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Rough Mill Improvement Guide for Managers and Supervisors

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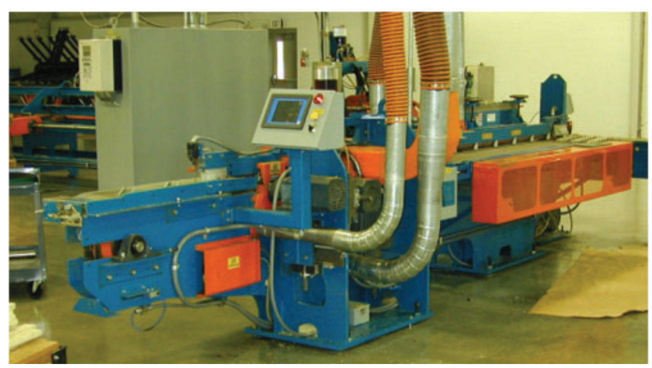

Abstract

Wood products manufacturers require an efficient recovery of product from lumber to remain profitable. A company's ability to obtain the best yield in lumber cut-up operations (i.e., the rough mill) varies according to the raw material, product, processing equipment, processing environment, and knowledge and skill of the rough mill's employees. This book discusses several key principles that can help manufacturers understand and solve yield and production problems. Our publication was inspired by the 1981 publication "Rough Mill Operator's Guide" written by Edward K. Pepke and Michael J. Kroon. Computer-based technologies and new rough mill layouts and equipment are prevalent in today's rough mills, therefore, they are given considerable emphasis in this contemporary version of the Pepke-Kroon guide.

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Foreword

Wood product companies require an efficient recovery of product from lumber to remain profitable. A company's ability to obtain the best yield in lumber cut-up operations (i.e., the rough mill) varies according to the raw material, product, processing equipment, processing environment, and knowledge and skill of the rough mill's employees. This book discusses several key principles that can help manufacturers contemplate and solve yield and production problems.

In 1981, Edward K. Pepke and Michael J. Kroon published Rough Mill Operator's Guide, which has gone out of print. Since that time, the proliferation of computer technology has changed the way many rough mills operate. With advanced technology, there is a need to educate operators and managers. Without education and training, the technology is often ineffective, or worse, it is detrimental to the goal of improving rough mill performance. Clearly, there is a need for a contemporary version of the guide. However, many of the principles presented by Pepke and Kroon are still valid. Both the newer technologies and processing strategies and the long-established methods that still apply are discussed in this publication "Rough Mill Improvement Guide for Managers and Supervisors," and a future companion publication, "The Rough Mill Operator's Guide."

Our initial goal was to update the "Operator's Guide." However, in preparing for rough mill improvement workshops, we realized there also was a lack of updated educational materials for managers and supervisors. This book is a compilation of material the authors generated to teach the workshops. The "Operator's Guide" will be published separately, and together with this publication, will provide a pair of useful educational resources for rough mill owners and operators.

This book is divided into three sections. The first section covers the importance of product yield as it relates to value, the impact of lumber grade and quality characteristics on yield, and the use of part grades and scheduling in the rough mill. The second section reviews both traditional and modern cut-up operations in the rough mill, focusing on the major processes of ripping and crosscutting lumber. The third section presents additional issues and operations that impact yield, such as the lay-up of edge-glued panels, fingerjointing, and moulders.

Both this publication and the operator's guide were inspired by the earlier work of Pepke and Kroon. Their 1981 operator's guide has been in great demand for many years. We thank them for the information they assembled and conveyed in that publication and for the good sense they demonstrated in developing a guide that targets the rough mill operator. Technology development will surely continue at a rapid pace. However, it is our hope that the principles discussed in this book will remain valid over many years as have the principles that originally were conveyed by Pepke and Kroon.

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PRODUCT YIELD, VALUE, AND QUALITY REQUIREMENTS

Lumber Processing Efficiency, Yield, and Value

The Importance of Lumber Processing Efficiency

After lumber has been kiln dried, sawing it into rough sized components, parts, or blocks is often the next step in the value-added process. This is the function of the rough mill. Rough mill yield is a measure of the rough mill's efficiency at converting rough sawn lumber into useful parts. In manufacturing these parts, the rough mill removes undesirable wood characteristics or defects. The sawn parts may then be sent to the moulder for profiling or laid up to be glued as a panel. In this chapter we will examine yield to understand the influence it has on profitability and its limitations as a management tool.

What is a satisfactory yield in the rough mill? This question is difficult to answer. Many process factors affect rough mill yield, including lumber species, mix of lumber grades, lumber drying quality, lumber size, cutting bill sizes, part quality, operator experience, plant layout, machinery, processing sequence dictated by plant layout, and production scheduling. These factors interact so that a slight change in any factor may have a large impact on yield—and hence on the profitability of the rough mill. In fact, with the exception of the kiln department, no other department has the concentrated potential for savings that exists in the rough mill.

During the past two decades, the supply of high-quality lumber has consistently fallen short of demand and lumber costs are higher than ever. In 1999, lumber costs averaged 50 percent of total manufacturing costs in a sample of U.S. dimension plants that produced parts for furniture or cabinet manufacturers (Fig. 1). For the typical furniture plant, lumber is usually the largest material cost item and can exceed 12 percent of the total production cost (U.S. Department of Commerce 1999).

The cost of native hardwood lumber continues to outpace the price of furniture. This price differential has widened in the past decade (Fig. 2) (U.S. Department of Labor 2000) making it more important than ever that the lumber cut-up operation be as efficient as possible.

As lumber is processed, value is added at each step of the process, as illustrated in Figure 3 (adapted from Pepke and Kroon 1981). A rough mill processing 12 thousand board feet (12 Mbf) of dried lumber per day valued at $900/Mbf can save approximately $58,000 per year by improving rough mill yield by just 1 percent. (Calculations showing how to estimate savings are

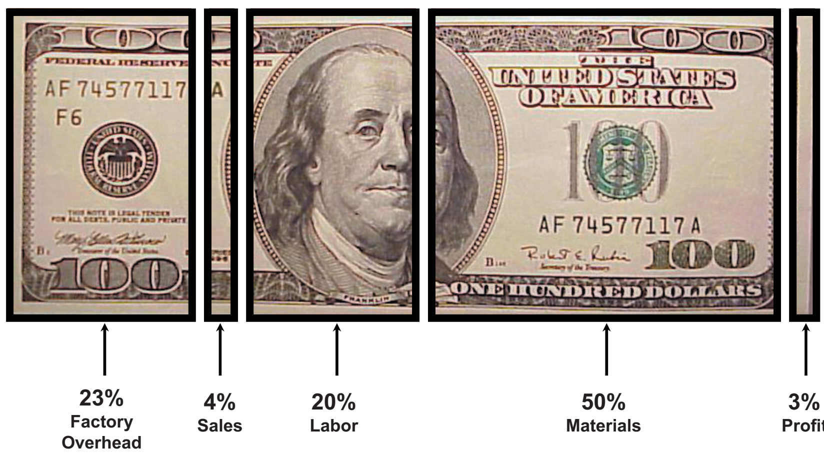

Figure 1.—Where do the dollars go in rough mill manufacturing? (Wood Component Manufacturers Association 1999.)

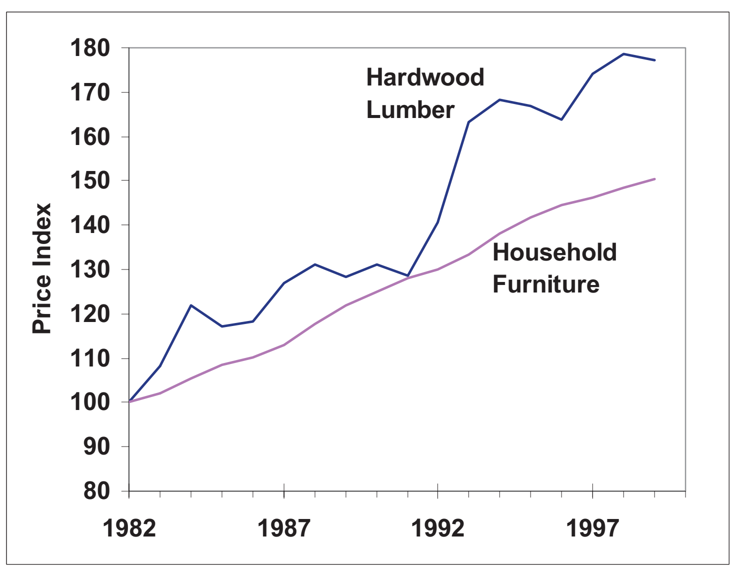

Figure 2.—Producer price indices for hardwood lumber and household furniture, adjusted to 1982=100.

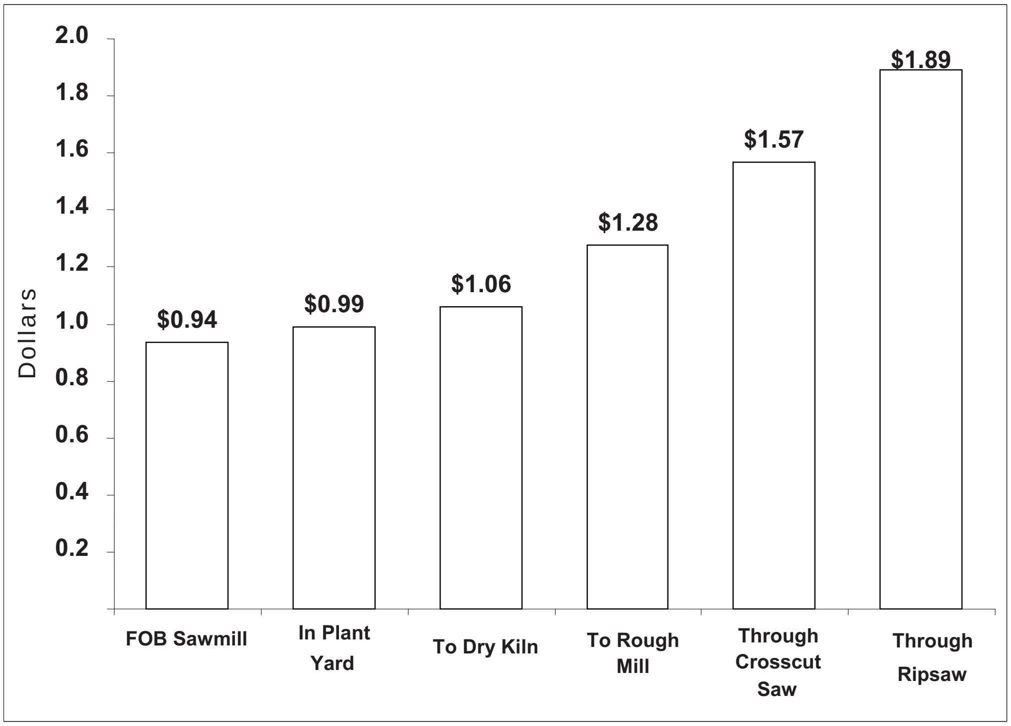

Figure 3.—Approximate value increase of 1 board foot of lumber as it is processed by each operation through the rough mill (adapted in 2000 from Pepke and Kroon 1981 by applying an inflation factor of 1.8).

discussed later in this section.) The high value of dried lumber justifies an extensive effort to maximize yield!

