log and the relative value of each piece of lumber. He must also decide the effects that grain, taper of the log, defects, etc., will have on the lumber's value. Until recently, the only ways to evaluate a head sawyer's performance were in terms of the profitability of the firm or an evaluation by another sawyer.

The advent of the computer provides an excellent tool for comparing the ability of a sawyer to achieve optimal recovery. In time, it is probable that the sawyer will be replaced by computers (Hollack and Bulgrin, 1970). Several researchers are currently working on simulation models that make the same fundamental decisions as the head sawyer.

Reynolds developed a sawmill simulation model that is designed to obtain the maximum yield from a log (1970).
The model takes into account the position of defects as well as diameter, sizes of boards desired, kerf, and the choice of the sawing pattern to maximize yield while minimizing the number of defects in the boards.

Hallock and Lewis developed a program that evaluated the effect of different sizes and positions for the first opening cut of a log (1971). Hallock also developed a model to evaluate the effect that reducing kerf would have on the lumber yield of various size logs (1962).

McDonald, Cox, and Bulgrin have developed a system to locate lumber defects by ultrasonics (1969). Hallock and Bulgrin used a similar scanner system, coupled with a computer, that measures boards, locates defects, chooses the best sawing pattern, and can give visual instructions to the worker or can set the saws automatically (1970).

Bulgrin estimates that the savings generated by the experimental computer system will be three to four times the cost (Bulgrin, 1971). Bulgrin is currently studying the application of sensors and computers for the evaluation of wood quality (Progress Report, 26 Sep, 1972).

Richards is currently working on a model on hardwood log breakdown (1971). Peter and Bamping developed an


Numerous other simulation models have been developed for production scheduling and forestry field work. While conducting interviews for my forestry thesis with small and medium-size mill owners, I found most owners would not invest in a computer system due to the expected high cost (Shepherd, 1972).

The simulation model used in the evaluation of the Thrasher system was developed by Leo Cummins and Denny Culbertson (1972). The model does not maximize the volume of lumber obtained from a log, but maximizes the log yield value. Attempting to convert a log into the maximum volume of lumber that can be obtained would result in producing many small-size boards that have far less value than larger pieces of lumber.

Lumber is sold by grade as well as by size. The grade
of lumber is based on the type, size, and number of defects found in the lumber. Common defects are knots, splits, checking, stain, and decay. The best grades of wood are obtained from the outside area of a log referred to as the sap wood. The inner log, called the heartwood, generally contains far more defects. The defects are not as serious or "degrading" to dimension lumber (two inches thick) as they are to boards (one inch thick lumber). For each thousand board feet of lumber, dimension of the same grade is generally worth more money than boards (See Table I). The model, therefore, maximizes the volume of dimension lumber that can be obtained from the log (See Table II).

The model assumes the first cut in a log (opening face) is always made to obtain a board four inches wide (from side one). This assumption can be dropped or altered to cut another size of lumber, but an opening face of four inches should be retained. The first cut in a log determines the volume of wood remaining in a log. In essence, the remaining cuts depend on how much material was removed on the first cut of side one. Hallock and Lewis explored all logical choices for this first cut for such sawing procedures as center flitch cutting, centered sawline, and variable face opening, and found that cutting for an opening face of four inches resulted in the best lumber yield (1971).
TABLE I

CURRENT WHOLESALE PRICES
PER THOUSAND BOARD FEET
DOUGLAS FIR - RANDOM LENGTHS

For Week of 23 April to 30 April, 1973

<table>
<thead>
<tr>
<th>#3 and Better Common</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 x 4 $182</td>
</tr>
<tr>
<td>1 x 6 196</td>
</tr>
<tr>
<td>1 x 8 ... 183</td>
</tr>
<tr>
<td>1 x 10 183</td>
</tr>
<tr>
<td>1 x 12 203</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>#2 and Better Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 x 4 $204</td>
</tr>
<tr>
<td>2 x 6 202</td>
</tr>
<tr>
<td>2 x 8 193</td>
</tr>
<tr>
<td>2 x 10 213</td>
</tr>
<tr>
<td>2 x 12 212</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Posts, Beams &amp; Timbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 x 4 $205</td>
</tr>
<tr>
<td>4 x 6 205</td>
</tr>
<tr>
<td>4 x 8 210</td>
</tr>
<tr>
<td>4 x 10 210</td>
</tr>
<tr>
<td>4 x 12 220</td>
</tr>
<tr>
<td>6 x 6 220</td>
</tr>
<tr>
<td>12 x 12 225</td>
</tr>
</tbody>
</table>

Don West, Intermountain Company, Missoula, Montana.
TABLE II
SIMPLIFIED FLOWCHART OF SAWMILL SIMULATION MODEL

INPUT - DATA, KERF, WIDTH AND THICKNESS OF LUMBER, DIAMETER - CURRENT PRICES

CALCULATE AREA REQUIRED BY OPENING FACE AND BY CHOICE 1 ($H_j$, $j = 1$)

CALCULATE THE REMAINING AREA OF LOG, DIMENSIONS OF THE CANT, AND SIDES 3 AND 4

CALCULATE THE MAX. CHOICE ($H_i$) THAT CAN BE OBTAINED FROM SIDES 3 AND 4

PREDETERMINE THE DIMENSION LUMBER IN THE CANT

SUM VALUES OF CANT AND SIDES 1, 2, 3, AND 4 FOR CHOICE $H_i$

INCREASE $j$ OF $H_i$

$J = J + 1$

IS $J \geq 7$

NO

YES

CHOOSE $H_i$ THAT GIVES MAX. LUMBER VALUE

LIST LOG VALUE AND CUTTING SEQUENCE TO OBTAIN THE LUMBER
The sawing procedures used after the initial cut was made had less effect on the relative yield of the log than the choice of the size of the cut for opening face (Hallock and Lewis, 1971).

For logs between 9 and 14 inches in diameter, the sawyer has seven logical choices of cut for side two. The seven choices are referred to as \( H_j \) (\( j = 1, \ldots, 7 \)). Each choice, as with the opening face, will result in different volumes of the log being removed. Since dimension lumber is the most valuable lumber and is obtained from the center of the log, increasing the amount of lumber removed from side two will reduce the volume of the wood available for the dimension lumber (Exhibit 3). The seven choices are: cutting for a 4 or a 6-inch slab, a 1 x 6 or 1 x 4 board, a 2 x 4 or a 2 x 6 dimension, or cutting for a combination of a board and dimension. Cutting for any thickness larger than a two-inch dimension will result in reducing the material available for dimension lumber in the cant and sides three and four. In 13- and 14-inch logs, the cutting for dimension lumber on side two will often result in the width of the lumber cut being large enough for a 2 x 8 to be recovered from side two (Exhibit 3).

Once side two has been cut, the remaining dimensions of the log are calculated for each of the seven choices of cut
COMPARATIVE BREAKDOWN OF A 14-INCH LOG USING TWO DIFFERENT CHOICES OF CUT FOR SIDE 2

THRASHER MILL

A1 and A2 - Opening face; cutting for a 1 x 4 board, Side 1.

B1 - Cutting a 4" Slab, Side 2

B2 - Cutting for a 2 x 8 & 1 x 4, Side 2

C1 - Sides 3 and 4 are now removed to leave cant. Sides 3 and 4 are cut to produce a 1 x 12, 2 x 10, 2 x 4

C2 - Sides 3 and 4 are now removed to leave cant. Sides 3 and 4 are cut to produce a 2 x 8 and a 2 x 6
for side two. These dimensions measure the area available on the two remaining sides (sides three and four) and the cant. The dimensions of the cant are determined by the size of the cut on side two. These dimensions are subtracted from the remaining area of the log to determine the area available for lumber in sides three and four. The maximum size lumber is then removed from sides three and four, without reducing the size of the nominal cant.

The model then chooses the cutting sequence that will yield the largest value of lumber from the log (Exhibit 3) by exploring all possible cutting sequences and comparing their resultant values (Cummins and Culbertson, 1972).

Upon first inspection of the lumber prices in Table I, it seems as if two 1x8 boards would be worth more money than a 2x8 dimension. A 1x8 sells for $183 per thousand board feet, while a 2x8 sells for $193 per thousand board feet. One might assume that cutting for two 1x8's would generate $366 for the same volume of wood. This is due to the prices being quoted in one-thousand board feet (nominal sizes). Converting the prices per board foot volume of each size of lumber into cubic content per lineal foot and then multiplying by 1,000 gives an accurate relationship between the various nominal sizes of lumber. Table III is an end view of a piece of lumber worth X amount per area of wood
**TABLE III**

CONVERSION OF CURRENT LUMBER PRICES PER 1,000 BOARD FEET (MBF) TO LUMBER PRICES PER 1,000 LINEAL FEET (MLF)

<table>
<thead>
<tr>
<th>NOMINAL SIZE</th>
<th>PRICE PER BOARD FOOT (BF)</th>
<th>PRICE PER LINEAL FOOT (LF)</th>
<th>PRICE PER MLF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 x 4</td>
<td>$182</td>
<td>18.20$</td>
<td>6.00$</td>
</tr>
<tr>
<td>1 x 6</td>
<td>196</td>
<td>19.60</td>
<td>9.80</td>
</tr>
<tr>
<td>1 x 8</td>
<td>183</td>
<td>18.30</td>
<td>12.26</td>
</tr>
<tr>
<td>1 x 10</td>
<td>183</td>
<td>18.30</td>
<td>15.19</td>
</tr>
<tr>
<td>1 x 12</td>
<td>203</td>
<td>20.30</td>
<td>20.30</td>
</tr>
<tr>
<td>2 x 4</td>
<td>$204</td>
<td>20.40$</td>
<td>13.67$</td>
</tr>
<tr>
<td>2 x 6</td>
<td>202</td>
<td>20.20</td>
<td>20.20</td>
</tr>
<tr>
<td>2 x 8</td>
<td>193</td>
<td>19.30</td>
<td>25.67</td>
</tr>
<tr>
<td>2 x 10</td>
<td>213</td>
<td>21.30</td>
<td>35.57</td>
</tr>
<tr>
<td>2 x 12</td>
<td>212</td>
<td>21.20</td>
<td>41.40</td>
</tr>
</tbody>
</table>
multiplied by 1,000 feet. This procedure also accounts for the fact that lumber is sold in random lengths.

