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1977 G B HARPOLE, H HALLOCK
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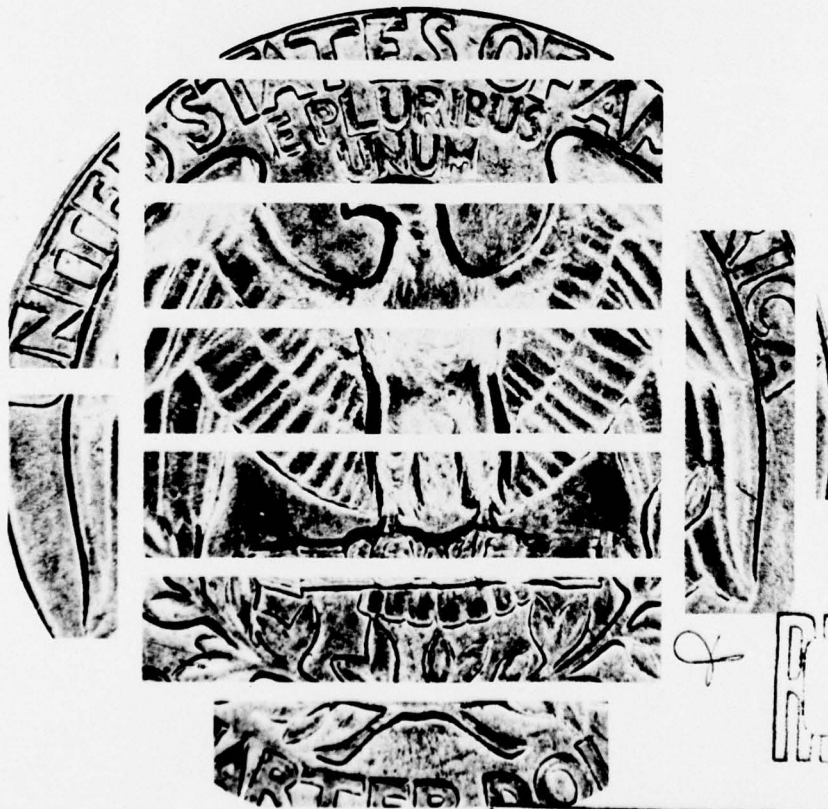
INVESTMENT OPPORTUNITY: BEST OPENING FACE SAWING

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ABSTRACT

Lumber yields can be increased through the use of computer controlled sawing techniques which employ opening face data available from the Forest Products Laboratory's Best Opening Face (BOF) program. This paper discusses the BOF sawing concept, equipment and operating requirements, and provides a method for estimating the investment value of BOF sawing as a sawmill improvement project.

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INVESTMENT OPPORTUNITY: BEST OPENING FACE SAWING

9 Forest service
research paper

By

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GEORGE B. HARPOLE Economist
and

11 1977

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INTRODUCTION

Rising costs of roundwood supplies and of manufacturing are economic incentives for lumber producers to invest in projects that will improve sawmill efficiency. Best opening face (BOF) sawing is one investment opportunity available to lumber manufacturers to increase lumber yields.

Lumber yields, especially from small logs, can usually be increased 10 percent or more through the proper positioning of logs in the log transport system, combined with optimized sawline positioning for sawing lumber of prespecified thicknesses and widths.^{2,3,4} The problem of maximizing lumber yields is basically a problem of fitting rectangles into a circle. BOF sawing provides a key to fixing the positions of all faces and sawlines to maximize the lumber yields. This paper discusses the BOF sawing concept, equipment and operating requirements, and provides a method for assessing potential investments in BOF sawing as sawmill improvement projects.

¹Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

²Hallock, H., and D. W. Lewis. 1971. Increasing softwood dimension yield from small logs. USDA For. Serv. Res. Pap. FPL 166. For. Prod. Lab., Madison, Wis.

³Hallock, H., and D. W. Lewis. 1973. Best Opening Face for second-growth timber. Chap. 4. In *Modern Sawmilling Techniques*, Vol. 1. Proc. First Sawmill Clinic [Portland, Ore. Feb. 1973.] Miller-Freeman Publications, Inc., San Francisco, Calif.