Yield Measurement and Part Values

Defining Yield. Our first task is to define yield and describe its measurement. The most basic definition of yield in a manufacturing plant is the ratio of the amount of primary product output to the amount of raw material input, expressed as a percentage. We can further refine the definition for a rough mill: yield is the amount of usable parts cut from a given quantity of lumber (Wengert and Lamb 1994). Yet even this more precise definition allows variation in the manner in which rough mill yield is calculated. The result is that yield numbers between companies, between plants of the same company, and even between departments of the same plant often cannot be compared because of differences in how yield is calculated.

Some of the issues that need to be addressed in measuring yield in your rough mill include:

- Will green or dry (gross or net) lumber volume be used? (dry volume is recommended)
- Will only parts that meet the cutting bill be tallied? (yes… recommended) (the cutting bill is a list of part sizes and quantities that need to be cut by the rough mill)
- Will defective parts or setup parts be tallied? (no… not recommended)
- Will parts cut to meet the overage allowance be counted? (yes… recommended)
- Will nominal or actual thickness be used? (actual is recommended)

It also is recommended that yield be fully defined within the business unit. For example:

Percent rough mill yield is defined as the sum of the volume of wood parts that are needed to satisfy the cutting bill (this will include parts of all fixed lengths and widths, panels made up of random width parts, and specified overages) divided by the volume of dry lumber used.

This can be expressed as:

% Yield=[Volume of Rough Parts and Panels (board feet) ÷ Volume of Rough, Dry Lumber (board feet)] X 100 (Eq. 1)

A more traditional method is to use the surface area rather than the volume, which works well in most situations. It should be recognized, however, that using surface area instead of volume will neglect yield losses that occur when thicker lumber is used because the specified thinner lumber was not available (for example, using 6/4 lumber when 5/4 lumber was required).

Only parts that satisfy the cutting bill should be tallied as product volume. This means short lengths not on the cutting bill that are salvaged and set aside for later use should not be counted until they actually fulfill a cutting bill part request (sometime in the future). Known defective parts passed along as setup pieces should not be counted as part of yield. Rough mill yield, however, should be credited with parts cut to meet an overage allowance (extra parts included in cutting schedule to ensure that required numbers are available for assembly in the event that parts are damaged or rejected in subsequent processing stages). Finally, the actual part sizes should be used to calculate part volume. The most important point that needs to be re-emphasized is that regardless of how you calculate yield, the method should be fully communicated, understood, and agreed upon throughout the business unit.

<u>Yield: A limited performance indicator</u>. Yield can be used to measure the effectiveness of an operation in converting a raw material into a value-added product. Yield can directly affect manufacturing costs by the large impact it exerts on the material costs for parts, which in turn impacts profitability. However, the consideration of yield alone can be misleading since yield is not the only factor in the profitability equation. Consequently, care must be taken to ensure that yield is not over-emphasized in the production setting.

An example will illustrate this point. In two separate cases, consider the material costs required to produce 1 Mbf of parts (note that labor is not included in these calculations).

In Case 1, No. 1 Common lumber costing $900/M board feet is used to produce 1 Mbf of parts with a yield of 53 percent. As shown in the following calculation, the cost of the No. 1 Common lumber required to produce 1 Mbf of parts is $1,698.

Case 1: No. 1 Common:
1 Mbf parts/53% yield X $900/Mbf lumber =
$1,698/Mbf parts

In Case 2, the same 1 Mbf cutting bill is produced by cutting No. 2 Common lumber costing only $600/Mbf but yields only 38 percent. The lumber cost to produce 1 Mbf of parts is $1,578.

Case 2: No. 2 Common
1 Mbf parts/38% yield X $600/Mbf lumber =
$1,578/Mbf parts

In this example, we see that though the yield is lower with the No. 2 Common lumber, and by paying 33 percent less for the raw material, the cost associated with the decrease in yield is offset. The result is the material cost for the 1 Mbf of parts is reduced from $1,698 to $1,578, which equates to a 12¢ per board foot reduction in part cost (from $1.70 to $1.58). Of course, more labor will be required with the lower grade of lumber, and this will, to some extent, reduce the raw material cost savings achieved by using a lower grade lumber.

The main conclusion to draw from this example is that yield alone does not provide a complete picture of profitability in the rough mill. This example also introduces the concept of evaluating the rough mill process based on the unit product cost—in this case, dollars per Mbf of parts.

Thus, using only yield to measure rough mill efficiency can lead to poor management decisions. Yield improvement, however, can strongly impact profit.

<u>The least cost concept</u>: a better approach. For many operations, the rough mill processes most of the raw material (lumber) used in their final products. This presents an opportunity for the rough mill to impact overall profitability by maximizing the value of the products produced and by minimizing manufacturing

costs. The relationship between profit, product value, and manufacturing costs is straightforward:

Profit = Value of Parts Produced - Manufacturing Costs (Eq. 2)

Let's examine the profit equation to determine what rough mill personnel can do to increase rough mill profit. First, manufacturing cost will be considered by reviewing its two major components. If only the direct costs are considered while ignoring the indirect costs associated with factory overhead, then an estimate of manufacturing costs can easily be obtained:

Manufacturing Costs = Lumber Costs + Labor Costs (Eq. 3)

Of course, lumber costs change according to the species, grade, thickness, and the volume of lumber processed. Rough mill managers may be able to control the incoming lumber grade mix, which in turn will impact yield and lumber usage and consequently the lumber cost. For the most part, however, the rough mill manager's actions are constrained by the dictates of the product, the purchased lumber delivered to the rough mill, and the mill's processing capacity. Considering labor costs, most rough mill operations in the United States do not have excess labor that can be trimmed without significant capital expense, so labor costs are not easily influenced. Thus, manufacturing costs are difficult to impact significantly without major changes in plant layout or product.

The other term in the profit equation (Eq. 2) to consider is the value of parts produced. This is best illustrated by considering a component parts manufacturer. Assuming that all parts manufactured are sold, the value of the parts and panels produced can be equated to the total dollars received for those products. The per-unit value ($ per board foot of product) received for the rough mill product is largely determined by market forces that are beyond the rough mill's control. However, it is important to remember that *rough mill practices can influence the quantity or volume of product manufactured from a given amount of lumber and labor through yield gain (or loss)*. If the volume of product can be increased without increasing labor or lumber costs, then, assuming the product's market unit value remains constant, the total value of parts produced will increase and consequently profit will increase.

Though the goal of the rough mill is to make a profit, the calculation of profit is difficult. The better method for measuring performance in the rough mill is the manufactured cost per unit (board foot) of product. To calculate the manufactured cost per board foot of product:

Manufactured Cost/Board Feet of Products = Manufacturing Cost/Product Board Feet (Eq. 4)

Obviously, the goal of the rough mill is to produce a product with the minimum manufactured cost per board foot of product—an idea referred to as the least cost concept. The way to reduce the manufactured cost per board foot of product, while keeping manufacturing costs constant, is to increase the volume of product.

A simple example will illustrate the calculation of the manufactured cost per board foot of product using only lumber and labor costs. These two cases will demonstrate the use of the least cost concept and highlight the projected impact (see Table 1) that yield improvement can have on the manufactured cost per board foot of rough mill parts.

The current situation is taken to be our base case (see Table 1, Case 1). We assume that our example rough mill currently processes 12 Mbf of lumber per day during an 8-hour shift. The rough mill employs 16 people with an average labor cost of $14/hour per person. On average, the dried lumber value is $900/Mbf at the rough mill infeed. The average rough mill yield is 53 percent, and therefore produces 6.36 Mbf of parts per shift. The lumber and labor cost per day is $12,592 (ignoring factory overhead). The parts cost is calculated as $1,979.87 per Mbf of parts, or $1.98 per board feet for Case 1.

Table 1.—The effect of yield improvement on the projected manufactured cost of one board foot of parts, illustrating the least cost concept.

	Case 1 Current	Case 2 Projected
Parts Yield	53%	54%
Lumber usage/day	12 Mbf	12 Mbf
Lumber cost	$900/Mbf	$900/Mbf
Costs/Day		
Lumber	$10,800	$10,800
Labor	$1,792	$1,792
Total costs/day	$12,592	$12,592
Parts Production		
Parts produced/day	6,360 board feet	6,480 board feet
Part costs/Mbf parts	$1,979.87	$1,943.21
Part costs/board feet parts	$1.98	$1.94

Next, we ask the question, "How much value would a 1 percent yield improvement over the base case be worth to the rough mill?" This leads to our second case (see Table 1, Case 2) in which it is assumed that an additional 1 percent yield of parts can be obtained from the lumber through improved operational procedures alone (using the same grade of lumber and the same amount of labor in the rough mill). Increasing the yield by 1 percent will increase the volume of parts produced by 120 board feet per day. This increase in output has occurred without an increase in the total manufacturing costs, so the part costs have been reduced to $1,943.21/Mbf of parts, a reduction of $36.66/Mbf. On a per-unit basis, the 1 percent yield increase has decreased unit costs by almost 2 percent and is worth $58,000 annually to the rough mill.

Using the same approach described in Table 1, Figure 4 illustrates the annual part savings associated with a 1 percent yield increase as a function of the current rough mill yield and lumber cost. For example, consider an operation that processes 12 Mbf per 8-hour shift employing 16 people earning an average wage of $14/hour. Assuming this rough mill achieves a 60 percent yield using lumber that on average costs $1,100/Mbf.

Figure 4 illustrates that the annual savings in part costs generated by raising the yield 1 percent will be approximately $61,000. (To find this value, locate the intersection of the solid line that represents 60 percent yield and the projected vertical dashed line from $1,100/Mbf lumber cost, and read the annual part value from the axis at left).