The output of the model is a dollar value plus a cutting sequence for manufacturing the log into lumber. The cutting sequence can either be expressed as a listing of cuts for each side or an end view diagram. (Exhibit 4).

The cutting of sides three and four could either be done on the head rig or by the gang saws along with the cant.

The simulation model allows the parameters of kerf, widths and thicknesses of lumber, diameter of logs, and the prices of lumber to be changed. Altering one parameter such as the kerf allows the model user to find the effect that various sizes of kerf have on the lumber yield. All parameters can be altered to evaluate a production system under optimal conditions. Changing the parameters to those of another system will give a comparison of the two systems. Not only does the model provide a technique for evaluating production systems, but it also allows a mill owner to evaluate the efficiency of his head sawyers.
EXHIBIT 4

BEST BREAKDOWN OF A 14" LOG USING THE THRASHER SYSTEM

CUTTING SEQUENCE

<table>
<thead>
<tr>
<th>SIDE 1</th>
<th>SIDE 2</th>
<th>SIDE 3</th>
<th>SIDE 4</th>
<th>CANT</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLAB</td>
<td>SLAB</td>
<td>SLAB</td>
<td>SLAB</td>
<td>FOUR 2 x 10 DIMENSIONS</td>
</tr>
<tr>
<td>1 x 4</td>
<td>2 x 6</td>
<td>2 x 6</td>
<td>2 x 6</td>
<td></td>
</tr>
<tr>
<td>BOARD</td>
<td>BOARD</td>
<td>DIMENSION</td>
<td>DIMENSION</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 x 8</td>
<td>2 x 8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DIMENSION</td>
<td>DIMENSION</td>
<td></td>
</tr>
</tbody>
</table>

VALUE OF 14" LOG IS $2601 MLF
CHAPTER V

RESULTS OF REDUCING KERF
AS CALCULATED BY THE SIMULATION MODEL

A test run was made for each manufacturing system using the simulation model developed by Leo Cummins. The selected log diameters were 10, 12, 13 and 14 inches. The logs were considered to be 16-feet long and without taper. The simulated sawing was done parallel to the central axis of the log.

Lumber values were those listed in Chapter V, Table III. The kerfs used for the Thrasher system were 0.125 inches on the head rig and 0.090 inches on the gang saws. For the conventional mill, 0.375 inches was used on the head rig and 0.190 inches on the gang saws, the width of the saws at the study mill.

Employing the conventional mill operation, the manufacturing process obtains 165.35 board feet of lumber from a 16-foot log which is 14 inches in diameter. On a 1,000 linear foot basis, this is a yield of $2,170. The seven possible choices of cut for side two and the subsequent values for sides three and four plus the value of the cant
are computed for each log diameter (Table IV). The cutting choice for each diameter is the sequence that yields the largest dollar value (Table V).

The same procedure was followed for the Thrasher system. The results of each choice of cut for side two is calculated in dollar values (Table VI). The maximum value is chosen and the board foot volume of a 16-foot log is calculated (Table VII). Using Thrasher's system of manufacturing, a 14-inch diameter log will yield $2,601 per thousand lineal feet and produce 202.67 board feet of lumber from a 16-foot log (Table VII).

It is fully realized that the grade of lumber is instrumental in determining the lumber's value. However, lumber grade is more a function of log grade than of the manufacturing process employed. Therefore, the lumber grade is held constant and equal for comparison of the two manufacturing systems.

Two other important variables are also not included in the calculations; taper in the log and wane in the lumber. The Cummins' model was altered slightly so that only the small-end diameter was used. This produces a right cylinder that extends the length of the log. In this manner, the taper was eliminated from the model as well as the consid-
TABLE IV

RESULTS OF SAWMILL SIMULATION MODEL USING THE CONVENTIONAL MILL OPERATION

LUMBER VALUE OF SIDES ONE AND TWO OBTAINED FOR EACH OF THE SEVEN CHOICES CUT FOR SIDE TWO

<table>
<thead>
<tr>
<th>CHOICE OF CUT (H) FOR SIDE TWO</th>
<th>14&quot; LOG</th>
<th>13&quot; LOG</th>
<th>12&quot; LOG</th>
<th>10&quot; LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIDE 1</td>
<td>$60.00</td>
<td>$60.00</td>
<td>$60.00</td>
<td>$60.00</td>
</tr>
<tr>
<td>SIDE 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H1</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
</tr>
<tr>
<td>H2</td>
<td>60.00</td>
<td>60.00</td>
<td>60.00</td>
<td>60.00</td>
</tr>
<tr>
<td>H3</td>
<td>98.00</td>
<td>98.00</td>
<td>98.00</td>
<td>98.00</td>
</tr>
<tr>
<td>H4</td>
<td>137.00</td>
<td>137.00</td>
<td>137.00</td>
<td>137.00</td>
</tr>
<tr>
<td>H5</td>
<td>202.00</td>
<td>202.00</td>
<td>202.00</td>
<td>202.00</td>
</tr>
<tr>
<td>H6</td>
<td>317.00</td>
<td>317.00</td>
<td>317.00</td>
<td>317.00</td>
</tr>
<tr>
<td>(1x4, 2x8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1x4, 2x8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1x4, 2x8)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1x4, 2x8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LUMBER VALUE OF CANT FOR EACH OF THE SEVEN CHOICES OF CUT FOR SIDE TWO</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<p>| H1                             | $414.00 | $414.00 | $256.70 | $202.00 |
| (1 - 2x12)                     |         |         |         |         |
| H2                             | 1423.00 | 1027.00 | 770.00  | 606.00  |
| (4 - 2x10)                     |         |         |         |         |
| H3                             | 1423.00 | 1027.00 | 770.00  | 606.00  |
| (4 - 2x10)                     |         |         |         |         |
| H4                             | 1027.00 | 1027.00 | 606.00  | 410.00  |
| (4 - 2x8)                      |         |         |         |         |
| H5                             | 1027.00 | 1027.00 | 606.00  | 410.00  |
| (4 - 2x8)                      |         |         |         |         |
| H6                             | 1027.00 | 808.00  | 606.00  | 410.00  |
| (4 - 2x8)                      |         |         |         |         |
| H7                             | 711.00  | 711.00  | 513.00  | 404.00  |
| (2 - 2x10)                     |         |         |         |         |
| (2 - 2x10)                     |         |         |         |         |
| (2 - 2x10)                     |         |         |         |         |</p>
<table>
<thead>
<tr>
<th>Side 3, 4</th>
<th>H₁</th>
<th>H₂</th>
<th>H₃</th>
<th>H₄</th>
<th>H₅</th>
<th>H₆</th>
<th>H₇</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$848.00</td>
<td>$749.00</td>
<td>$354.00</td>
<td>$262.00</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>(2x10, 2x10, (2x10, 2x8, (l - 2x8, (2x6, 1x4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2x4)</td>
<td>2x4)</td>
<td>1x6)</td>
<td>2x4)</td>
<td>2x4)</td>
<td>1x6)</td>
<td>2x4)</td>
</tr>
<tr>
<td>H₂</td>
<td>197.00</td>
<td>137.00</td>
<td>137.00</td>
<td>60.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1 - 2x4, (1 - 2x4)</td>
<td>(1 - 2x4)</td>
<td>(1x4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1x4)</td>
<td>1x4)</td>
<td>1x4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H₃</td>
<td>197.00</td>
<td>137.00</td>
<td>137.00</td>
<td>60.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1 - 2x4)</td>
<td>(1 - 2x4)</td>
<td>(1x4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H₄</td>
<td>197.00</td>
<td>137.00</td>
<td>137.00</td>
<td>60.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1 - 2x4)</td>
<td>(1 - 2x4)</td>
<td>(1x4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H₅</td>
<td>197.00</td>
<td>-----</td>
<td>137.00</td>
<td>-----</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>H₆</td>
<td>-----</td>
<td>-----</td>
<td>137.00</td>
<td>-----</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H₇</td>
<td>612.40</td>
<td>558.00</td>
<td>259.00</td>
<td>137.00</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>(2x10, 2x6)</td>
<td>(l8, 2x4)</td>
<td>(2x4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE IV (Continued)

LUMBER VALUES OF SIDES THREE AND FOUR OBTAINED UNDER EACH CHOICE OF CUT FOR SIDE TWO
<table>
<thead>
<tr>
<th>CHOICE OF CUT (H₁)</th>
<th>FOR SIDE 2</th>
<th>14&quot; LOG</th>
<th>13&quot; LOG</th>
<th>12&quot; LOG</th>
<th>10&quot; LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>$2170</td>
<td>$1972</td>
<td>$1025</td>
<td>$ 786</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>1937</td>
<td>1361</td>
<td>1164</td>
<td>846</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>1975</td>
<td>1459</td>
<td>1202</td>
<td>884</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>1618</td>
<td>1498</td>
<td>1077</td>
<td>727</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>1683</td>
<td>1289</td>
<td>1142</td>
<td>672</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>1404</td>
<td>1185</td>
<td>1257</td>
<td>732</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>1936</td>
<td>1887</td>
<td>1091</td>
<td>738</td>
<td></td>
</tr>
</tbody>
</table>