⁴Lewis, D. W., and H. Hallock. 1974. Best Opening Face Programme. Austral. For. Indust. J. 40(10): 21-31. November.

SAWING FOR THE BEST OPENING FACE

When softwood logs are converted to dimension lumber, shrinkage, mechanical, and geometric losses are inherent and unavoidable. Shrinkage of wood as it dries is a physical property. Saw kerf, planer shavings, and sawing variation may be classed as the mechanical losses of manufacturing. They cannot be avoided but can be reduced to minimum levels. The other source of loss is geometric -- that of converting more or less cylindrical logs to rectangular lumber of specific widths. A substantial volume of the log, usually 20 to 35 percent, is lost to slabs and edgings because of the basic differences between log and lumber shapes and the 2-inch nominal width increment factor. BOF sawing is concerned with this geometric loss.

Softwood dimension mills use two basic sawing methods: live sawing, in which all sawlines in the log are parallel; and cant sawing, in which side lumber and a cant are produced in one plane and the cant is further broken down in a 90° opposed plane. For live sawing, all sawing planes are established by the first, or opening, face. In cant sawing, two opening faces in 90° opposed planes establish all remaining sawlines.

The 2-inch-multiple width differential between successive widths of dimension lumber results in edging a flitch to one of these widths rather than the widest random width which could be made. Consequently, on a high proportion of flitches a substantial volume of sound wood remains in the edgings.

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Under any given set of conditions, the largest volume yield is obtained when sawlines are so placed in the log that the lumber is randomized by fitting specified-width flitches is minimized. Because all sawlines are related, the placement of the opening face is critical. Under any set of conditions, there are no rules of thumb or general matter, any rules at all as to where the opening face should be for any specific log.

The Best Opening Face computer program developed at the Forest Products Laboratory has the capability to model all sawing variables such as kerf, sawing variation, planing allowance, and length, diameter, and taper of the log -- to determine for straight logs the exact position of the sawlines that will result in the highest volume of lumber. It is a mathematical system that models the log and the sawing method, and compares all possible solutions to determine the best one.

It is difficult to obtain from industry numerical estimates of the increases in volume that have resulted from the application of the BOF system. However, an estimate can be made by comparing potential recoveries under two

conditions -- the best sawing solution and the poorest -- and then making the assumption that good sawyers might get results midway between these two extremes. The difference between yields resulting from the best and poorest opening faces -- but otherwise maximized recovery from logs in the 5- to 20-inch-diameter range -- is about 20 percent for live sawing and 27 percent for cant sawing. Because the difference is greatest for logs with small diameters (as much as 90 percent) and declines substantially with increases in diameters (as low as 6 percent) the effect of log mix is important (fig. 1). All in all, an estimate of 10 percent or more additional recovery from logs averaging between 5 and 16 inches in diameter seems reasonable.

A mill's sawing variables such as kerf, sawing variation, planing allowance, and mix of lumber sizes produced can be assumed to be unaffected by BOF sawing. It can be pragmatically assumed that any increase in lumber recovery will be accompanied by a proportionate increase in the production of planer shavings and sawdust. This also means that the production of wood chips will decrease more rapidly than lumber recovery will increase.