Figure 4 also shows that a higher average lumber cost, a higher volume throughput, or a lower base case yield will produce an even greater savings in part costs due to yield improvement (assuming labor costs are constant). The dotted lines in Figure 4 represent a 10 percent increase in lumber throughput (from 12 Mbf to 13.2 Mbf per day). If all factors are kept the same as in the previous example except for a 10 percent increase in throughput, the expected annual savings in part costs would increase to more than $66,000.

In summary, the proper measurement to determine how well a rough mill operates is not yield, but the manufactured cost per unit of part produced. The objective is to minimize this unit cost, which is sometimes referred to as the least cost concept.

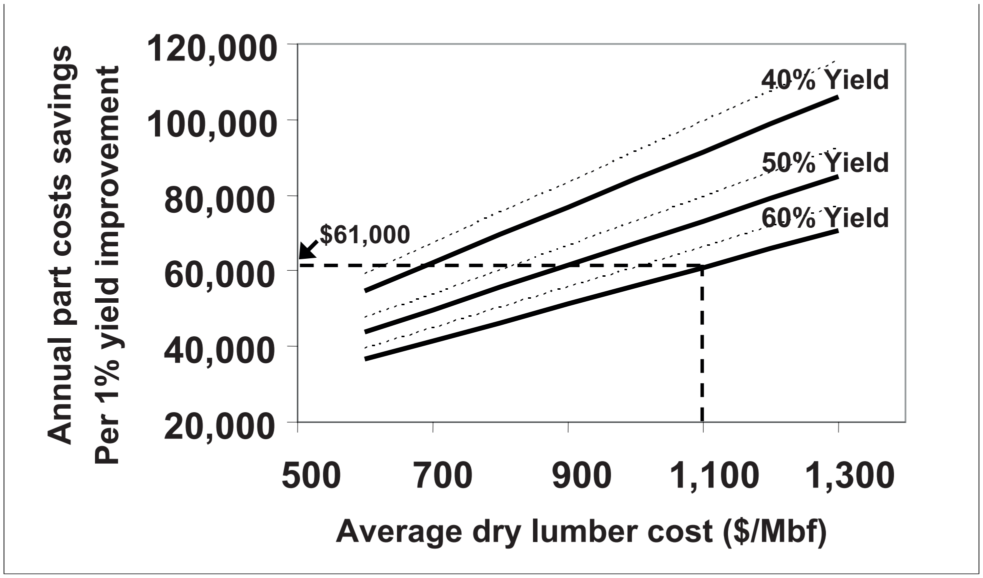

Figure 4.—Annual part cost savings from a 1 percent yield improvement for the rough mill processing 12 Mbf per day with 16 employees (dotted lines indicate a 10 percent increase in throughput, or 13.2 Mbf processed per day, with no increase in labor cost).

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Impact of Lumber on Yield and Value

Lumber Grade and Lumber Size

Most rough mill managers "choose" a particular lumber grade mix for a cutting order based on the lumber available in inventory and from suppliers and on the standard grade mix for the mill. The standard grade mix is one that has evolved based on observations of what runs smoothly through the mill and produces the needed parts with an acceptable yield. However, a standard grade mix may not be the best grade mix for a specific cutting order or for one species versus another. Even for a given cutting order, the best grade mix may change when relative lumber prices change, when the length and width of the lumber supply changes, when rough mill equipment or operator expertise changes, or when there are changes in cutting order specifics such as part pricing, sizes, and quality, numbers of parts, or turnaround time on the order.

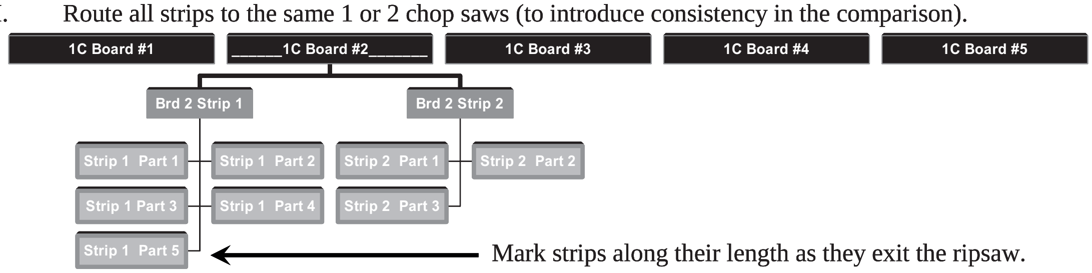
Choosing the best lumber grade mix should not be a single decision for all species and all cutting orders (except for rough mills that focus on a particular product so that they produce the same part sizes using the same species every day). Choosing the best lumber grade mix should not be a one-time event or a once-a-year activity—it should be done whenever lumber prices, products, or rough mill operations change.

In choosing the best lumber grade mix to process, it is helpful to run frequent studies in the rough mill using small groups of boards of a given grade (e.g., five boards). The basic design for these small-scale yield studies is shown in Figure 5. These boards are tracked through the rough mill and the yield is calculated based on the tally at the sort station. Several five-board runs can be conducted for each lumber grade in a single day with minimum disruption. If this is done for every significant cutting order, your rough mill managers will be better able to answer the question, "What is the best lumber grade mix for this rough mill to run on this cutting order given current prices, equipment, etc.?" It also will help you

I. Randomly select 5 boards of a single grade and length. Measure and record surface measure, length, width, crook. Mark the ends of each board with a crayon mark.

II. Put a crayon mark along the length of the strips as they come out of the ripsaw (before they advance to the crosscut saw). Do a dot count of the number of strips of each rip width that are recovered from the 5 boards.

III. Route all strips to the same 1 or 2 chop saws (to introduce consistency in the comparison).



IV. Do a dot count of the number of parts of each length recovered from the strips. Count parts produced for each strip width (different columns on the tally sheet for each width).

V. # Parts x Part Length x Part Width / 144 = SM of parts of given size recovered.

VI. Add the SM's of all part lengths and widths and divide by the SM of the boards to obtain rough yield.

VII. Run the study at least three times on the same lumber grade and length and then run it on other lengths and grades.

VIII. Run the series of yield studies described here for all important cutting bills.

Figure 5.—Steps in a small-scale, five-board, rough mill yield study -- rip-first example.

answer the question, "What is the break-even sales price for this cutting order when cut from each lumber grade?"

Computer Programs for Optimum Lumber Grade Mix

In lieu of mill studies, computer programs can be used to estimate the optimal lumber grade mix. Two types of programs can be used: least-cost lumber grade mix programs and lumber cut-up simulation programs.

Least-cost lumber grade-mix programs provide "optimal" grade-mix estimates using lumber prices, part sizes and quantities, production costs, and a list of available lumber grades that the user inputs. The least-cost lumber grade mix is then derived from expected lumber yields that are contained in the programs' yield tables. Unfortunately, the yield tables are based on crosscut-first lumber processing so predicted rip-first yields might not be reliable. The yield tables also have some other shortcomings. The advantage of this type of program is that it is easy to use and provides quick answers. If a rough mill manager must choose between frequent least-cost grade mix computer runs to assist in the grade-mix decision and infrequent rough mill grade-based yield studies, the more frequent computer runs probably are preferred.

While several least-cost lumber grade-mix programs have been developed, many are difficult to obtain and/or complicated to run. The more familiar of these programs include:

- The Furniture Cutting Program — written, distributed, and supported by Dr. Hank Huber of Michigan State University until his retirement (no longer distributed by Michigan State).
- The Rough Mill Cost-Cutter Program — written, distributed, and supported by Dr. Philip H. Steele of Mississippi State University.
- OPTIGRAMI V2 — written, distributed, and supported by personnel at the USDA Forest Service research laboratory in Princeton, WV (phone: 304-431-2700; fax: 304-431-2772).

Lumber cut-up simulation programs are somewhat more complicated for evaluating optimal lumber grade mix but can provide better comparisons of the relative yields and cost factors for different lumber grade mixes and cutting bills. These programs are run repeatedly with different lumber grades to determine the optimal lumber-grade mix. Both rip-first and crosscut-first simulation programs are available. The advantage of this type of computer program is that the user can provide more specific information on the rough mill processing system (e.g., type of gang ripsaw, cutting priorities, part quality). In addition, rip-first yields are not erroneously based on crosscut-first yields as is the case for two of the least-cost grade-mix programs.

Lumber cut-up simulation programs can be run manually or tied into another program that can serve as an interface for optimum lumber grade-mix runs. Currently available lumber cut-up simulation programs include:

- CORY — written, distributed, and supported by Dr. Charlie Brunner of Oregon State University.
- RIP-X — written, distributed, and supported by Dr. Philip Steele and others at Mississippi State University.
- ROMI 3.0 — written, distributed, and supported by Ed Thomas at the USDA Forest Service research laboratory in Princeton, WV and available for download (free-of-charge) at: http://www.fs.fed.us/ne/princeton/software/index.html (Fig. 6).

Impact of Lumber Grade on Yield

When comparing the part yield of one grade of lumber with another, it is best to use rough mill yield studies or a cut-up simulator. Data derived from simulations of a variety of cutting bills are presented in Table 2.