**BEST SEQUENCE OF CUT AND BEST CHOICE OF CUT FOR SIDE TWO**

<table>
<thead>
<tr>
<th>CHOICE OF CUT (Hᵢ)</th>
<th>FOR SIDE 2</th>
<th>14&quot; LOG</th>
<th>13&quot; LOG</th>
<th>12&quot; LOG</th>
<th>10&quot; LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side 1</td>
<td>1x4&quot; Board</td>
<td>1x4&quot; Board</td>
<td>1x4&quot; Board</td>
<td>1x4&quot; Board</td>
<td></td>
</tr>
<tr>
<td>Side 2</td>
<td>1 - 4&quot; Slab</td>
<td>1x4&quot; Slab</td>
<td>1x4, 2x8</td>
<td>1x6</td>
<td></td>
</tr>
<tr>
<td>Side 3</td>
<td>2 - 2x10's</td>
<td>2x10, 2x8</td>
<td>2x4</td>
<td>1x4</td>
<td></td>
</tr>
<tr>
<td>Side 4</td>
<td>1 - 2x4</td>
<td>2x4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cant</td>
<td>1 - 2x12</td>
<td>2x12</td>
<td>3 - 2x6</td>
<td>3 - 2x6</td>
<td></td>
</tr>
</tbody>
</table>

**LOG VALUE/MLF OF LUMBER**

<table>
<thead>
<tr>
<th>Side 1</th>
<th>Side 2</th>
<th>Side 3</th>
<th>Side 4</th>
<th>Cant</th>
</tr>
</thead>
<tbody>
<tr>
<td>$2170</td>
<td>$1972</td>
<td>$1257</td>
<td>$ 884</td>
<td></td>
</tr>
</tbody>
</table>

**BOARD FOOT VOLUME FOR 16' LOGS**

<table>
<thead>
<tr>
<th>Side 1</th>
<th>Side 2</th>
<th>Side 3</th>
<th>Side 4</th>
<th>Cant</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.33</td>
<td>5.33</td>
<td>5.33</td>
<td>5.33</td>
<td></td>
</tr>
<tr>
<td>0.00</td>
<td>0.00</td>
<td>26.66</td>
<td>8.00</td>
<td></td>
</tr>
<tr>
<td>64.00</td>
<td>58.67</td>
<td>10.67</td>
<td>5.33</td>
<td></td>
</tr>
<tr>
<td>64.00</td>
<td>58.67</td>
<td>10.67</td>
<td>5.33</td>
<td></td>
</tr>
<tr>
<td>32.00</td>
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<td>48.00</td>
<td>48.00</td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL BFV**

<table>
<thead>
<tr>
<th>Side 1</th>
<th>Side 2</th>
<th>Side 3</th>
<th>Side 4</th>
<th>Cant</th>
</tr>
</thead>
<tbody>
<tr>
<td>165.35</td>
<td>154.67</td>
<td>101.32</td>
<td>71.99</td>
<td></td>
</tr>
</tbody>
</table>
### TABLE VI

RESULTS OF SAWMILL SIMULATION MODEL USING
THE THRASHER PRODUCTION SYSTEM

LUMBER VALUES OF SIDES ONE AND TWO OBTAINED
FOR EACH OF THE SEVEN CHOICES
OF CUT FOR SIDE TWO

<table>
<thead>
<tr>
<th>CHOICE OF CUT (H_i) FOR SIDE 2</th>
<th>14&quot; LOG</th>
<th>13&quot; LOG</th>
<th>12&quot; LOG</th>
<th>10&quot; LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side 1</td>
<td>$ 60.00</td>
<td>$ 60.00</td>
<td>$ 60.00</td>
<td>$ 60.00</td>
</tr>
<tr>
<td>Side 2</td>
<td>$ 0.00</td>
<td>$ 0.00</td>
<td>$ 0.00</td>
<td>$ 0.00</td>
</tr>
<tr>
<td>H1</td>
<td>$ 60.00</td>
<td>$ 60.00</td>
<td>$ 60.00</td>
<td>$ 60.00</td>
</tr>
<tr>
<td>H2</td>
<td>98.00</td>
<td>98.00</td>
<td>98.00</td>
<td>98.00</td>
</tr>
<tr>
<td>H3</td>
<td>137.00</td>
<td>137.00</td>
<td>137.00</td>
<td>137.00</td>
</tr>
<tr>
<td>H4</td>
<td>202.00</td>
<td>202.00</td>
<td>202.00</td>
<td>202.00</td>
</tr>
<tr>
<td>H5</td>
<td>317.00</td>
<td>317.00</td>
<td>317.00</td>
<td>262.00</td>
</tr>
<tr>
<td>H6</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>H7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

LUMBER VALUE OF CANT FOR EACH OF THE
SEVEN CHOICES OF CUT FOR SIDE TWO

<p>| H1                             | $ 828.00 | $ 711.00 | $ 711.00 | $ 513.00 |
| H2                             | 1423.00  | 1423.00  | 1027.00  | 606.00   |
| H3                             | 4 - 2x10 | 4 x 2x10 | 4 - 2x8  | 3 - 2x6  |
| H4                             | 1423.00  | 1027.00  | 1027.00  | 606.00   |
| H5                             | 4 - 2x10 | 4 - 2x8  | 4 - 2x8  | 3 - 2x6  |
| H6                             | 1027.00  | 1027.00  | 1027.00  | 411.00   |
| H7                             | 3 - 2x10 | 2 - 2x10 | 3 - 2x10 | 3 - 2x8  |</p>
<table>
<thead>
<tr>
<th>Side 3, 4</th>
<th>( H_1 )</th>
<th>( H_2 )</th>
<th>( H_3 )</th>
<th>( H_4 )</th>
<th>( H_5 )</th>
<th>( H_6 )</th>
<th>( H_7 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$ 696.00</td>
<td>$ 538.00</td>
<td>$ 423.00</td>
<td>$ 262.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( 1 \times 12, 2 \times 10, 2 \times 10, 1 \times 6 ), ( 1 \times 8, 2 \times 6 ), ( 1 \times 4, 2 \times 6 )</td>
<td>( 2 \times 8, 2 \times 6 ), ( 2 \times 8, 2 \times 4 ), ( 1 \times 6, 1 \times 4 )</td>
<td>( 2 \times 8, 2 \times 6 ), ( 2 \times 8, 2 \times 4 ), ( 1 \times 6, 1 \times 4 )</td>
<td>( 2 \times 8, 2 \times 6 ), ( 2 \times 8, 2 \times 4 ), ( 1 \times 6, 1 \times 4 )</td>
<td>( 2 \times 8, 2 \times 6 ), ( 2 \times 8, 2 \times 4 ), ( 1 \times 6, 1 \times 4 )</td>
<td>( 2 \times 8, 2 \times 6 ), ( 2 \times 8, 2 \times 4 ), ( 1 \times 6, 1 \times 4 )</td>
<td>( 2 \times 8, 2 \times 6 ), ( 2 \times 8, 2 \times 4 ), ( 1 \times 6, 1 \times 4 )</td>
</tr>
</tbody>
</table>
TABLE VII

THRASHER MILL SYSTEM

SUMMATION OF VALUES FOR FOUR SIDES
PLUS THE CANT FOR EACH OF THE SEVEN
CHOICES OF CUT

<table>
<thead>
<tr>
<th>CHOICE OF CUT (H₄)</th>
<th>FOR SIDE 1</th>
<th>14&quot; LOG</th>
<th>13&quot; LOG</th>
<th>12&quot; LOG</th>
<th>10&quot; LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>$2284.00</td>
<td>$1847.00</td>
<td>$1597.00</td>
<td>$1097.00</td>
<td></td>
</tr>
<tr>
<td>H2</td>
<td>2459.00</td>
<td>2329.00</td>
<td>1463.00</td>
<td>1000.00</td>
<td></td>
</tr>
<tr>
<td>H3</td>
<td>2496.00</td>
<td>1967.00</td>
<td>1501.00</td>
<td>1038.00</td>
<td></td>
</tr>
<tr>
<td>H4</td>
<td>2536.00</td>
<td>2010.00</td>
<td>1540.00</td>
<td>1077.00</td>
<td></td>
</tr>
<tr>
<td>H₅</td>
<td>2601.00</td>
<td>2075.00</td>
<td>1545.00</td>
<td>1142.00</td>
<td></td>
</tr>
<tr>
<td>H₆</td>
<td>2320.00</td>
<td>2190.00</td>
<td>1618.00</td>
<td>853.00</td>
<td></td>
</tr>
<tr>
<td>H₇</td>
<td>2243.00</td>
<td>1677.00</td>
<td>1651.00</td>
<td>1104.00</td>
<td></td>
</tr>
</tbody>
</table>

BEST SEQUENCE OF CUT AND BEST CHOICE
OF CUT FOR SIDE TWO

<table>
<thead>
<tr>
<th>CHOICE OF CUT (H₄)</th>
<th>FOR SIDE 2</th>
<th>14&quot; LOG</th>
<th>13&quot; LOG</th>
<th>12&quot; LOG</th>
<th>10&quot; LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₅</td>
<td>1x4 Board</td>
<td>1x4 Board</td>
<td>1x4 Board</td>
<td>1x4 Board</td>
<td>1x4 Board</td>
</tr>
<tr>
<td></td>
<td>2x6</td>
<td>1x4 Board</td>
<td>6&quot; Slab</td>
<td>2x6</td>
<td></td>
</tr>
<tr>
<td>Side 1</td>
<td>2x8 &amp; 2x6</td>
<td>2x8, 2x4</td>
<td>2x4, 1x4</td>
<td>2x4</td>
<td></td>
</tr>
<tr>
<td>Side 2</td>
<td>2x8, 2x4</td>
<td>2x4, 1x4</td>
<td>2x4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side 3</td>
<td>4 - 2x10's</td>
<td>3 - 2x10's</td>
<td>3 - 2x8's</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cant</td>
<td>Dimension</td>
<td></td>
<td>16.00</td>
<td>63.99</td>
<td></td>
</tr>
<tr>
<td>TOTAL VALUE/MLF OF LUMBER</td>
<td>$2601.00</td>
<td>$2329.00</td>
<td>$1651.00</td>
<td>$1142.00</td>
<td></td>
</tr>
</tbody>
</table>