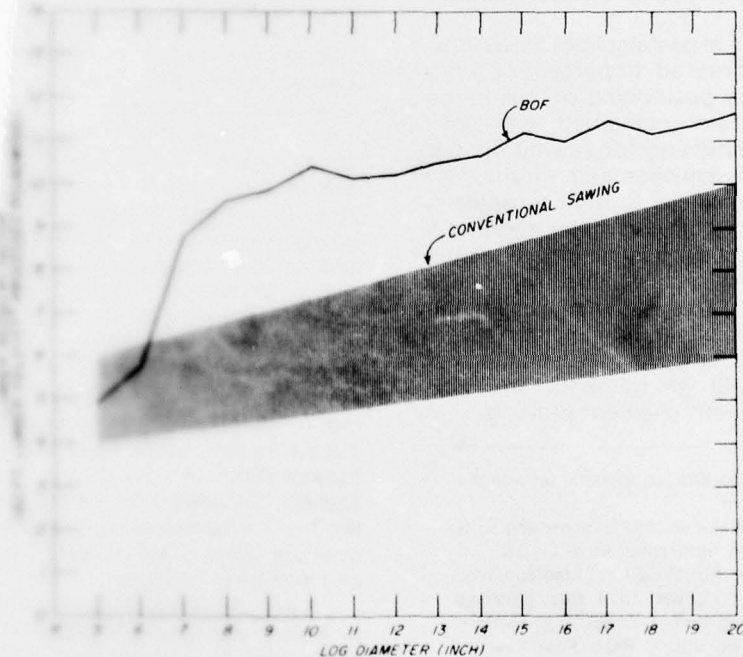


Figure 1. -- Estimated lumber recovery factors for sawing with and without Best Opening Face sawing control.

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BOF EQUIPMENT REQUIREMENTS

Certain basic requirements must be met to apply BOF type sawing systems. Scanning equipment capable of determining the log's diameter, length, and taper must be combined with a log handling and transport system capable of maintaining the log in a known position in space from scanning through completed sawing.

Two options are available with respect to the computer control system: Mini-computer systems and systems using medium-capacity computers. A mini-computer can accept and process log scanner data, look up the predetermined sawing solutions, and generate the log and saw-position control outputs. Because solutions can be stored for only a limited number of taper classes, this system does not promise quite the level of recovery possible if the system were operated in real time with a medium-capacity computer which can provide a solution for each log processed.

INVESTMENT AND OPERATING COSTS

The price of BOF sawing equipment and installation costs will vary in proportion to their sophistication, and whether the system is installed as an improvement project for an existing mill or incorporated into the construction of a new mill. The cost of a BOF system using a medium-capacity computer may be as much as \$500,000 installed as an improvement to an existing mill. The cost of a BOF system using a mini-computer may be as little as \$50,000 if incorporated into the design of a new mill.

In general, there will only be one type of operating cost associated with the use of a BOF sawing system, i.e. overhead costs, or those costs that will vary with the complexity and cost of the BOF sawing system such as for maintenance and repairs. Annual overhead costs can normally be expected to be about 6 percent of the installed cost of the system.

THE INVESTMENT VALUE OF A BOF SAWING SYSTEM

The investment value of a BOF sawing system will be largely dependent upon the profit contribution that may be realized from the use of the system. Once a proposed BOF

sawing system's profit contribution has been estimated, a maximum installed investment value for the system can be estimated. Assuming a 5-year economic life for BOF computer control equipment, the primary data required for estimating an investment value are (1) the average prices of lumber, wood chips, sawdust, and planer shavings, (2) the expected increase in lumber recovery that would result from BOF sawing, (3) sawdust and planer shavings produced, as a percentage of the volume of lumber produced, (4) the average annual cubic foot volume of logs processed, (5) an estimate of the annual average overhead costs for the BOF system (repairs, maintenance, supplies, etc.) as a percent of the installed equipment cost, and (6) the rate of return that might be expected for comparable investments.

Using discounted cash flow analyses, one can calculate the largest investment possibly justified by the project's expected profit contribution. It will be equal to the present value of the annual stream of after-tax profit contributions (net benefits) expected to result from the project. Present value is calculated by discounting after-tax profit contributions at a rate of interest appropriate for alternative investments with similar risk. For sawmill improvement projects not expected to influence the average volume of log throughput, such as BOF sawing, the project's annual after-tax profit contribution will be the difference between the increase in total revenues less the increased costs of taxes and overhead (maintenance, repair, and supplies). The resulting investment value then is the maximum expense justifiable for BOF sawing equipment and any associated increases in annual working capital requirements.

The project's before-tax profit contribution can be calculated as the increase in the converted value of the cubic foot volume of the logs processed resulting from BOF sawing. That is,

$$\begin{array}{r} \text{Average} \\ \text{annual profit} \\ \text{contribution} \\ \text{(AAPC)} \end{array} = \begin{array}{r} \text{Marginal} \\ \text{value of} \\ \text{substitution} \\ \text{(MVS)} \end{array} \times \begin{array}{r} \text{Cubic feet} \\ \text{of} \\ \text{substitution} \\ \text{(CFS)} \end{array} \quad (1)$$

where

MVS is the value, per cubic foot, of producing lumber, sawdust, and planer shavings instead of wood chips, and

CFS is cubic foot increase in the volume of lumber produced due to BOF sawing.