When comparing simulation-derived part yields from No. 1 and 2A Common lumber, the differences in yield between rip-first and crosscut-first systems for each grade appear to be significant. It is important to note that the computer simulation of the cut-up process assumes an ideal, fully optimized operation. The yields from actual operations typically are lower since the potential yield gains from full optimization are difficult to achieve in practice. The rip-first configuration produced

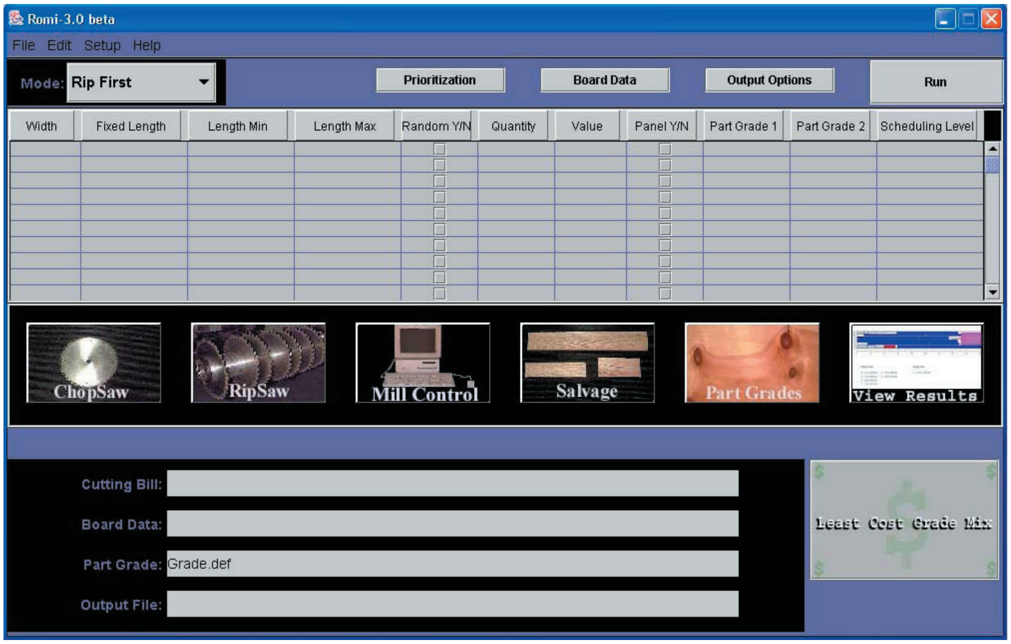


Figure 6.—A screen image of the main menu of the ROMI 3.0 cut-up simulation program.

consistently higher part yield when processing No. 1 Common lumber than the crosscut-first configuration (six of seven cutting orders) (Buehlmann et al. 1999). The crosscut-first configuration produced higher part yield than the rip-first configuration when cutting No. 2A Common lumber into C2F parts, though this result was less consistent (four of seven cutting orders). When a cutting order calls for wider parts from No. 2A Common lumber, the crosscut-first system outperforms the rip-first system. For narrower parts (less than 3.5 inches), the rip-first system seems to perform better.

Impact of Lumber Grade on Productivity and Operating Costs

Higher lumber yields do not necessarily mean greater profits. The cost element must be weighed for every decision. Although the purchase price of higher grade lumber is more than for lower grade lumber, processing costs for lower grade lumber are usually greater than for higher grade lumber because more cutting operations are required to isolate usable board sections from defects (Gatchell and Thomas 1997, Gatchell et al. 1999, Steele et al. 1999). For FAS lumber (the highest grade of hardwood lumber), most of the cutting is for sizing the parts since only a few defects need to be removed. Also, more cuttings produced from upper grade lumber are primary parts rather than higher cost salvage parts (Gatchell and Thomas 1997, Gatchell et al. 1999). Other costs associated with processing lower grade lumber that are difficult to quantify include higher part reject rates (due to defecting mistakes and machining defects that arise where cross-grain occurs near knots) and longer inspection times for operators as they try to make decisions concerning part placement and the importance of defect blemishes.

The number of cutting operations required to extract needed parts climbs significantly when the lumber grade is decreased from FAS to No. 1 Common to No. 2A Common in both gang-rip-first and crosscut-first rough mills. For a difficult cutting order, the number of chopsaw cuts (in a rip-first rough mill) required per part produced is 27 percent higher for 1 Common lumber than for FAS lumber and 53 percent higher for 2A Common lumber than for FAS lumber (Gatchell and Thomas 1997). The number of crosscuts required (in a crosscut-first rough mill) to fill the same cutting order is 70 percent higher for 1 Common lumber than for FAS lumber and 200 percent higher for 2A Common lumber than for FAS lumber (Steele et al. 1999). For the straight-line ripsaw in the crosscut-first rough mill, the number of cutting operations required to extract needed parts also

Table 2.—Generalized part yield benchmarks for rip and crosscut-first rough mills and different lumber grades.

Rough mill type	Rip-first					Crosscut-first			
Lumber grade	FAS[a]	1C[b]	2C[b]	1C[b]	2C[b]	1C[b]	2C[b]	1C[b]	2C[b]
Cutting quality	C2F	C2F	C2F	C1F	C1F	C2F	C2F	C1F	C1F
Yield (%)	74	65	51	75	66	64	53	70	64

[a] FAS, rip-first yields are based on simulations of 12 cutting bills (Wiedenbeck and Thomas 1995).
[b] No. 1 and 2A Common yields are based on simulations of the same seven cutting bills for both the rip-first and crosscut-first mill configurations. This was a rigorous analysis that allowed direct comparison of the relative difference in yields expected for 1C versus 2C lumber when cutting a variety of cutting orders (Buehlmann et al. 1998, 1999).

increases significantly as lumber grade is reduced. Fortunately, this increase is not as great as for the crosscut saw. The productivity of the crosscut saw-straight-line ripsaw system is less affected by a reduction in lumber grade when cutting an order that is made up of shorter and narrower parts than when cutting larger parts (Steele et al. 1999).

Impact of Lumber Size on Yield and Value

Lumber length affects part yield and value in several ways. Obviously, more boards typically will be required to obtain longer parts when cutting shorter lumber (e.g., 4 to 8 feet long). Where part-size requirements emphasize shorter lengths, short lumber can be used. For some cutting orders, long lumber provides a higher part yield than short lumber in a crosscut-first rough mill. This is because there are more ways in which required lengths can be combined to fit a longer board. Thus, there is less potential yield loss associated with crosscut waste. Also, 2 inches of end trim on a short board represents greater yield loss than on a long board. By contrast, in rip-first operations, shorter lumber may give higher yields (typically 1 to 3 percent) than long lumber (Wiedenbeck 1992). This is primarily due to the fact that longer boards tend to have more crook (or sidebend) and, consequently, produce lower strip yields when they pass through the gang ripsaw. Lumber width also impacts rough mill yield, particularly when narrow lumber is used in rip-first rough mills. This impact is most significant for gang ripsaws with fixed arbors and when there are a limited number of part widths in the cutting order. Of course, wider parts are more difficult to obtain from narrow lumber and wider cutting orders will produce more waste when narrower boards are being processed. The impact of width on yield in a rip-first rough mill can be so important that it dictates buying upper grade lumber for some orders.

FAS and F1F (First 1-Face) lumber is wider than Selects and Common grade lumber. The width differences can be large. For example, the average width of 4/4-inch-thick, dry, FAS and F1F red oak lumber measured in a mid-1990s multi-mill study was approximately 7¾ inches. The average width of the Selects grade lumber was closer to 5¼ inches (Fig. 7). The average width of 1 Common lumber increased to approximately 7 inches but the average width of 2A Common lumber was only to 5¼ inches.

For gang-rip-first rough mills that cut parts wider than 3 inches on an occasional to frequent basis, the best strategy for keeping yield up and lumber costs down is to note differences in lumber width from one supplier to the next. Significant differences in the distribution of lumber

Figure 7.—FAS grade lumber, pictured at the top, typically is significantly wider than Selects grade lumber, pictured at the bottom.

widths among suppliers have been measured. In an unpublished 1996 Forest Service study[1], the percentage of dry, red oak boards at least 8 inches wide from five mills ranged from 7 to 27 percent, while the percentage of boards less than 5 inches in width ranged from 8 to 26 percent. These widths were for mixed-grade lumber made up of similar percentages of Uppers and No. 1, 2, and 3 Common boards at each mill.

Processing efficiency is important when comparing lumber dimensions. From a material-handling standpoint, it is easier to handle short and narrow lumber than longer or wider lumber in manual operations. Even so, productivity usually is greater when processing wider, longer lumber than when processing narrower, shorter lumber of the same quality. However, the difference in productivity is not as great as with automated systems. Processing short and narrow lumber with automated systems can be more problematic and less efficient because there are fewer board feet in each piece of lumber. For many automated systems, processing gaps (e.g., space between boards passing through work stations) lead to lower machine utilization rates when processing short and narrow lumber. In a gang-rip-first rough mill, efficiency losses associated with loading the ripsaw's infeed conveyor (repositioning the fence) can be a problem when using short lumber. Similarly, narrow lumber occupying a machine that processes lumber in a linear direction is less productive on a volume-per-hour basis than when wider lumber (e.g., gang ripsaw, planer, moulder, automated chopsaw) is processed.

[1]Unpublished data on file at U.S. Department of Agriculture, Forest Service, Northeastern Research Station, 241 Mercer Springs Road, Princeton, WV 24740. Jan Wiedenbeck, investigator.

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Part Grades and Rough Mill Scheduling

Part Grades and Rough Mill Yield

The quality requirements of each part manufactured in the rough mill are dictated by the final product design. A dining room table with a high gloss finish requires that clear wood components be used while a rustic bedroom dresser can incorporate parts containing some of the natural characteristics of the wood. Part quality standards or grades need to be established to ensure that product standards are maintained and that part yield and productivity are maximized in the rough mill. Often in the value-added wood products industry, the manufacture of clear, defect free parts is the stated goal. The definition, description, recognition, and recovery of alternative part quality grades (other than clear wood) can be challenging and thus is frequently ignored.

Managers need to keep in mind that part specifications exist in the operator's mind whether they are the intended company specifications or not. It is the management's responsibility to define, in writing, the part-grade specifications and the allowable characteristics and requirements of each product. This step can be a major undertaking. It is the task of managers and supervisors to ensure that part-grade specifications are clearly communicated, understood, and followed by their operators. This can be a time-consuming effort, especially in operations with a high rate of employee turnover. The following actions can help reduce repetitive managerial effort:

- Quality grades should be written
- Quality specifications should be included on part route sheets and cutting bills
- Sample parts and panels should be prepared which indicate acceptable defects and unacceptable defects (including parts that will have a machined profile)
- A software tutorial can incorporate photographs, examples, and written definitions that can easily be modified and expanded

Failure to define and communicate part grades leaves operators in doubt, thus unnecessary cuts are made to remove blemishes producing parts that are unnecessarily clear and yields that are reduced. Part grades should be included with part specifications on route sheets.

An example of a grading scheme might define part-grade requirements as Clear-One-Face (C1F), Clear-Two-Faces (C2F), Sound, and Re-rip. In addition, grade specifications may address questions such as:

- Are pin knots allowed?
- Can small, ingrown knots be included?
- Are there limitations on where the knot can occur?
- Is heartwood/variable color allowed?
- Can skip dressing be included?
- Can salvage parts be recovered?
- Are there grain (quartersawn or flatsawn) requirements?
- Are glue lines allowed or does the part need to be solid?