BOARD FOOT VOLUME FOR 16 FOOT LOGS

<table>
<thead>
<tr>
<th>Cant</th>
<th>Side 1</th>
<th>5.33</th>
<th>5.33</th>
<th>5.33</th>
<th>5.33</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&quot;</td>
<td>16.00</td>
<td>5.33</td>
<td>0.00</td>
<td>16.00</td>
</tr>
<tr>
<td></td>
<td>&quot;</td>
<td>37.33</td>
<td>37.33</td>
<td>16.00</td>
<td>10.67</td>
</tr>
<tr>
<td></td>
<td>&quot;</td>
<td>37.33</td>
<td>37.33</td>
<td>16.00</td>
<td>10.67</td>
</tr>
<tr>
<td>TOTAL BFV</td>
<td>202.67</td>
<td>191.99</td>
<td>117.34</td>
<td>106.66</td>
<td></td>
</tr>
</tbody>
</table>
erations for wane in lumber. Neglecting the major factor contributing to wane and taper results in log values slightly lower that if the taper was included. This in no way invalidates the results, however.

A comparison of the values obtained from each production system reveals an average increase in value of 22.92 per cent when using the Thrasher system (Table VIII).

Assuming the average increase in value of 22.92 per cent will hold for all diameters tested, then the Thrasher system will produce approximately 23 per cent more revenue from the same volume of raw material (timber). This 23 per cent increase in value is based on 1,000 lineal feet of logs which is 62.5 logs 16 feet in length. The conventional mill studied purchased approximately 35 million board feet of logs during 1972 (log tally). This 35 million board feet of logs was converted into approximately 53 million board feet of lumber worth approximately 6.5 million dollars (@ $120 MBF). Increasing gross revenues by 23 per cent would bring the sales to 8.0 million dollars, with no increase in the cost for raw materials.

If the mill owner converts the green end of the mill to the Thrasher system, then other changes in the operation
<table>
<thead>
<tr>
<th></th>
<th>14&quot; LOG</th>
<th>13&quot; LOG</th>
<th>12&quot; LOG</th>
<th>10&quot; LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thrasher System</td>
<td>$2601</td>
<td>$2329</td>
<td>$1651</td>
<td>$1142</td>
</tr>
<tr>
<td>Conventional Mill</td>
<td>2170</td>
<td>1972</td>
<td>1257</td>
<td>884</td>
</tr>
</tbody>
</table>

Increase Using the Thrasher System:
- 14" Log: $431
- 13" Log: $357
- 12" Log: $394
- 10" Log: $258

% Increase:
- 14" Log: 19.86%
- 13" Log: 18.10%
- 12" Log: 31.34%
- 10" Log: 29.19%

Average % Increase = \( \frac{1440}{5283} \times 100 = 22.92\% \)
will be necessary. The additional volume of lumber produced will require either an additional shift at the planer or a planer with increased capacity. Also, an additional man on the green chain and possibly one additional man sorting for resaw will be required. An additional man will also be required for the increased number of saw sharpenings, estimated to be 2,000 per year, and for the babbit guides used for the saw that need frequent replacement.

Many of the mill owners base their operating decisions on the overrun percentage that the mill's operation produces. Overrun is a rough indicator of a mill's efficiency in converting logs into lumber. Overrun is derived by subtracting the log scale of logs used from the actual lumber obtained by the manufacturing process (mill scale) and dividing the result by the log scale. Since overrun is a function of the log scale used as well as the manufacturing process, the exact nature of the log scale must be known in order to draw meaningful relationships. Most mill owners do not know the extent that various log scaling formulas can affect the evaluation of operations, nor can they readily convert from one scale to another.

Since the United States Forest Service uses the Scribner Decimal C scale in the Western states, that scale is used in this paper. The Scribner Decimal C is most accurate for logs 20 inches or more in diameter (16-foot logs) - (Avery,
1967).

In essence, any amount by which the actual overrun exceeds that which is reflected in the Forest Service appraisal is material received free from the Forest Service if the timber is purchased at the appraisal price. The overrun for the mill studied was 41 per cent during normal operations. The 41 per cent means that 41 per cent more lumber was obtained from the logs than was scaled for on the timber sale. Currently, the Forest Service includes a 14.7 per cent overrun when calculating a timber appraisal. One advantage of having a high overrun is the competitive advantage in bidding for a timber sale. A mill can afford to pay more for logs if it has a high overrun.

The overrun is a result of not considering the taper of a log when scaling, allowing for a 1/4-inch kerf, and assuming that the entire log will be cut into one-inch boards. Most mills are able to obtain lumber from the sides of the log that are not included in the scaling formulas. Cutting for dimension will also increase overrun.

The conventional mill, using the simulation model, was able to obtain an average overrun of 40.95 per cent, with a larger kerf than is used in the scale [0.375 inches compared to 1/4-inch used by scale] and without using the
taper of the log. The Thrasher system, using the model, produced an average overrun of 76.76 per cent (Table IX). With the Thrasher system 39 per cent more lumber was obtained than from the conventional mill for the test logs. The additional recovery will place the mill owner in a relatively strong position when bidding against other mills for timber sales. The mill owner also has a higher margin than his competitors, creating a distinct advantage in periods of low lumber prices.

Another method of evaluating the ability of a mill to convert a log into lumber is to calculate the volume (in cubic feet, actual size) of lumber obtained from the volume of a log in cubic feet. This method of calculating recovery eliminates overrun and considerations for taper, width of kerf, and sizes of lumber commonly included in scaling formulas. Lumber recovery is expressed in per cent of log volume (Table X). Using the simulation model, the Thrasher system was able to convert 64.30 per cent of the test logs into lumber on a volume scale. The remaining 35.70 per cent of the log is sawdust and wood chips. The conventional mill recovered 50.26% of the log in lumber for the test logs. Calculating recovery by volume gives a good indication of the efficiency of the workers and equipment, and can be directly compared to other mills when the log mix is known.
TABLE IX

COMPARISON OF SCALED LOG VOLUME TO CONVENTIONAL MILL TALLY FOR 16-FOOT LOGS
SCRIBNER DECIMAL C

<table>
<thead>
<tr>
<th></th>
<th>14&quot; DIAM.</th>
<th>13&quot; DIAM.</th>
<th>12&quot; DIAM</th>
<th>10&quot; DIAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log Scale</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scribner Decimal C (1/4-inch kerf) BFV</td>
<td>110</td>
<td>100</td>
<td>80</td>
<td>60</td>
</tr>
<tr>
<td>Conventional Mill Tally BFV</td>
<td>165.35</td>
<td>154.67</td>
<td>101.33</td>
<td>71.99</td>
</tr>
</tbody>
</table>

Overrun: 
\[
\frac{\text{Mill Tally} - \text{Log Tally}}{\text{Log Tally}} \times 100
\]

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Log Tally</td>
<td>50.32%</td>
<td>54.67%</td>
<td>26.66%</td>
<td>19.98%</td>
</tr>
</tbody>
</table>

Average Overrun = 40.95%

COMPARISON OF SCALED LOG VOLUME TO MILL TALLY OF THRASHER SYSTEM FOR 16-FOOT LOGS

<table>
<thead>
<tr>
<th></th>
<th>14&quot; DIAM.</th>
<th>13&quot; DIAM.</th>
<th>12&quot; DIAM</th>
<th>10&quot; DIAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log Scale</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thrasher Tally BFV</td>
<td>110</td>
<td>100</td>
<td>80</td>
<td>60</td>
</tr>
<tr>
<td>Thrasher Tally BFV</td>
<td>202.67</td>
<td>191.99</td>
<td>117.34</td>
<td>106.66</td>
</tr>
</tbody>
</table>

Overrun: 
\[
\frac{\text{Mill Tally} - \text{Log Tally}}{\text{Log Tally}} \times 100
\]

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Log Tally</td>
<td>84.25%</td>
<td>91.99%</td>
<td>46.67%</td>
<td>77.78%</td>
</tr>
</tbody>
</table>

Average Overrun = 76.76%

1 Straight Scale, no deduction for defects
TABLE X

VOLUMETRIC COMPARISON
OF LUMBER RECOVERY BY THRASHER SYSTEM
AND THE CONVENTIONAL MILL USING THE
SIMULATION MODEL

<table>
<thead>
<tr>
<th>LOG DIAM (INCHES)</th>
<th>16 FOOT, THRASHER NO TAPER SYSTEM</th>
<th>PERCENT LUMBER RECOVERY OF THE RECOVERED BY THRASHER SYSTEM</th>
<th>LUMBER VOLUME RECOVERED</th>
<th>PERCENT LUMBER RECOVERY OF THE CONVENTIONAL MILL</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>17.09 Cu. Ft.</td>
<td>0.6822</td>
<td>9.423 Cu. Ft.</td>
<td>0.5514</td>
</tr>
<tr>
<td>13</td>
<td>14.77 Cu. Ft.</td>
<td>0.6994</td>
<td>8.808 Cu. Ft.</td>
<td>0.5963</td>
</tr>
<tr>
<td>12</td>
<td>13.23 Cu. Ft.</td>
<td>0.4965</td>
<td>5.855 Cu. Ft.</td>
<td>0.4426</td>
</tr>
<tr>
<td>10</td>
<td>8.73 Cu. Ft.</td>
<td>0.6931</td>
<td>3.966 Cu. Ft.</td>
<td>0.4543</td>
</tr>
<tr>
<td>TOTAL:</td>
<td>53.82 Cu. Ft.</td>
<td>64.30%</td>
<td>27.052 Cu. Ft.</td>
<td>50.26%</td>
</tr>
</tbody>
</table>

Av. Recovery

Av. Recovery
The model considered a complete changeover to the Thrasher system. The percentage increase, if only one section of the sawmill were converted would necessarily be smaller. However, conversion of only one unit of the mill would still increase total recovery and should be based on a comparison with the equipment it is replacing.