Marginal Value of Substitution (MVS)

As indicated earlier, increasing the recovery of lumber products through BOF sawing will also increase the relative volume of sawdust and planer shavings produced. Because the volume of sawdust and planer shavings is assumed to be produced in direct proportion to the volume of lumber produced, the marginal value of the substitution (MVS) of lumber for wood chips can be approximated using the following equation:

$$\begin{aligned} \text{MVS}/\text{ft}^3 &= (\text{\$Lbr}/\text{ft}^3 - \text{\$Chips}/\text{ft}^3) \\ &+ \frac{\% \text{Dust}}{\% \text{Lbr}} (\text{\$Dust}/\text{ft}^3 - \text{\$Chips}/\text{ft}^3) \quad (2) \\ &+ (\Delta \text{\$Lbr}/\text{ft}^3 \times \frac{\% \text{Lbr}}{100}) \end{aligned}$$

where

$\text{\$Lbr}/\text{ft}^3$ is $\frac{\text{Average realization for lumber(dollars)/M bd. ft.}}{\text{Cubic feet of solid wood volume/M bd. ft}}$

$\text{\$Chips}/\text{ft}^3$ is $\frac{\text{Average realization for wood chips/Unit}}{\text{Cubic feet of solid wood volume/Unit}}$

$\text{\$Dust}/\text{ft}^3$ is $\frac{\text{Average realization for sawdust and planer shavings/Unit}}{\text{Cubic feet of solid wood volume/Unit}}$

$\% \text{Dust}$ is percent of roundwood volume converted to sawdust and planer shavings, Δ

$\% \text{Lbr}/\text{ft}^3$ is percent of roundwood volume converted to lumber, and

$\Delta \text{\$Lbr}$ is estimate of the increase in the value of lumber per cubic foot, as a result of BOF sawing.

The marginal value of substitution, then, is an approximation of the net value of converting a cubic foot of roundwood into lumber instead of into wood chips, including the estimate of possible increase in the value of the lumber product mix (table 1).

Table 1. -- Example of calculation of marginal value of substitution (MVS) for a BOF project

A. Sales realization per M bd. ft. of lumber	= \$80
Cubic feet of solid wood per M bd. ft.	= 56.625
Realization value per cubic foot of lumber, \$/br/ft ³	= \$1.413
B. Chip sales realization per unit (200 ft ³ green basis)	= \$20
Cubic feet of solid wood per unit	= 72
Realization value per cubic foot of wood chipped, \$chips/ft ³	= \$0.279
C. Average realization per unit of sawdust and shavings	= \$3.00
Cubic feet of solid wood per unit of sawdust and shavings	= 54
Realization value per cubic foot of wood converted to sawdust and shavings, \$dust/ft ³	= 0.056
D. Percent of log converted to sawdust or planer shavings, %dust	= 24%
Percent of log converted to lumber, %lbr	= 40%
Ratio of (sawdust plus planer shavings) to lumber, $\frac{\%dust}{\%lbr}$	= 0.60
E. Increase in value of lumber, Δ \$/br/ft ³	= 0.00
F. Calculations of MVS	
$MVS/ft^3 = (\$/br/ft^3 - \$/chips/ft^3 + \frac{\%dust}{\%lbr} (\$/dust/ft^3 - \$/chips/ft^3) + (\Delta\$/br/ft^3 \times \frac{\%lbr}{100})$	
$MVS/ft^3 = (\$1.413 - \$0.279) + \frac{24\%}{40\%} (\$0.056 - \$0.279) + (0.00 \times 0.40)$	
$MVS/ft^3 = (\$1.134) + 0.6(-\$0.223) + (0)$	
$MVS/ft^3 = \$1.134 - \$0.134 = \$1.000$	

Cubic Feet of Substitution

The total cubic foot volume of roundwood converted into lumber instead of wood chips as a result of BOF sawing can be calculated by multiplying the percentage increase in lumber recovery expected to result from BOF sawing by the average annual cubic foot volume of logs processed:

$$CFS = \Delta CRR_l \times \text{Average annual ft}^3 \text{ volume of logs processed} \quad (3)$$

where

CFS is cubic feet of substitution, and ΔCRR_l is expected change in the cubic recovery ratio of lumber due to BOF sawing.