Because part-grade requirements can have a large impact on both rough mill yield and part reject rates, operator training on part quality/grades can make a huge difference in rough mill profitability. For example, simulation research indicates that the inclusion of small defects (e.g., less than ½-inch diameter) on the backside of parts will increase rough mill yield by approximately 2 percent (compared to C2F) when processing No. 2A Common lumber. If moderate-sized defects (<1 inch) are allowed, the expected yield increase is 3.7 to 3.9 percent (again compared to C2F). (Buehlmann et al. 1998, 1999)

Scheduling the Cutting Order

Part scheduling in the rough mill is a difficult job. The scheduler must consider the needed parts of a certain thickness and species required over the next few weeks. Also, the scheduler must consider how long it will take to manufacture these parts, the available lumber (grade, thickness, species) and balance these needs with the schedule needs of other species/parts/thickness. To a degree, one of the goals of the scheduler is to minimize species and thickness changeovers in the rough mill. Of course, this must be balanced with the part requirements and timetables specified on the cut list obtained from the front office.

Though scheduling can be a complex task, the application of four principles will help maintain yield in the rough mill. Originally described (Pepke and Kroon 1981) with the conventional crosscut first operation in mind, these concepts have been expanded to address some aspects of computerized gang rip-first and crosscut rough mills.

1. Decide how many different parts should be cut. One key factor that determines rough mill yield is the number of parts that can be cut at any one time. Generally, the greater the number of different part sizes manufactured at any one time, the larger the number of possible part combinations that will fit into a board and the higher the yield (provided the sizes represent a range of lengths and widths). This is true regardless of the layout of the rough mill. Often the number of parts that can be cut simultaneously is dictated by sorting capacity limitations.

For any computerized optimization cut-up system, maintaining the greatest number of possible part-size combinations is of utmost importance to take full advantage of the computational power provided by the technology. For the fixed arbor gang rip-first rough mill, the gang saw should rip a minimum of three widths and preferably at least five widths. At the automated chop saw that commonly follows, it is preferable that 10 to 15 part lengths per strip width/grade combination be cut with the minimum acceptable number being five lengths. For many gang rip-first operations, the limiting factor is sort space. For example, the rough mill that rips four widths at the gang ripsaw and then cuts up to 10 different part lengths from each width has a total of 40 different part sizes that need to be sorted at the sort line.

In crosscut-first operations, the greater the number of sections cut simultaneously, the greater the number of combinations available to fit into the full length of lumber. In those mills that utilize optimizing crosscut saws, cutting 10 to 15 different lengths will provide enough length combinations to effectively utilize the total board length. For the conventional cut-first rough mill, five to nine well-distributed lengths help improve yield. In this situation, cutting a greater number of parts at the same time may improve the yield, but it also may make decisions at the cut-off saw more difficult for less experienced operators and hinder the ability to sort part lengths "downstream."

Part quality is another product characteristic that also is a factor in determining yield. The use of multiple part grades can improve part yield from lumber, although identification of quality zones on the lumber during the cut-up process can add difficulty to the manual optimization decision process. The use of part grades in gang rip-first operations, however, can be effective. At least two or three quality grades should be used to identify strip areas of differing quality at the chopsaw station. For example, part grades of C1F, C2F, sound, or rerip could be used. Each part width/grade combination would have a corresponding cut list of various length parts required by the cutting bill.

2. Decide which parts should be cut first. Usually, the best approach is to begin cutting the most difficult sizes first—long lengths or wide widths—including those parts needed in large quantities that will require a lot of board footage. The scheduler also needs to keep in mind that shorter lengths can be generated during the salvage operation and may not need to be scheduled at the primary cutting operations. At the same time, however, when long lengths (>50 inches) are being cut (either at the manual or optimizing crosscut saw), including medium and short lengths in the cut list will reduce loss at the tail end of the board or strip. Similarly, if 4-inch or wider strips are being gang-ripped from lumber that averages 6 inches in width, including narrower fixed width strips in the cut list will minimize waste edging strips.

The list of lengths to be cut simultaneously at the cut-off saw should consist of lengths and length combinations that will fill gaps on the backgauge (and therefore on the board). Large gaps, especially between the shorter lengths, are detrimental. For instance, consider the cutting bill that requires part lengths of 17, 22, 33, 42, and 58 inches. The 11-inch gap between the 22- and 33-inch parts likely would result in much waste as there are no combinations of lengths that totally will utilize clear cuttings in that range. In addition, it is important to choose nonmultiple lengths (for example, not 12, 24, 36, and 48 inches) since these combinations do not add cutting opportunities.

In furniture rough mills, the manufacture of edge-glued panels can be a significant portion of total production. In gang rip-first operations that use fixed arbors, “dummy” random strip widths, known as pocket widths, placed on the arbor for the purpose of generating panel stock, should be considered if their inclusion will help match the combination of arbor pockets with board widths. Obviously, care must be taken in using very narrow rips to fill the board since a large kerf loss could result from this practice. At the straight-line ripsaw in crosscut-first operations it is important that fixed-width solids and random widths for panel stock be cut simultaneously.

3. Decide which lumber should be used for the cutting bill. Many rough mill operations could do a better job of selecting lumber grades that efficiently meet the cutting bill requirements. Often the standard operating procedure is to run the package of lumber that is easiest to reach, sometimes regardless of grade. The ideal solution is to run the lowest (most inexpensive) lumber grades from which you can efficiently obtain the required parts. Usually, this means that higher grades will be used for longer or wider parts, and lower grade lumber will be used for shorter, easy to obtain parts. The ability to incorporate more low-grade lumber into the cut-up process is one potential opportunity that computerized optimizing saws offer, since complex combinations of clear areas and part sizes can be easily evaluated. Though substituting low-grade for high-grade lumber will reduce rough mill yield, the overall use of the wood is more efficient since cutting the large areas of clear wood found in higher grade lumber into small size parts is inefficient. Often, the most economical lumber to process is a mix of grades.

There are many reasons why a rough mill may not run the least cost grade mix of lumber to meet its cutting bills. The tendency is to run a higher grade lumber than is required by the cutting bill. Some of these grade-mix discrepancies are due to logistical problems while others are due to managerial problems.

Logistical problems include:

- Inability or difficulty in backing out (removing) partial lumber loads from the mill’s infeed system when part requirements shift
- Inability to access the package that should be run because it is blocked by other lumber packages in dry storage
- Lack of optimal grade lumber packages available for processing in dry storage
- Inadequate drying, machining, and waste-handling capacity due to increased volume requirements.

Managerial problems include:

- Management’s fear of low-grade lumber yields
- Lack of acceptance of low-grade lumber by dry-kiln and rough-mill employees
- Unacceptable results during prior attempts to shift the lumber grade mix (such as elevated reject rates) owing to ineffective training of employees.

One strategy employed by some rough mills whose lumber packages are sorted by grade is to begin cutting with the highest grade of lumber that will be used for the cutting bill. After most (70 to 90 percent) of the difficult cuttings are obtained (the hard-to-get parts are cut first), the high-grade lumber is substituted with a lower grade to meet the remainder of the cut list.

Lumber size issues also need to be considered in relationship to products and processes. Some of the potential impacts include:

- Excessive yield loss if lumber length is not well matched to part lengths at the crosscut saw
- Negative impact of crook in long lumber for gang rip-first yield
- Loss of yield and productivity when narrow lumber is used in gang-rip-first operations, especially if lumber width does not match product width and a fixed blade arbor is in use
- Reduced machine utilization rates resulting in lower productivity occur when processing short and narrow lumber.

4. Maintain the number of lengths being cut on either the crosscut or the chop saw. The importance of maintaining the number of section lengths being cut at the crosscut saw, or the number of part lengths being cut at the chop saw, cannot be over-emphasized. Too often at the end of the cutting bill, the cut-off saw may be cutting only one or two remaining lengths. When the number of length combinations is significantly reduced, the cut-off saw operator (or the optimizing saw) often has no choice but to waste wood. If these last parts are difficult to obtain, the amount of wasted wood is even greater.

For the automated chop saw cutting parts from previously ripped strips, the priority mode set with the software affects the yield obtained. The priority mode that maximizes yield can be used on chop saws if parts are being used to fill a finished goods inventory. However, most furniture plants are cutting to fulfill a specific number of parts required by an order or cutting bill. In this case, the priority mode most commonly used sets part values that establish cutting priorities according to the maximum value obtained per strip. These values are entered by the operator or supervisory personnel and need to be set carefully so that all part needs are met at about the same time.

As the needed quantities for specific lengths are reached, it is important to replace those parts with other similar length parts, beginning with the next most difficult length. This is especially the case at the crosscut saw if only five lengths are being cut. When the cutting bill does not require long lengths, or as the required quantities of long lengths are met, it may be possible to reduce the number of lengths being cut without sacrificing yield. Though cutting fewer lengths can be tolerated if the lengths are short, the rough mill that uses this strategy needs to remember that this practice can generate very expensive short parts if a high grade of lumber is used.

An additional factor is the just-in-time (JIT) manufacturing strategy now found in many plants. JIT strategy is driven by the desire to reduce inventories of finished goods and work-in-process. JIT requires smaller size runs in the rough mill than does non-JIT order processing. With fewer parts required by these smaller runs, the end of the cutting bill orders occur more frequently, making it more important to find additional lengths to fill in and making it more difficult to maintain yield through cutting bill completion. While saving money by reducing inventory, the JIT strategy may reduce yields in the rough mill by requiring lower volume cutting bills and hence more frequent changeovers. Some operations that rely on automated optimizing saws for primary lumber cut-up employ a separate, small, manual crosscut-first line to carefully complete cutting bills and to quickly make up any part shortages that occur without interrupting the primary operation.

Increasing the number of part grades and lengths that are processed simultaneously in the rough mill will improve yield providing part reject rates do not increase as a result of the change. Optimizing saws allow mills to process these larger and more complex cutting bills efficiently, but limitations imposed by insufficient sorting capacity frequently limit this yield improvement opportunity. Scheduling part production and lumber package selection to optimize yield is a complex task that can have a huge impact on rough mill yield. The person or people assigned to this task must constantly be aware of dry lumber inventories, order deadlines, production timetables, and rough mill production rates. Finally, they need to have a thorough understanding of how their scheduling decisions will impact part yield and cost.

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SECTION 2:
TRADITIONAL AND MODERN CUT-UP SYSTEMS

Crosscut Vs. Rip-First Processing

"Should we be crosscutting or ripping first in our rough mill?" There are good reasons why this question still exists for many mills. This decision depends on many factors and some of the more important ones are subject to change from day to day or at least year to year. There are at least 12 factors that affect the layout decision:

1. Lumber grade
2. Lumber width
3. Lumber length
4. Defect types
5. Lumber straightness and drying stresses
6. Part length and width needs
7. Part quality needs
8. Number of different parts
9. Part volume requirements
10. Available capital
11. Gluing requirements and product design specifics
12. Labor skills

The first five factors are lumber characteristics. Factors 6-9 are requirements specified by the cutting bill, and factors 10-12 relate to general business characteristics. Because the lumber characteristics and cutting bill requirements can change daily, a mill's decision between crosscut or rip-first processing will be tenuous at best. Consequently, some rough mill managers are opting to design "either-way" mills or to maintain dual processing capabilities when modernizing.