The increase in the lumber yield is a result of two factors; first there is a thinner kerf and thus less material is lost in sawdust, and second, smoother, more precise sawing requiring less planing and consequently less material lost in the form of planer shavings.

In the first instance, the thinner kerf used on a 14-inch diameter log 16-feet in length results in total sawdust production (resaw not included) of 3.130 cubic feet of sawdust as compared to 4.121 feet for the conventional mill. This is a reduction of 0.991 cubic feet, or 24.05 per cent ($\frac{4.121 - 0.991 \times 100}{4.121}$).

The reduction for each cut of the log is greater than indicated since the reduced kerf allows more lumber to be obtained requiring more cuts in the log. For example, optimal recovery for the 14-inch log produces 10 pieces of lumber 16 feet long using the Thrasher system while 8 pieces of lumber 16 feet long is obtained by the conventional system.
The second savings generated by the Thrasher system is the reduction in material removed in the planing operation. The Thrasher system has planing allowances of 0.050 inches for the widths of the lumber and 0.063 inches for the thicknesses. The corresponding values for the conventional mill are 0.175 inches and 0.240 inches. For a nominal 1 x 12 inch board, 16 feet in length, this is a difference of 305.7 cu. in., or 0.1769 cubic feet (Table XI).

For the optimal breakdown of a 14-inch log sixteen feet in length, the Thrasher system will reduce the volume of planer shavings by 1.37 cubic feet compared to the conventional mill operation. The net effect, adding the savings in sawdust to the savings in planer shavings, is a reduction in waste of 2.26 cubic feet. The Thrasher system produced 37.32 board feet of lumber more than the conventional mill, or 2.33 cubic feet of additional lumber. The Thrasher system not only converted the entire decrease in sawdust and planer shavings into lumber, but the system also reduced the volume of chipable material and coverted it into lumber for the 14-inch test log.
TABLE XI

DIFFERENCES IN VOLUME OF MATERIAL
THAT MUST BE PLANED FROM ROUGH GREEN LUMBER
WHEN COMPARING THE THRASHER SYSTEM TO THE
CONVENTIONAL MILL

<table>
<thead>
<tr>
<th>NOM. SIZE</th>
<th>REDUCTION IN SURFACING AREA (INCHES)</th>
<th>REDUCTION IN SURFACE AREA (ST.)</th>
<th>REDUCED VOLUME OF PLANING FOR 16' LUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>THICK. WIDTH</td>
<td></td>
<td>THICK. WIDTH</td>
</tr>
<tr>
<td>1x4</td>
<td>.177</td>
<td>.125</td>
<td>.1549</td>
</tr>
<tr>
<td>1x6</td>
<td>.177</td>
<td>.125</td>
<td>.1549</td>
</tr>
<tr>
<td>1x8</td>
<td>.177</td>
<td>.125</td>
<td>.1549</td>
</tr>
<tr>
<td>1x10</td>
<td>.177</td>
<td>.125</td>
<td>.1549</td>
</tr>
<tr>
<td>1x12</td>
<td>.177</td>
<td>.125</td>
<td>.1549</td>
</tr>
<tr>
<td>2x4</td>
<td>.177</td>
<td>.125</td>
<td>.2876</td>
</tr>
<tr>
<td>2x6</td>
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<td>.125</td>
<td>.2876</td>
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<tr>
<td>2x8</td>
<td>.177</td>
<td>.125</td>
<td>.2876</td>
</tr>
<tr>
<td>2x10</td>
<td>.177</td>
<td>.125</td>
<td>.2876</td>
</tr>
<tr>
<td>2x12</td>
<td>.177</td>
<td>.125</td>
<td>.2876</td>
</tr>
</tbody>
</table>
CHAPTER VI

SUMMARY: CONCLUSIONS AND RECOMMENDATIONS

The Thrasher system is compared to a conventional mill operation by use of a simulation model that determines the optimal recovery of lumber from logs. Diameters of 10, 12, 13, and 14 inches were chosen for the initial run. The Thrasher system resulted in an average increase in dollar value of 22.92 per cent for the test logs.

The estimated increase in revenue of $1.5 million is based on an average sale price of $120 per thousand board feet. The cost of capital is assumed to be 10 per cent, and the depreciation schedule used for the evaluation of assets is sum-of-the-years digits. The effective life of the asset is estimated to be ten years.

The cost of converting to the Thrasher system ranges from $1.0 million to $1.0 million, dependent on the auxiliary equipment installed with the saw milling operation. The cost of $1.5 million includes a new debarker and chipper and replacement of the conveyor and electric motors. The $1.0 million includes only the saw milling equipment and conveyors.
With the installation of the new head rig and gang saws plus the new conveyor system, it is possible that production rates will be increased during the actual sawing operation. Consequently, if the complete package is not purchased, other parts of the saw mill may become a bottleneck for production and reduce the total benefits of the Thrasher system. The mill owner is considering a total conversion with the exception of the electric motors. The estimated cost is $1.3 million (estimated by the mill owner).

The present facilities (to be replaced) are completely depreciated, and sale of such equipment should bring approximately $100,000 (estimated by author). The net cash flow resulting from conversion to the Thrasher system is approximately $687,000 in the first year (Table XII). The internal rate of return generated by the conversion is approximately 50 per cent for the ten-year life of the asset (Table XIII). The payback period, often used by mill owners in evaluating production systems, is 1.9 years for the Thrasher system (Table XIII). Both the payback period and the internal rate of return are dependent on the sale price of the lumber. The price used in the calculations ($120 MBF) is far below current market prices and quite conservative.

Investment in such a system would result in the mill owner having a strong competitive advantage. The system
TABLE XII

EFFECT ON CASH FLOWS OF CONVERTING TO THE THRASHER SYSTEM OVER THE TEN-YEAR LIFE OF THE ASSET 1 JANUARY 1974 to 31 DECEMBER 1983 (IN MILLIONS)

<table>
<thead>
<tr>
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<tr>
<td>Labor: Planer (12 men)</td>
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<td>.126</td>
<td>.132</td>
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<td>Sawmill (3 men)</td>
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<td></td>
<td>.035</td>
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<td>.041</td>
<td>.043</td>
<td>.045</td>
<td>.057</td>
<td>.049</td>
<td>.051</td>
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<td>Revenue Loss, 10% Reduction in Chip Volume (10% x 23,000 units @ $2 per unit)</td>
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<td>.055</td>
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<td>Total Increased Cash Expenses:</td>
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<td>Plus Depreciation</td>
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<td>Total Increase in Expense</td>
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<td>.384</td>
<td>.370</td>
<td>.358</td>
<td>.345</td>
<td>.333</td>
<td>.321</td>
<td>.309</td>
<td>.298</td>
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<td>Change in Income Before Int &amp; Tax</td>
<td>1.116</td>
<td>1.130</td>
<td>1.142</td>
<td>1.155</td>
<td>1.167</td>
<td>1.179</td>
<td>1.191</td>
<td>1.202</td>
<td>1.212</td>
<td>1.221</td>
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<td>Less Interest:</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>.120</td>
<td>.108</td>
<td>.096</td>
<td>.084</td>
<td>.072</td>
<td>.060</td>
<td>.048</td>
<td>.036</td>
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<td>.012</td>
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<td>1.046</td>
<td>1.071</td>
<td>1.095</td>
<td>1.119</td>
<td>1.143</td>
<td>1.166</td>
<td>1.188</td>
<td>1.209</td>
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<td>Taxes (@ 50%)</td>
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<tr>
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<td>.536</td>
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<td>.559</td>
<td>.576</td>
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TABLE XII (Continued)

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<th>Change In</th>
<th>Change In</th>
<th>Change In</th>
<th>Change In</th>
<th>Change In</th>
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<td>Less Principal Payment</td>
<td>.596 .587 .578 .569 .559 .548 .543 .528 .518 .507</td>
<td>Less Principal Payment</td>
<td>.596 .587 .578 .569 .559 .548 .543 .528 .518 .507</td>
<td>Less Principal Payment</td>
<td>.596 .587 .578 .569 .559 .548 .543 .528 .518 .507</td>
<td>Less Principal Payment</td>
<td>.596 .587 .578 .569 .559 .548 .543 .528 .518 .507</td>
<td>Less Principal Payment</td>
<td>.596 .587 .578 .569 .559 .548 .543 .528 .518 .507</td>
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</tr>
<tr>
<td>Credit</td>
<td>.091</td>
<td>Credit</td>
<td>.091</td>
<td>Credit</td>
<td>.091</td>
<td>Credit</td>
<td>.091</td>
<td>Credit</td>
<td>.091</td>
<td>Credit</td>
<td>.091</td>
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</tbody>
</table>

Labor costs increased by 5% per year
Depreciation schedule is sum-of-the-year-digits
Interest of 10% on remaining balance
Ten yearly payments of $120,000 per year
Investment tax credit of 7% on new investment
(.07 x $1.3 million equals $91,000).
### TABLE XIII

CALCULATIONS OF INTERNAL RATE OF RETURN AND PAYBACK PERIOD

<table>
<thead>
<tr>
<th>YEAR</th>
<th>NET CASH FLOW (IN THOUSANDS)</th>
<th>PRESENT VALUE INTEREST FACTOR (50%) (IN THOUSANDS)</th>
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<tbody>
<tr>
<td>1</td>
<td>687</td>
<td>.667</td>
</tr>
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<td>2</td>
<td>587</td>
<td>.444</td>
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<tr>
<td>3</td>
<td>578</td>
<td>.296</td>
</tr>
<tr>
<td>4</td>
<td>569</td>
<td>.198</td>
</tr>
<tr>
<td>5</td>
<td>559</td>
<td>.132</td>
</tr>
<tr>
<td>6</td>
<td>548</td>
<td>.088</td>
</tr>
<tr>
<td>7</td>
<td>543</td>
<td>.059</td>
</tr>
<tr>
<td>8</td>
<td>528</td>
<td>.039</td>
</tr>
<tr>
<td>9</td>
<td>518</td>
<td>.026</td>
</tr>
<tr>
<td>10</td>
<td>507</td>
<td>.017</td>
</tr>
</tbody>
</table>

**Total Present Value**

$1,199,340.00

Payback = $1,200,000/year = 1.9 years

\[
\text{Payback} = \frac{\$687,000 + 587,000}{\text{year}}
\]
would allow the owner to purchase stumpage at a relatively higher price than his competitors and sell his lumber at a lower price if conditions warranted.