The CFS result then is the total annual cubic foot volume of roundwood that will be converted into lumber instead of into wood chips (table 2). The additional volume of wood chips unavoidably traded in for sawdust and planer shavings is accounted for in the calculation for the marginal value of substitution. The cubic feet of substitution refers only to the volume of lumber substituted for wood chips.

Table 2. -- Example of calculation of cubic feet of substitution (CFS) for a BOF project

A. Average annual volume of logs processed in M bd. ft., log scale	= 8,176
B. Average number of cubic feet of wood per M bd. ft., log scale	= 200
C. Average annual cubic foot volume of logs processed	= 1,635,200
D. Expected change in cubic recovery ratio of lumber due to BOF sawing (ΔCRR_g)	= +0.05
E. Calculation of CFS	
CFS = ΔCRR_g x average annual cubic foot volume of logs processed, and	
CFS = 0.05 x 1,635,200 = 81,760	

Investment Values

Having the MVS/ft³ and CFS estimates, a BOF sawing project's annual average profit contribution (AAPC) can be estimated using equation (1) ($AAPC = MVS/ft^3 \times CFS$). With this estimate, the investment value of an installed BOF computer controlled sawing system (IVS), and the first year increase in working capital requirements (WCR) can be approximated by using figure 2, or equations (4) and (5):

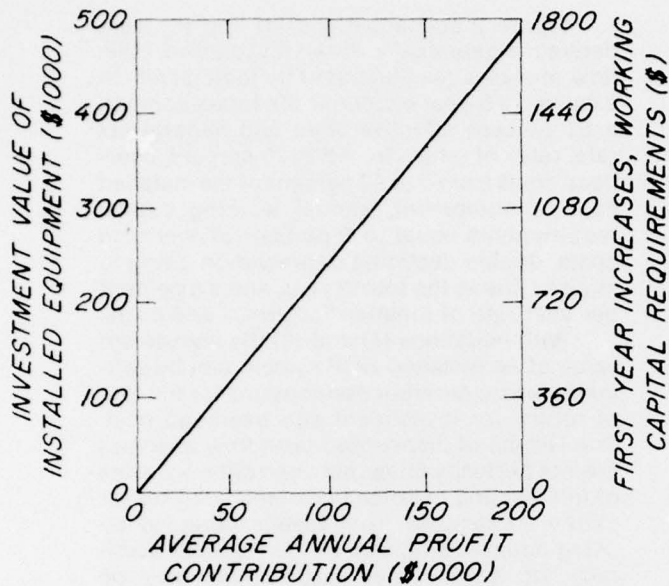


Figure 2. -- Investment value of an installed BOF computer-controlled sawing system and the first year increase in working capital requirements based on the project's annual average profit contribution. These values are based on discounted cash flow analyses, assuming a 5-year economic life for equipment, a 51 percent effective tax rate, a 15 percent rate of return for investment capital, overhead cost as 6 percent of the installed costs of equipment, annual working capital requirements equal to 6 percent overhead costs, double declining depreciation going to straight line in the fourth year, and a 5 percent per year rate of inflation for prices and costs.

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$$IVS (n = 5) = 94,250 + 2.545 (AAPC) - 4,344 (OHR) - 5,869 (ROR) \quad (4)$$

$$WCR = IVS \times \frac{OHR}{100} \times \frac{WCP}{100} \quad (5)$$

where

- IVS is investment value of installed BOF sawing system expressed in dollars,
- n is assumed economic life of system,
- ROR is appropriate rate of return, expressed as a percent, for comparable investment opportunities,
- OHR is first year overhead cost (maintenance, repairs, etc.) expressed as a percent of the IVS value,
- WCR is first year working capital requirements expressed as total dollars, and
- WCP is working capital requirements expressed as a percent of overhead costs.