For mills that lack the capital resources or floor space to build and operate an either-way mill, the decision should be based not only on current operating conditions but also on the anticipated average operating state over the next 10 years. Thoughtful consideration must be given to whether lumber grade, species, or size changes might be forthcoming. Will workforce turnover rates change? How will product sizes, quality specifications, and quantities change? Will greater emphasis be placed on increasing production levels? Will kiln drying operations improve? Are shifts in furniture design specifications being planned?

Whether you are making the processing layout decision for the future of your rough mill or considering how to optimally distribute boards between the crosscut and rip-first lines in your either-way mill, the lumber characteristics discussed in the following sections are important in the processing decision.

Grade

The intermediate grades of lumber (e.g., No. 1 & No. 2A Common) produce a higher yield of longer parts when gang-ripped-first compared to crosscut-first processing (Gatchell 1987). In fact, some rough mill managers have reported that adopting gang-rip-first processing reduced their grade mix and thus lumber costs and these savings paid for the capital investment almost immediately (Mullins 1990). This effect is more evident when crosscut-saw operators or optimizing crosscut-saw markers are less experienced. Deciding which defects to remove on the crosscut saw and which to leave for removal at the ripsaws and salvage operation is difficult for even the most experienced operator.

One also must consider productivity when processing lower grade lumber. Generally, gang-rip-first operations can process 20 percent more lumber than crosscut-first operations for each hour of labor. When gang ripping, there are two relatively minor productivity concerns related to lumber grade: 1) FAS and F1F grade lumber usually are somewhat wider on average than 1C, 2AC, and 3AC lumber, and wider lumber leads to greater machine productivity; and 2) lower grade boards might break up in the machines more often than higher grade boards, causing downtime. By contrast, there is a large productivity impact related to lumber grade in a crosscut-first mill: the crosscut saw must make 70 percent more cuts when processing 1C compared to FAS and 200 percent more cuts when cutting 2AC versus FAS!

Width

Wider lumber typically yields a higher part volume when cut in a rip-first system than in a crosscut-first system primarily because of the difficulty associated with optimizing the crosscut decision when wider boards are processed. For lumber narrower than 4.5 inches, the decision on how to optimally cut a board becomes relatively easy for the crosscut saw operator or lumber marker (Gatchell 1987). Thus, a mill that processes a large amount of narrow lumber can be efficient with crosscut-first processing, and a narrow board in an either-way rough mill can be sent to the crosscut-first line. Also, the negative yield impact of edgings is greater for narrow lumber when ripping first, especially when a fixed-arbor gangsaw is used. If a significant portion of the wider parts in the rough mill cutting order are required to be solid, nonglued-up parts, crosscut-first processing of wider boards may be required to fill orders.

Considering rough mill productivity, the amount of lumber processed per hour in automated systems in which the lumber runs linearly through a high-speed saw (e.g., gang ripsaw or automated crosscut saw) is higher for wider boards. Since gang-rip-first mills tend to be more automated, this supports the recommendation that wider lumber benefits from being gang-ripped first. By contrast, when wider boards are processed in a manual crosscut-first rough mill, the size and weight of the wider lumber can slow processing so that the productivity gains associated with having more volume per lineal foot of lumber are diminished or eliminated.

Length

The advantage of crosscutting-first versus gang-ripping-first based on lumber length is ambiguous. Longer lumber (>11 feet) produces relatively higher yields than shorter lumber (<9 feet) in both rip-first and crosscut-first systems if the lumber is straight (Gatchell 1991, Hamner et al. 2002, Wiedenbeck 1992). Lumber that is crooked (sidebend) is better cut in a crosscut-first operation (or at least cut into two pieces with a pop-up saw) rather than a rip-first operation (Gatchell 1987). The shortest lumber (4-7 feet) can produce slightly higher yields than 8-foot-long and longer lumber in a gang-rip-first cut-up system, but the yield gains seldom will compensate for the negative production effects that arise when short lumber is processed (Wiedenbeck 1992).

If your lumber is predominantly shorter than 10 feet and you are cutting part orders that demand a high percentage of longer parts, rip-first processing will yield a greater proportion of the long parts you need. If you are focused on a species that tends to end-check and you experience numerous end-checks in your dry lumber, rip-first processing usually is the better choice regardless of lumber length and part length requirements. More wood is lost when short lumber is crosscut across the entire board width to eliminate end-checks than when strips that are produced by the ripsaw are end-trimmed. Thus, some strips need not be trimmed as severely as others since the end checks will vary in length. There is one exception: gang-rip-first mills that operate automatic strip chopping lines that are set up to end trim 1 inch from each strip may produce parts with checks when longer checks are encountered. Thus, part-reject rates could increase. Manual cutting operations are a better option than automated cutting (for trimming full-width boards or strips) when longer checks are common.

Another consideration relates to the handling of lumber. If your crosscut-first system entails manual handling of lumber (at the saw or at the marker station), shorter lumber offers certain processing advantages: it is lighter, less bulky, and easier for the person who is making defecting decisions to evaluate and optimize quickly and accurately. However, when short lumber is processed in an automated rip-first rough mill, processing inefficiencies can be expected (similar to those associated with processing narrow boards). Processing gaps (i.e., space between boards) lead to lower machine utilization. This is a critical cost factor when the rough mill is using expensive, automated equipment.

Defect Types

A basic principle of rough mill defecting is to isolate defects in a single strip or crosscut section in the initial cutting stage (rip or crosscut) so that the number of additional cutting operations required to remove the defects from the strips or crosscut sections are minimized. Therefore, defects that run along the length of the board are more easily isolated and removed with rip-first processing (Fig. 8); defects that run across the board or that are clustered are suited for crosscut-first processing (Fig. 9).

For either-way mills, boards with wane, splits/shake, pith, and stain are candidates for the gang-rip-first saw. Boards with spike knots, knot clusters, large face knots, clustered

Figure 8.—Split, stain, and wane defects that run for some distance along the length of the board are best removed in a rip-first operation.

Figure 9.—Defect clusters and large defects that occupy a significant cross-section of the board are best removed in a crosscut-first operation.

worm or pin holes, decay zones, and crook are candidates for the crosscut-first saw.

For mills considering a switch to a crosscut-first system or to a rip-first system, defect type must be evaluated in a broader sense. Lower grade lumber (e.g., 1C, 2AC, and 3AC) has more defects of every kind, but the length of the wane zones and the occurrence of pith and pith-related checks and small knots point to gang-rip-first processing. Species considerations may be important for the rough mill that specializes (and will continue to specialize) in one or two species. Some species are more prone to splits and checks (e.g., red oak) and, therefore, might be best suited to gang-rip-first processing. Tree species with minimum taper (e.g., yellow-poplar) produce fewer boards with wane in the sawmill. Thus, a furniture rough mill that specializes in this species may do well using a crosscut-first system. Species that tend to retain limbs (e.g., white pine) produce a lot of knotty boards. Processing these species in a crosscut-first rough mill might be a good option if knots are to be removed as defects. In all cases, the grade and size of the lumber and the quality and size requirements of the needed parts must be considered (and usually given more weight) along with defect type and species.

Lumber Straightness and Drying Stresses

As mentioned earlier, lumber with crook or sidebend (Fig. 10) should be crosscut-first. One study showed that crosscutting boards before ripping when ½ inch or more crook is present produces rough mill yields that are on average 3 percent greater than those when gang-ripping-first without crosscutting for crook (Gatchell 1991). Of the red oak lumber processed in eastern U.S. rough mills, 75 percent appear to have minimal crook (less than ½ inch), while about 7 percent have crook in excess of 1 inch. Depending on the drying quality of the lumber processed by the rough mill, this may be one of the more important factors to consider when deciding between crosscut-first and gang-rip-first processing.

Although cupped boards (Fig. 10) are less common today due to the prevalence of relatively narrow lumber, they should be ripped-first when encountered. Also, boards that contain drying stresses due to inadequate equalizing and conditioning at the end of the kiln-drying cycle will crook and twist more if gang-ripped-first into long, narrow strips than if crosscut into shorter pieces before being ripped.

The following factors also are important when evaluating crosscut-first versus gang-rip-first as they are related to the criteria for parts specified in the cutting bills.

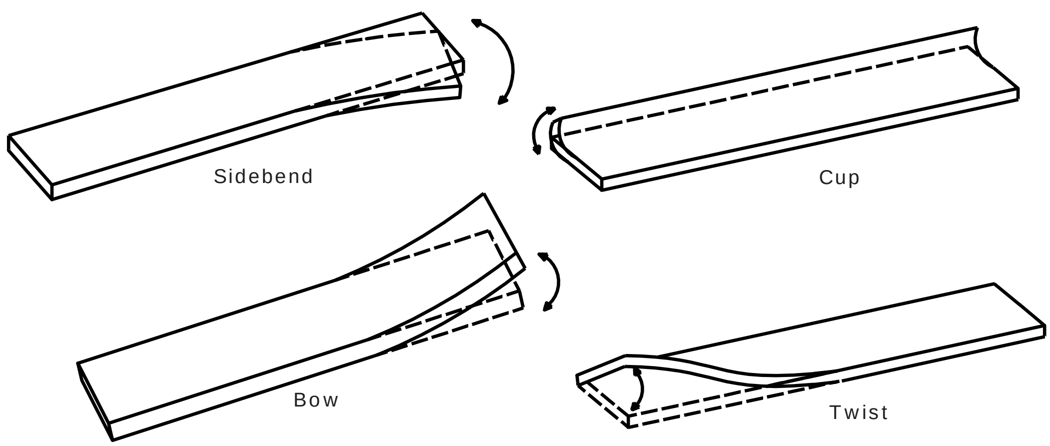

Figure 10.—Forms of lumber warpage — sidebend, also known as crook, is the most prevalent form encountered in hardwood processing operations.

Part Length and Width Needs

The lengths and widths of your rough mill's part requirements are especially important to consider when deciding whether to crosscut or gang-rip-first. Many experts advise that gang-rip-first processing typically yields more long-length parts from a given grade of lumber than crosscut-first processing. If your mill's orders tend to run toward longer lengths, gang-rip-first processing should be considered. On the other hand, if your orders demand a high percentage of wider parts (i.e., wider than 3 inches) crosscut-first processing usually will produce a higher yield.