The Thrasher system also reduces the volume of sawdust that is produced by the manufacturing process. The savings in sawdust and planer shavings will result in an increase in lumber production without an increase in the volume of raw materials. Since no local market exists for sawdust, any sawdust produced at the mill site must be disposed of. This disposal cost for each per cent of sawdust salvaged must also be included in any savings generated by the Thrasher system. With the impending closure of the teepee burner, this savings could be an important factor in the decision regarding the Thrasher system.

The purchase price of the Thrasher system may vary with each sale. Certainly the price will depend on the size of the installation and the products the mill is designed to produce.

The Thrasher system would be an excellent investment for a firm contemplating a change or replacement of equipment.
BIBLIOGRAPHY


Multiple-Use Sustained Yield Act, Public Law 86-517, 86th Congress, June 1, 1960.


APPENDIX
**TABLE XIV**

**COMMON FRACTIONS AND THEIR DECIMAL EQUIVALENTS**

<table>
<thead>
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<th>FRACTIONS</th>
<th>DECIMALS</th>
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<td>.0313</td>
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<td>3/64</td>
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</tr>
<tr>
<td>1/16</td>
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<td>9/32</td>
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<td>19/64</td>
<td>.2969</td>
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<td>5/16</td>
<td>.3125 (Av.kerf)</td>
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<th>DECIMALS</th>
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<tr>
<td>7/16</td>
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<td>29/64</td>
<td>.4531</td>
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<tr>
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<td>31/64</td>
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<tr>
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### TABLE XV

**CONVENTIONAL MILL**

MONTHLY PRODUCTION FIGURES
BY YEARS BEGINNING
JANUARY 1968
TO
JANUARY 1972
SAWMILL ONLY
(IN MBF)

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<td>Jan.</td>
<td>3,240</td>
<td>4,622</td>
<td>4,710</td>
<td>4,820</td>
<td>4,903</td>
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<tr>
<td>Feb.</td>
<td>3,900</td>
<td>4,724</td>
<td>4,693</td>
<td>4,710</td>
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<td>April</td>
<td>2,975</td>
<td>4,091</td>
<td>3,995</td>
<td>4,000</td>
<td>3,595</td>
<td>3,731</td>
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<tr>
<td>May</td>
<td>1,650</td>
<td>2,919</td>
<td>3,360</td>
<td>3,127</td>
<td>4,673</td>
<td>3,146</td>
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<td>June</td>
<td>2,590</td>
<td>3,897</td>
<td>4,078</td>
<td>3,965</td>
<td>4,700</td>
<td>3,846</td>
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<tr>
<td>July</td>
<td>4,130</td>
<td>4,650</td>
<td>4,580</td>
<td>4,628</td>
<td>4,796</td>
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<tr>
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<td>4,713</td>
<td>4,617</td>
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<td>4,672</td>
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<td>4,728</td>
<td>4,786</td>
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<td>Oct.</td>
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<td>4,800</td>
<td>4,890</td>
<td>4,863</td>
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<td>Nov.</td>
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<td>4,813</td>
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<td>4,866</td>
<td>4,931</td>
<td>4,973</td>
<td>4,857</td>
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**YEARLY TOTAL**

45,067 52,882 53,518 53,618 53,340 52,143

45,000 52,900 53,500 53,700 53,300 52,100

* Extreme Cold Weather Closed the Mill for nine Working Days, Not counted in Averages for Month of November.
<table>
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<tr>
<th>YEARS</th>
<th>PRODUCTION MMBF</th>
<th>TOTAL COSTS</th>
<th>AV. COSTS/MBF</th>
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<td>45.0</td>
<td>$ 682,765</td>
<td>15.151</td>
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<td>1969</td>
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<td>1970</td>
<td>53.5</td>
<td>801,914</td>
<td>14.984</td>
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<tr>
<td>1971</td>
<td>53.7</td>
<td>803,137</td>
<td>14.956</td>
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<tr>
<td>1972</td>
<td>53.3</td>
<td>797,261</td>
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</tr>
<tr>
<td>TOTAL</td>
<td>258.4</td>
<td>$3,879.365</td>
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Five Year Average Cost per MBBF = $14.8920

INCLUDES:

Yarding, Debarker, Unloading Logs, Saw Milling, Resaw, and Sorting, Stacking, and Storing in Yard
TABLE XVII

INLAND MILLS*
WESTERN WOOD PRODUCTS ASSOCIATION
DECEMBER 7, 1972

LUMBER PRICE INDEXES
QUARTER AVERAGES
1969-1972

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<td>111.88</td>
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<td>108.77</td>
<td>135.74</td>
<td>155.42</td>
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<td>4th Qtr</td>
<td>108.31</td>
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<td>137.08</td>
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</thead>
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<td>79.79</td>
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<td>2nd Qtr</td>
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<td>79.90</td>
<td>99.65</td>
<td>119.40</td>
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<tr>
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<td>89.26</td>
<td>79.70</td>
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<td>101.64</td>
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<td>84.21</td>
<td>112.64</td>
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</table>

*Published: Portland Oregon
### TABLE XVIII

**CUBIC CONTENT OF COMMONLY MANUFACTURED LUMBER SIZES DRESSED TO 1972 W.W.P.A. STANDARD LUMBER SIZES**

<table>
<thead>
<tr>
<th>NOMINAL SIZE</th>
<th>DRESSED SIZE DRY</th>
<th>CUBIC CONTENT PER LINEAL FOOT (IN CU.IN.)</th>
<th>NOMINAL BOARD FEET/FOOT</th>
<th>CUBIC FOOT CONTENT FOR 16' LUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1x3</td>
<td>24/32x2 1/2</td>
<td>22.500</td>
<td>.250</td>
<td>0.208</td>
</tr>
<tr>
<td>1x4</td>
<td>24/32x3 1/2</td>
<td>31.500</td>
<td>.333</td>
<td>0.292</td>
</tr>
<tr>
<td>1x6</td>
<td>24/32x5 1/2</td>
<td>49.500</td>
<td>.400</td>
<td>0.458</td>
</tr>
<tr>
<td>1x8</td>
<td>24/32x7 1/2</td>
<td>67.500</td>
<td>.667</td>
<td>0.625</td>
</tr>
<tr>
<td>1x10</td>
<td>24/32x9 1/2</td>
<td>85.500</td>
<td>.833</td>
<td>0.792</td>
</tr>
<tr>
<td>1x12</td>
<td>24/32x11 1/2</td>
<td>103.500</td>
<td>1.000</td>
<td>0.958</td>
</tr>
<tr>
<td>2x2</td>
<td>1 1/2 x 1 3/4</td>
<td>31.500</td>
<td>.333</td>
<td>0.292</td>
</tr>
<tr>
<td>2x4</td>
<td>1 1/2 x 3 1/2</td>
<td>63.000</td>
<td>.667</td>
<td>0.583</td>
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<td>1 1/2 x 5 1/2</td>
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<td>1.000</td>
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<tr>
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<td>1 1/2 x 7 1/4</td>
<td>130.500</td>
<td>1.333</td>
<td>1.208</td>
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<td>2x10</td>
<td>1 1/2 x 9 1/4</td>
<td>166.500</td>
<td>1.667</td>
<td>1.542</td>
</tr>
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<td>2x12</td>
<td>1 1/2 x 11 1/4</td>
<td>202.500</td>
<td>2.000</td>
<td>1.875</td>
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<td>3 3/4 x 3 1/2</td>
<td>157.500</td>
<td>1.333</td>
<td>1.458</td>
</tr>
<tr>
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<td>3 3/4 x 5 1/2</td>
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<td>2.000</td>
<td>2.292</td>
</tr>
<tr>
<td>4x8</td>
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<td>326.250</td>
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<td>3 3/4 x 9 1/4</td>
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EXHIBIT 5  

CONVENTIONAL MILL  
WOOD REQUIRED TO MANUFACTURE  
COMMON NOMINAL SIZES OF LUMBER  

WOOD REQUIRED FOR A NOMINAL DIMENSION 2 INCHES IN THICKNESS,  
6 INCHES IN WIDTH  

<table>
<thead>
<tr>
<th></th>
<th>THICKNESS</th>
<th>WIDTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Finished Size</td>
<td>1.500</td>
<td>3.500</td>
</tr>
<tr>
<td>Head Rig Kerf</td>
<td>0.375</td>
<td>------</td>
</tr>
<tr>
<td>Edger Kerf</td>
<td>------</td>
<td>0.190</td>
</tr>
<tr>
<td>Allowance for Variation</td>
<td>0.035</td>
<td>0.060</td>
</tr>
<tr>
<td>Planing Allowance</td>
<td>0.050</td>
<td>0.050</td>
</tr>
<tr>
<td>Allowance for Rough Cut</td>
<td>0.090</td>
<td>0.090</td>
</tr>
<tr>
<td>5 per cent Shrinkage Allowed</td>
<td>0.075</td>
<td>0.175</td>
</tr>
<tr>
<td>TOTAL WOOD REQUIRED</td>
<td>2.125&quot;</td>
<td>4.065</td>
</tr>
</tbody>
</table>