Figure 2 and equations (4) and (5) were derived algebraically from discounted cash flow analyses (as illustrated by table 3) which assumed a 5-year economic life for equipment, a 51 percent effective state and Federal tax rate, rates of return from 8 to 20 percent, overhead costs from 5 to 10 percent of the installed cost of equipment, annual working capital requirements equal to 6 percent of overhead costs, double declining depreciation going to straight line in the fourth year, and a 5 percent per year rate of inflation for prices and costs.

With equations (4) and (5) the investment value of an installed BOF system can be estimated using different assumptions for the rate of return for investment and overhead cost. The results of discounted cash flow analyses are not perfectly linear between different rates of interest and overhead cost and will vary for extreme examples from results obtained by using equations (4) and (5). For greater accuracy, or where other assumptions may be preferred to be used (effective tax rate, working capital requirements, economic life, etc.) detailed cash flow analyses should be used.

In the analysis presented here, and as illustrated in table 1, a BOF sawmill improvement project is characterized as an investment project in which there are two principle components to the total investment: (1) the investment required to cover the cost of purchasing and installing BOF computer control equipment, and (2) the investment required to cover the increase in working capital requirements due to the increased overhead expenses carried in the manufacturing costs of unsold products. For these reasons, the investment value of BOF computer control equipment and the investment required to cover the first year increase in working capital requirements are approximated as first-year beginning values.

The increases in working capital requirements indicated for the second through fifth years (table 3) are due to the effects of the 5 percent per year rate of inflation assumed and not covered by the first year increase in working capital. The full amount of money invested as working capital is assumed to be recovered at the end of the fifth year. The salvage value of the BOF computer control equipment is assumed to be zero.

U.S. Forest Products Laboratory.

Investment opportunity: Best opening face sawing, by George B. Harpole and Hiram Hallock. Madison, Wis., FPL, 1977.

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Table 3. -- Financial summary for a BOF computer control investment project yielding a 15 percent rate of return

	Year ending values					
	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
	Dol	Dol	Dol	Dol	Dol	Dol
Cubic feet of substitution ¹	--	81,760	81,760	81,760	81,760	81,760
Marginal value of substitution (\$/ft ³) ²	--	1.000	1.050	1.103	1.158	1.216
Total profit contribution	--	81,760	85,848	90,140	94,647	99,380
Overhead costs ³	--	12,000	12,600	13,230	13,892	14,586
Installed cost of BOF system	200,000	--	--	--	--	--
Increase in working capital	720	36	38	40	42	-876
Total investment	200,720	--	38	40	42	-876
Depreciation ⁴	--	80,000	48,000	28,800	21,600	21,600
After-tax profit contribution (earnings)	--	74,982	60,372	52,374	50,586	52,565
After-tax cash flow	-200,720	74,946	60,333	52,334	50,544	53,441
Accumulated after-tax net cash flow	-200,720	-125,774	-65,441	-13,107	37,437	90,878

¹See table 2.

²See table 1.

³Includes maintenance, repair and supplies costs.

⁴Double declining going to straight line in 4th year.

SUMMARY AND CONCLUSIONS

Lumber yields can be increased through the use of computer controlled sawing techniques which employ opening face data available from the Forest Products Laboratory's Best Opening Face (BOF) program. Improvements in lumber yields from BOF sawing are highest for logs smaller than 16 inches in diameter. Recovery of lumber products can probably be increased 10 percent or more over conventional sawing methods for such logs.

Certain basic requirements must be met to apply BOF type sawing systems. Sawing equipment capable of determining the log's

diameter, length, and taper must be combined with a log handling and transport system capable of maintaining the log in a known position in space from scanning through completed sawing.

Two options are available with respect to the computer control system. A mini-computer can be used but does not promise quite the level of recovery possible with a medium-capacity computer. By estimating the potential profit contribution that may result from BOF sawing, the investment value or maximum installed value of a BOF sawing system can be estimated.