For the either-way rough mill, it follows that more of the long-part requirements be set up for cutting on the gang-rip-first side of the rough mill and more of the wider part requirements be scheduled on the crosscut-first side. Maintaining a range of cutting sizes (short to long and narrow to wide) on both sides of the mill is necessary to optimize yield for each processing line and for the total rough mill.

Part Quality Requirements

From a yield standpoint, it is usually better to process cutting orders that call for Clear-One-Face (C1F) parts or character-marked (CM) parts or a combination of part qualities (e.g., C1F and C2F) in a gang-rip-first rough mill. Whether the crosscut-first rough mill is manual or optimizing with a defect marking station, discriminating between acceptable and unacceptable defects on two faces of a full-width board is much more difficult than making the same judgment on a narrower width strip. This dependence on human judgment in cutting lumber to length is the key issue related to part quality when deciding between crosscut-first and rip-first processing. The level of difficulty rises significantly with multiple part grades when humans are making the cutting decision – this is one of the advantages of having a (semi-) automatic optimizer. In addition, computer simulations have shown that when cutting CM parts out of 1C and 2AC lumber, gang-rip-first processing tends to produce slightly higher yields than crosscut-first processing (Buehlmann et al. 1999). As attempts are made to expand markets for CM parts and furniture, this finding could become more important to rough mill managers.

Number of Different Parts

Optimizing yield by cutting many more sizes and qualities of parts in the rough mill is possible with a gang-rip-first system with optimizing chopsaws or with optimizing crosscut-first sawing. However, a mill that cuts more types of parts at a time must be able to efficiently sort and handle larger varieties of parts. This is easier to do with a gang-rip-first system than a crosscut-first system. Crosscutting 20 different part lengths that are then sorted and moved to different ripping stations is more complex than chopping 20 different part sizes (after ripping) that need only be stacked on carts and moved to storage or the machine room.

Table 3.—Comparison matrix for factors that affect the crosscut versus rip-first decision.

Layout	Factor									
	Lower grade lumber	Narrow lumber	Longer lumber	Lumber with crook	Long parts required	Wide parts required	Check-prone species	Waney lumber	Varied part qualities	Exper-ienced labor
Rip-first	+[a]	-	+	-	+	-	+	+	+	?
Crosscut-first	-[b]	+	?	+	-	+	-	-	-	+

[a] "+" indicates the preferred rough-mill layout for the given factor.
[b] "-" indicates the layout that is the most negatively affected by each factor.

Part Volume Requirements

For rough mills with high part-volume requirements, automated systems (particularly gang-rip-first) are more productive (based on input lumber volume) per 1,000 hours of labor. Conversely, when significant capital investments are made in automated and/or optimizing sawing systems, high throughput and utilization rates are needed to offset the added depreciation expense so that the manufacturing cost per unit can be maintained or improved.

Available Capital

Switching to an automated gang-rip-first system from a manual crosscut system is capital-intensive. The rough mill must have sufficient market volume, sufficient "upstream" capacity (lumber supplier, dry kiln, and lumber storage) and sufficient "downstream" capabilities (sorting, storage, machining, etc.) to accommodate the changeover.

Gluing Requirements and Furniture Design Specifics

Quality edges suitable for gluing from gang-ripsaws are readily produced using fixed-arbor saws and most moveable-blade saws in 2003. The consideration that remains is whether glue lines are acceptable in wider furniture/cabinet pieces such as drawer fronts, tabletops, etc. A high demand for wider solid parts calls for crosscut-first processing of higher grade lumber. A second design factor that affects the crosscut versus rip-first decision is the degree of color and grain matching required in the secondary product. It is easier to match color and grain with less handling and reinspection when the lumber is crosscut first. Parts recovered at the straight-line ripsaw from a given board section will have relatively similar color and grain compared to strips that are mixed together coming out of the gang ripsaw.

Labor Skills

Defect recognition, decision-making skills, and mill savvy are necessary traits for a crosscut-first saw operator if a crosscut-first rough mill is to operate near its profit potential. The same is true for board markers and, to a lesser extent, for strip markers. For rough mills that operate in a competitive labor market that experiences high turnover rates, including the more experienced and higher paid employees, gang-rip-first processing generally requires less experienced personnel.

Five factors that affect the crosscut versus gang-rip-first rough mill layout decision should be given the highest priority: lumber grade, part size requirements, part volume requirements, availability (or lack) of skilled labor, and furniture design requirements. Other lumber factors (width, length, straightness) are presented for consideration by the either-way rough mill with the flexibility to process specific boards through a gang-ripsaw or a crosscut saw to derive the maximum yield from each board. Table 3 is a simplistic framework for comparing some of the factors discussed in this paper.

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Optimizing Operations on a Manual Crosscut Saw

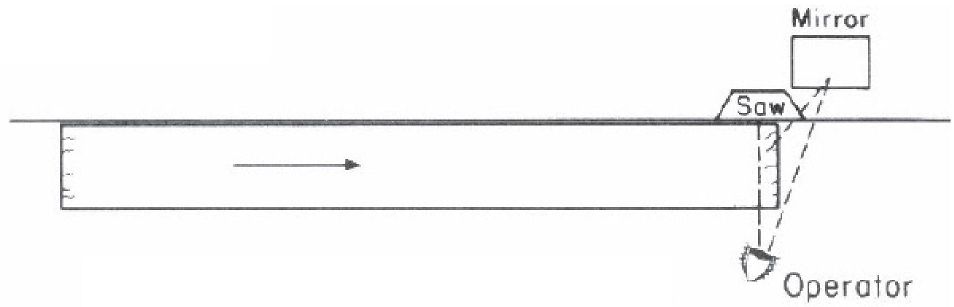

Figure 11.—The initial end trim at the crosscut saw can be minimized with the use of a mirror.

The crosscut saw cuts lumber across the grain into board sections whose lengths are required by the cutting bill. To obtain the best yield, the cutoff-saw operation should not try to remove all defects; most defecting can be best done at the "downstream" ripping operation that not only removes defects but also produces parts from the board sections. The decisions made by the cutoff sawyer will affect your company's production and profitability. However, it is the responsibility of the rough mill supervisor to ensure that the cutoff operator has been given part grade specifications and understands the allowable characteristics and requirements of each product. The cutoff saw operator must know whether the part grade requirements are C1F, C2F, Sound, and so on. In addition, supervisory personnel must instruct the operators whether it is appropriate to cut parts to maximize yield or to maximize value.

Design of the Workstation

Workstation design is important in determining the productivity and yield. Mirrors should be used at each crosscut saw so the operator can easily inspect the freshly sawn end for drying checks, as shown in Figure 11. Sufficient lighting must be provided so defects can be seen and the correct sawing decision made. Mirrors will require additional lighting. The crosscut saw operator should not have to expend a lot of effort to bring full-size lumber to the workstation. The operator's main job is to properly cut the lumber, which, by itself, can be very demanding. Preferably, each piece of lumber is conveyed to the workstation by a material handling system or another worker. If the lumber is manually fed, either by the operator or a helper, a scissors lift will facilitate the job by raising the lumber package to the workstation thus reducing material handling time and effort and reducing the risk of injury.

Board Inspection and First Cut

Prior to cutting, the crosscut sawyer should inspect both sides of the board considering what parts can be obtained at the ripping and salvage operations. In effect, the operator is the optimizer in the manual crosscut saw operation. The operator first must look and think before cutting. C1F specifications require cutting with the best face of the lumber up (visible to the operator). C2F grade parts should be cut with the worst face up. It is important to keep in mind that the crosscut saw is not an island, but must work in consideration and cooperation with the other operations. Operator cross training is useful in helping operators better understand product requirements. Experienced and conscientious crosscut saw operators can identify hard-to-find parts they know will be required in a week or two although they are not in the current cutting bill. Sections containing those parts are cut out and set aside for future use.

The first cut to square the end also should remove end checks (if present). The end trim should be as small as possible, only 1 inch, and perhaps as small as ½ inch for well-dried stock containing only minor end-checking. Inspection of the freshly cut end for drying checks should be made and additional end trim cut if needed. However, the crosscut saw operator should not take an exceptionally long end trim in order to remove a single, long end check or split (Fig. 12). A mirror should be used to facilitate this inspection, as described earlier.

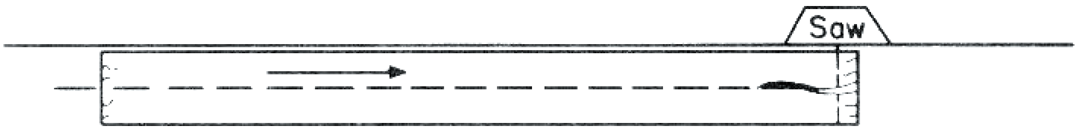

Figure 12.—Long end splits usually should be removed at the ripsaw rather than at the crosscut saw.

While the board is being cut, care should be taken to keep it against the fence to ensure square ends and maintain length accuracy and repeatability. Failure to do so may result in parts that are too short to meet specifications or too long so they create processing problems when incorporated into edge-glued panels.

Defect Removal

As mentioned above, the crosscut saw should not try to remove all defects. Many defects, especially those that run with the length of the board, such as long splits, can be ripped out later with less waste (Fig. 12). Those defects that run across the width of the board should be considered for removal at the crosscut saw. A few rules of thumb coupled with examples may help you develop defecting guidelines at your crosscut saw.

When round logs are sawn into rectangular boards, wane (defined as bark or the absence of wood) allowed by the lumber grading rules is left on the board. In addition, natural wood characteristics, such as knots, are included in the sawn boards. The job of the rough mill is to remove those characteristics that do not meet product criteria. If the crosscut saw operation is performed first, coordination with ripsaws allows wane, pith, and some knots to be removed by ripping or at the salvage operation. Board examples and recommended defect removal strategies are shown in Figure 13.

One rule of thumb used by some rough mills is for the crosscut saw operator to remove defects that extend over 50 percent of the board width. Saddle wane extending across the full width of the board should be removed at the crosscut saw (Fig. 13B).

Spike knots and multiple knot clusters, including the distorted grain around the knots, also should be removed at the crosscut saw (Fig. 14). Distorted or sloping grain around knots may lead to torn grain or fuzzy grain in later machining, and guidelines for its removal should be developed (guidelines will depend on species, degree of slope, additional machining to be performed, and the end product).