WOOD REQUIRED FOR A NOMINAL BOARD ONE INCH IN THICKNESS,  
6 INCHES IN WIDTH  

<table>
<thead>
<tr>
<th></th>
<th>THICKNESS</th>
<th>WIDTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Finished Size</td>
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<td>5.500</td>
</tr>
<tr>
<td>Head Rig Kerf</td>
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<tr>
<td>Edger Kerf</td>
<td>------</td>
<td>0.190</td>
</tr>
<tr>
<td>Planing Allowance</td>
<td>0.050</td>
<td>0.050</td>
</tr>
<tr>
<td>Allowance for Variation</td>
<td>0.035</td>
<td>0.060</td>
</tr>
<tr>
<td>Allowance for Rough Cut</td>
<td>0.090</td>
<td>0.090</td>
</tr>
<tr>
<td>5 per cent Shrinkage Allowed</td>
<td>0.036</td>
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<td>TOTAL WOOD REQUIRED</td>
<td>1.336</td>
<td>6.166</td>
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Ibid.
EXHIBIT 5 (Continued)

CONVENTIONAL MILL
WOOD REQUIRED TO MANUFACTURE
COMMON NOMINAL SIZES OF LUMBER

WOOD REQUIRED FOR WIDTHS OF 3, 8, 10, 12 INCHES

<table>
<thead>
<tr>
<th>NOMINAL</th>
<th>3 IN.</th>
<th>8 IN.</th>
<th>10 IN.</th>
<th>12 IN.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Finished Size</td>
<td>2.500</td>
<td>7.500</td>
<td>9.500</td>
<td>11.250</td>
</tr>
<tr>
<td>Edger Kerf</td>
<td>.190</td>
<td>.190</td>
<td>.190</td>
<td>.190</td>
</tr>
<tr>
<td>Planing Allowance</td>
<td>.050</td>
<td>.050</td>
<td>.050</td>
<td>.050</td>
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<tr>
<td>Allowance for Variation</td>
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<td>.060</td>
<td>.060</td>
<td>.060</td>
</tr>
<tr>
<td>Allowance for Rough Cut</td>
<td>.090</td>
<td>.090</td>
<td>.090</td>
<td>.090</td>
</tr>
<tr>
<td>5 per cent Shrinkage All.</td>
<td>.125</td>
<td>.375</td>
<td>.475</td>
<td>.563</td>
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<tr>
<td>TOTAL WOOD REQUIRED</td>
<td>3.015</td>
<td>8.265</td>
<td>10.365</td>
<td>12.203</td>
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</tbody>
</table>

WOOD REQUIRED FOR THICKNESSES OF 4 AND 6 INCHES

<table>
<thead>
<tr>
<th>NOMINAL</th>
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<th>6 IN.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Finished Size</td>
<td>3.750</td>
<td>5.750</td>
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<td>Head Rig Kerf</td>
<td>.375</td>
<td>.375</td>
</tr>
<tr>
<td>Planing Allowance</td>
<td>.050</td>
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<td>Allowance for Variation</td>
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<td>.035</td>
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<tr>
<td>Allowance for Rough Cut</td>
<td>.090</td>
<td>.090</td>
</tr>
<tr>
<td>5 per cent Shrinkage Allowance</td>
<td>.188</td>
<td>.288</td>
</tr>
<tr>
<td>TOTAL WOOD REQUIRED</td>
<td>4.488</td>
<td>6.588</td>
</tr>
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</table>


2 Ibid.
### TABLE XIX

CONVENTIONAL MILL
TOTAL VOLUME OF WOOD NEEDED
TO PRODUCE THE NOMINAL SIZES UNDER
THE PRESENT MANUFACTURING SYSTEM PER LINEAL FOOT
(LUMBER DRESSED TO 1972 SPECIFICATIONS\(^1\))

<table>
<thead>
<tr>
<th>NOMINAL SIZE</th>
<th>DIMENSIONS (EXHIBIT A)</th>
<th>CUBIC CONTENT PER LINEAL FOOT</th>
<th>PER CENT SAVINGS USING THRASHER SYSTEM (EXHIBIT B)</th>
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<tbody>
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<td>1x3</td>
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<td>48.336</td>
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<td>1.336x4.065</td>
<td>65.170</td>
<td>31.40</td>
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<td>1x6</td>
<td>1.336x6.166</td>
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<td>1.336x8.265</td>
<td>132.505</td>
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<td>1.336x10.365</td>
<td>166.172</td>
<td>28.71</td>
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<td>1x12</td>
<td>1.336x12.203</td>
<td>195.638</td>
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<td>103.658</td>
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<td>2.125x6.296</td>
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<td>21.92</td>
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<td>210.758</td>
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<td>264.308</td>
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<td>6.588x6.296</td>
<td>497.737</td>
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\(^1\) Ibid.
EXHIBIT 6

THRASHER SYSTEM
WOOD REQUIRED TO MANUFACTURE
COMMON NOMINAL SIZES OF LUMBER

WOOD REQUIRED FOR A NOMINAL DIMENSION 2 INCHES IN
THICKNESS AND 4 INCHES IN WIDTH

<table>
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<td>Finished Size</td>
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</tr>
<tr>
<td>Edger Kerf</td>
<td>-----</td>
<td>.090</td>
</tr>
<tr>
<td>Allowance for Variation</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Planing Allowance</td>
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<td>.050</td>
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<tr>
<td>Allowance for Rough Cut</td>
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<td>5 per cent Shrinkage Allowance</td>
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<tr>
<td>TOTAL WOOD REQUIRED</td>
<td>1.766</td>
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WOOD REQUIRED FOR A NOMINAL BOARD 1 INCH IN
THICKNESS AND 6 INCHES IN WIDTH

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<td>Edger Kerf</td>
<td>-----</td>
<td>.090</td>
</tr>
<tr>
<td>Allowance for Variation</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Planing Allowance</td>
<td>.0625</td>
<td>.050</td>
</tr>
<tr>
<td>Allowance for Rough Cut</td>
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<td>-----</td>
</tr>
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<td>0.976</td>
<td>5.915</td>
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</table>

1 Ibid.
2 Ibid.
EXHIBIT 6 (Continued)

THRASHER SYSTEM
WOOD REQUIRED TO MANUFACTURE
COMMON NOMINAL SIZES OF LUMBER

WOOD REQUIRED FOR NOMINAL WIDTHS OF 3, 8, 10, 12 INCHES

<table>
<thead>
<tr>
<th></th>
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<th>10 IN.</th>
<th>12 IN.</th>
</tr>
</thead>
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<td>2.500</td>
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<td>9.500</td>
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<td>Edger Kerf</td>
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<td>.090</td>
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<td>Allowance for Variation</td>
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</tr>
<tr>
<td>Planing Allowance</td>
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<td>.050</td>
<td>.050</td>
<td>.050</td>
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<tr>
<td>Allowance for Rough Cut</td>
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<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>5 per cent Shrinkage Allowance</td>
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<td>.575</td>
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<td>2.815</td>
<td>8.015</td>
<td>10.115</td>
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WOOD REQUIRED FOR NOMINAL THICKNESSES
OF 4 AND 6 INCHES

<table>
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<th>6 IN.</th>
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<td>Head Rig Kerf</td>
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<td>Allowance for Variation</td>
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<td>------</td>
</tr>
<tr>
<td>Planing Allowance</td>
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<td>.063</td>
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<td>Allowance for Rough Cut</td>
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<td>5 per cent Shrinkage Allowance</td>
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<td>TOTAL WOOD REQUIRED</td>
<td>4.126</td>
<td>6.266</td>
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</table>

1^Ibid.
2^Ibid.
### TABLE XX

**THRASHER SYSTEM**

TOTAL VOLUME OF WOOD NEEDED TO PRODUCE THE NOMINAL SIZES OF LUMBER USING THE THRASHER SYSTEM OF MANUFACTURING (LUMBER DRESSED TO 1972 SPECIFICATIONS)\(^1\)

WESTERN WOOD PRODUCTS ASSOCIATION

<table>
<thead>
<tr>
<th>NOMINAL SIZE</th>
<th>DIMENSIONS (EXHIBIT B)</th>
<th>CUBIC CONTENT PER LINEAL FOOT</th>
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<tbody>
<tr>
<td>1x3</td>
<td>.976x2.815</td>
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</tr>
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<td>.976x3.817</td>
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<td>.976x5.915</td>
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<td>6.226x5.915</td>
<td>441.923</td>
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</table>

\(^1\) Ibid.
TABLE XXI

ADDITIONAL VOLUME OF WOOD USED
ADDITIONAL VOLUME OF WOOD USED
BY CONVENTIONAL MILL AS COMPARED TO
THRASHER SYSTEM OF MANUFACTURING

<table>
<thead>
<tr>
<th>NOMINAL SIZE</th>
<th>CUBIC CONTENT PER LINEAL FOOT (A)</th>
<th>CUBIC CONTENT PER LINEAL FOOT (B)</th>
<th>PER CENT DIFFERENCE IN WOOD</th>
<th>SAVINGS(^1)</th>
<th>INCREASE(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1x3</td>
<td>32.969</td>
<td>48.336</td>
<td>31.79</td>
<td>46.61</td>
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</tr>
<tr>
<td>1x4</td>
<td>44.705</td>
<td>65.170</td>
<td>31.40</td>
<td>45.78</td>
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</tr>
<tr>
<td>1x6</td>
<td>69.277</td>
<td>98.853</td>
<td>29.92</td>
<td>42.69</td>
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</tr>
<tr>
<td>1x8</td>
<td>93.872</td>
<td>132.505</td>
<td>29.16</td>
<td>41.16</td>
<td></td>
</tr>
<tr>
<td>1x10</td>
<td>118.467</td>
<td>116.172</td>
<td>28.71</td>
<td>40.27</td>
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<tr>
<td>1x12</td>
<td>143.062</td>
<td>195.638</td>
<td>26.87</td>
<td>36.75</td>
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<tr>
<td>2x2</td>
<td>42.702</td>
<td>56.801</td>
<td>24.82</td>
<td>33.02</td>
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<tr>
<td>2x4</td>
<td>80.890</td>
<td>103.658</td>
<td>21.96</td>
<td>28.15</td>
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</tr>
<tr>
<td>2x6</td>
<td>125.351</td>
<td>160.548</td>
<td>21.92</td>
<td>28.08</td>
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</tr>
<tr>
<td>2x8</td>
<td>169.854</td>
<td>210.758</td>
<td>19.41</td>
<td>24.08</td>
<td></td>
</tr>
<tr>
<td>2x10</td>
<td>214.357</td>
<td>264.308</td>
<td>18.90</td>
<td>23.30</td>
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</tr>
<tr>
<td>2x12</td>
<td>258.860</td>
<td>311.177</td>
<td>16.81</td>
<td>20.21</td>
<td></td>
</tr>
<tr>
<td>4x4</td>
<td>188.987</td>
<td>218.925</td>
<td>13.68</td>
<td>15.84</td>
<td></td>
</tr>
<tr>
<td>4x6</td>
<td>292.864</td>
<td>339.077</td>
<td>13.63</td>
<td>15.78</td>
<td></td>
</tr>
<tr>
<td>4x8</td>
<td>396.839</td>
<td>445.120</td>
<td>10.85</td>
<td>12.17</td>
<td></td>
</tr>
<tr>
<td>4x10</td>
<td>500.814</td>
<td>558.217</td>
<td>10.28</td>
<td>11.47</td>
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<tr>
<td>4x12</td>
<td>604.789</td>
<td>657.205</td>
<td>7.98</td>
<td>8.67</td>
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</tr>
<tr>
<td>6x6</td>
<td>441.923</td>
<td>497.737</td>
<td>11.21</td>
<td>12.63</td>
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</tr>
</tbody>
</table>

\(^1\)Savings—Wood Volume Saved by Converting to the Thrasher System

\(^2\)Increase in Wood required by the Conventional Mill over the Thrasher System.
### TABLE XXII

1966 OUTPUT OF ROUNDWOOD PRODUCTS FROM MONTANA TIMBERLANDS BY LAND OWNERSHIP, CLASS AND PRODUCT, 1966

<table>
<thead>
<tr>
<th>LAND OWNERSHIP CLASS</th>
<th>TOTAL VOLUME (-MCF-)</th>
<th>NATIONAL FOREST</th>
<th>OTHER FOREST</th>
<th>PUBLIC INDUSTRY</th>
<th>PRIVATE INDUSTRY</th>
<th>ALL OWNERSHIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saw Logs</td>
<td>195,603</td>
<td>48.4</td>
<td>9.0</td>
<td>13.6</td>
<td>11.1</td>
<td>82.1</td>
</tr>
<tr>
<td>Veneer Logs</td>
<td>27,884</td>
<td>7.9</td>
<td>.2</td>
<td>1.4</td>
<td>2.2</td>
<td>11.7</td>
</tr>
<tr>
<td>Pulp Wood</td>
<td>3,753</td>
<td>1.6</td>
<td>---</td>
<td>---</td>
<td>.05</td>
<td>1.6</td>
</tr>
<tr>
<td>Commercial Poles</td>
<td>2,472</td>
<td>.7</td>
<td>.05</td>
<td>.1</td>
<td>.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Mine Timbers</td>
<td>2,974</td>
<td>.05</td>
<td>---</td>
<td>1.3</td>
<td>.05</td>
<td>1.3</td>
</tr>
<tr>
<td>Misc. Ind. Wood²</td>
<td>256</td>
<td>.05</td>
<td>---</td>
<td>.05</td>
<td>.1</td>
<td>.1</td>
</tr>
<tr>
<td>Posts, Fuelwood, Misc. Farm Timbers</td>
<td>5,289</td>
<td>.8</td>
<td>.05</td>
<td>.1</td>
<td>1.3</td>
<td>2.2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>238,231</strong></td>
<td><strong>59.4</strong></td>
<td><strong>9.2</strong></td>
<td><strong>16.5</strong></td>
<td><strong>14.9</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

1 FOREST INDUSTRY—Lands owned by companies or individuals operating wood-using plants.

2 Includes house logs, converter poles, etc.

TABLE XXIII

LUMBER PRODUCTION
U.S. IN MILLION BD. FT.

<table>
<thead>
<tr>
<th>Year</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>1954</td>
<td>36,356</td>
</tr>
<tr>
<td>1955</td>
<td>37,380</td>
</tr>
<tr>
<td>1956</td>
<td>38,199</td>
</tr>
<tr>
<td>1957</td>
<td>32,901</td>
</tr>
<tr>
<td>1958</td>
<td>33,385</td>
</tr>
<tr>
<td>1959</td>
<td>37,166</td>
</tr>
<tr>
<td>1960</td>
<td>32,926</td>
</tr>
<tr>
<td>1961</td>
<td>32,019</td>
</tr>
<tr>
<td>1962</td>
<td>33,178</td>
</tr>
<tr>
<td>1963</td>
<td>34,706</td>
</tr>
<tr>
<td>1964</td>
<td>36,559</td>
</tr>
<tr>
<td>1965</td>
<td>36,762</td>
</tr>
<tr>
<td>1966</td>
<td>36,584</td>
</tr>
<tr>
<td>1967</td>
<td>34,741</td>
</tr>
<tr>
<td>1968</td>
<td>36,473</td>
</tr>
<tr>
<td>1969</td>
<td>35,597</td>
</tr>
</tbody>
</table>

AVERAGE STUMPAGE PRICES

<table>
<thead>
<tr>
<th>Year</th>
<th>Douglas Fir</th>
<th>Ponderosa Pine</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961</td>
<td>$27.60</td>
<td>$12.10</td>
</tr>
<tr>
<td>1962</td>
<td>24.80</td>
<td>16.10</td>
</tr>
<tr>
<td>1963</td>
<td>27.90</td>
<td>15.80</td>
</tr>
<tr>
<td>1964</td>
<td>38.10</td>
<td>19.00</td>
</tr>
<tr>
<td>1965</td>
<td>42.60</td>
<td>19.80</td>
</tr>
<tr>
<td>1966</td>
<td>50.00</td>
<td>19.80</td>
</tr>
<tr>
<td>1967</td>
<td>41.70</td>
<td>22.20</td>
</tr>
<tr>
<td>1968</td>
<td>61.20</td>
<td>30.20</td>
</tr>
<tr>
<td>1969</td>
<td>82.20</td>
<td>71.00</td>
</tr>
<tr>
<td>1970</td>
<td>41.90</td>
<td>32.10</td>
</tr>
</tbody>
</table>

TIMBER PRODUCTS WHOLESAL Price INDEXES=100

<table>
<thead>
<tr>
<th>Year</th>
<th>LUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>92.1</td>
</tr>
<tr>
<td>1961</td>
<td>87.4</td>
</tr>
<tr>
<td>1962</td>
<td>89.0</td>
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<tr>
<td>1963</td>
<td>91.2</td>
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<tr>
<td>1964</td>
<td>92.9</td>
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<tr>
<td>1965</td>
<td>94.0</td>
</tr>
<tr>
<td>1966</td>
<td>100.1</td>
</tr>
<tr>
<td>1967</td>
<td>100.0</td>
</tr>
<tr>
<td>1968</td>
<td>117.4</td>
</tr>
<tr>
<td>1969</td>
<td>131.5</td>
</tr>
<tr>
<td>1970</td>
<td>113.7</td>
</tr>
</tbody>
</table>

### TABLE XXIII (Continued)

**FOREST PRODUCTS CUT OFF NATIONAL FOREST SERVICE LAND**

<table>
<thead>
<tr>
<th>Year</th>
<th>Fisher</th>
<th>Hunters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>14,535</td>
<td>7,591</td>
</tr>
<tr>
<td>1961</td>
<td>15,986</td>
<td>8,535</td>
</tr>
<tr>
<td>1962</td>
<td>17,008</td>
<td>8,827</td>
</tr>
<tr>
<td>1963</td>
<td>18,151</td>
<td>9,938</td>
</tr>
<tr>
<td>1964</td>
<td>19,358</td>
<td>10,817</td>
</tr>
<tr>
<td>1965</td>
<td>16,197</td>
<td>14,100</td>
</tr>
<tr>
<td>1966</td>
<td>14,709</td>
<td>13,119</td>
</tr>
<tr>
<td>1967</td>
<td>13,956</td>
<td>13,249</td>
</tr>
<tr>
<td>1968</td>
<td>14,521</td>
<td>14,043</td>
</tr>
<tr>
<td>1969</td>
<td>14,868</td>
<td>14,158</td>
</tr>
<tr>
<td>1970</td>
<td>15,239</td>
<td>14,308</td>
</tr>
</tbody>
</table>

During 1970, Montana had 6,248,000 visitor days on Forest Service Lands.

Federal Government paid to Montana for timber cut off Federal land:

- 1968: $1,744,000
- 1969: $4,231,000
- 1970: $3,089,000