Operations with experienced crosscut saw operators and a strong yield focus are able to improve upon the 50 percent of board width rule of thumb for defecting at the crosscut saw. The more rigorous rule of thumb used by these operations is if a strip of clear lumber is available between the defect and opposite side of the board that is at least equal in width to the narrowest "solid" width on the cutting bill, then the defect will not be removed at the cutoff saw. Instead these defects will be left and removed later by the rip or salvage saws in order to recover a part.

If the crosscut saw operator determines that a defect should not be removed at that operation, the question remains into which length should the defect be placed? If the defect is placed in the shortest length section, the crosscut sawyer eliminates most options for recovering

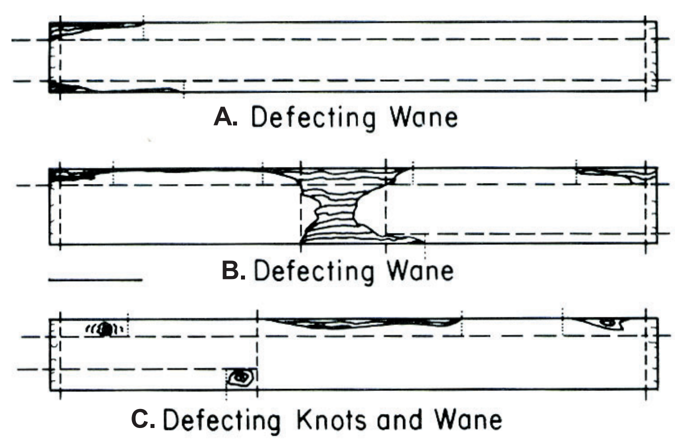

Figure 13.—Removal of wane and knots using crosscuts, rips, and salvage cuts; full-width dashed lines show the first crosscut, horizontal dashed lines show rip cuts performed on the shorter pieces, light vertical lines show chop cuts made on the already crosscut and ripped strips.

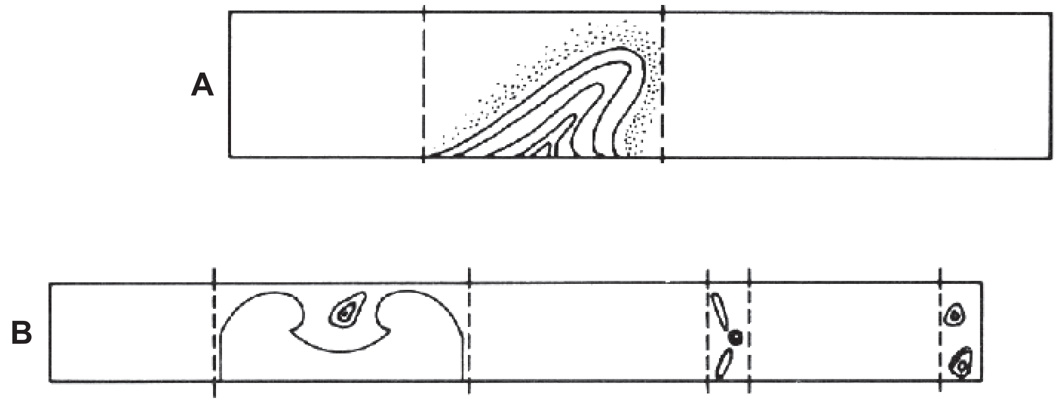

Figure 14.—Large defects and those extending across the board width should be removed at the crosscut saw: A) Cuts should be made to remove spike knots and fuzzy grain; B) Solid line indicates patterns to be cut at band saw, thus eliminating knot.

a part at either the ripsaw or the salvage saw. It is often better for the crosscut operator to place the defect into an intermediate length, thereby providing the opportunity for the salvage saw to squeeze out a required shorter part.

Although it may seem to have a minor impact on yield, it is important for the operator to maximize the available clear wood by running the saw blade into the defect and removing only wood containing the defect. Doing this four times on an 8-foot board with a typical crosscut blade kerf of ¼ inch will potentially boost yield as much as 1 percent.

Lengths Cut

There should be between five and nine different part lengths to be cut at the crosscut saw, representing short, medium, and long lengths. Each length available for the crosscut saw operator to cut represents an option. As part requirements are met and a part length is removed from the crosscut saw stops, a new length should be added to replace the completed length and to maintain as many lengths as possible from which the operator can choose.

For each board, the most difficult-to-find sizes should be sought first (generally long or wide parts). Of course, flexibility must be maintained in the decisionmaking process to prevent excessive yield losses within a board. For example, if taking the longest (and hence most valuable) part results in excessive yield loss, it might be better to cut an intermediate and a short length to improve yield.

Backgauge

The shorter lengths usually should be cut as a last resort to minimize end trim losses. End trim is the leftover wood at the trailing end of the board that is too short to produce a part of required length and thus is wasted. The backgauge (Fig. 15) is a simple device that can be located above the infeed table of any crosscut saw. A backgauge will help reduce end trim loss. Each cutting length set on the “stops” also is marked on the backgauge (Fig. 16). In addition, combinations that represent multiple lengths also are marked on the backgauge.

Use of the backgauge will minimize end trim loss and effectively allow the operator to plan and place cuts between defects. When the board is placed on the infeed

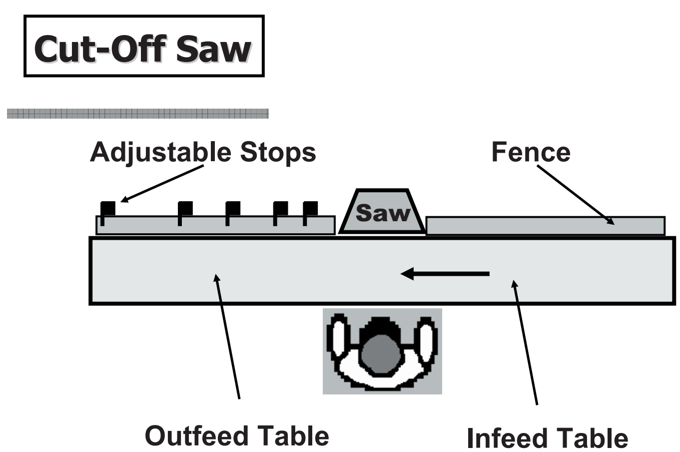

Figure 15.—The manual cut-off saw’s basic layout. The backgauge is located just above the fence on the infeed side of the saw.

table, the operator views both sides of the board and places the poorest face up (assuming C2F parts are being cut). Remembering the defects on the underside of the board, the operator visually scans the face for defects and decides which lengths to cut while using the backgauge as a guide.

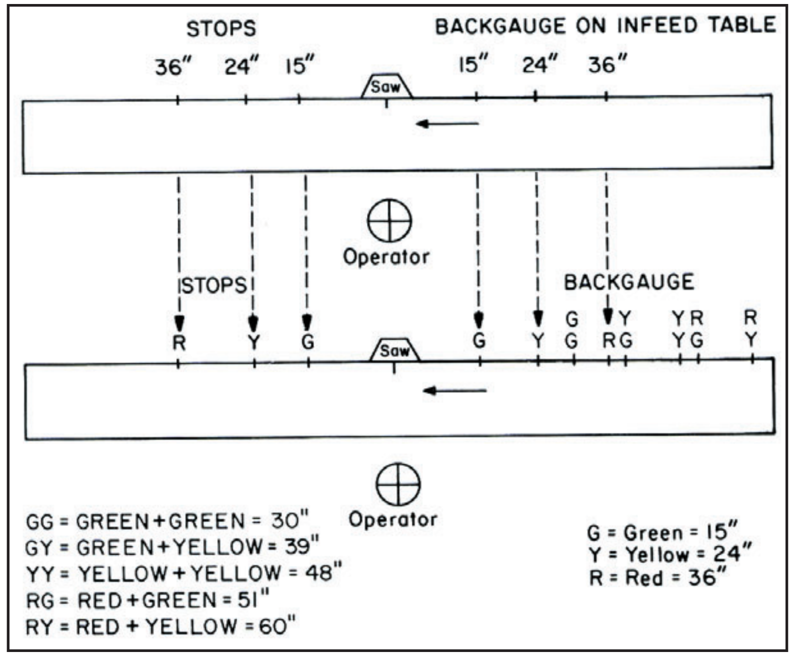

Figure 16.—The backgauge, located on the infeed table at the crosscut saw, uses color coded pegs or lights to indicate the different section lengths required.

Figure 17 illustrates the use of a backgauge. An 11-foot No.1 Common board is placed on the infeed table with the poorest face up. The operator examines the board for defects to be removed at the crosscut saw and decides to first cut a clear 36-inch piece, designated as the red stop. The next choice to cut another 36-inch piece assumes that the defect will be removed at the ripsaw. Note the future ripping of the 36-inch piece containing the defect will yield a narrower 36-inch piece and later at the salvage operation either one 24-inch or two 15-inch pieces.

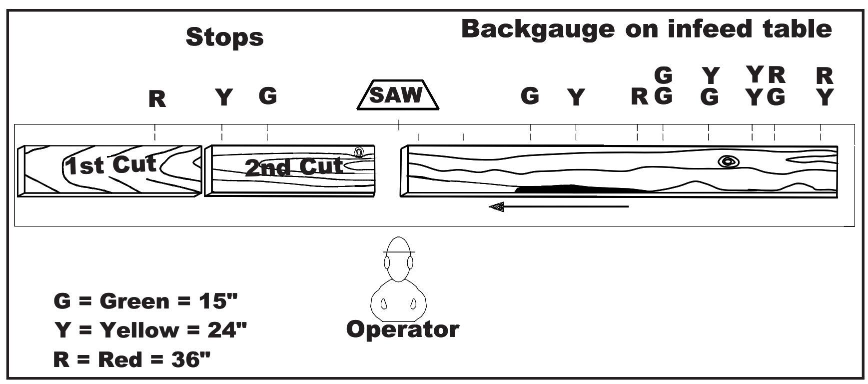

Figure 17.—Using the backgauge, the operator first cuts a 36-inch section followed by another 36-inch section containing a defect (that will be removed in the rip operation).

At this point, the operator has removed 6 feet from the original 11-foot board as shown in Figure 18. Guided by the backgauge, the operator sees that the end of the board falls just beyond the mark that indicates the red and yellow combination (RY). The operator knows that a 36-inch (red) and a 24-inch (yellow) section can be cut with a small amount of end trim waste. This system allows lumber to be defected strategically and end trim to be minimized, resulting in improved utilization of the wood.

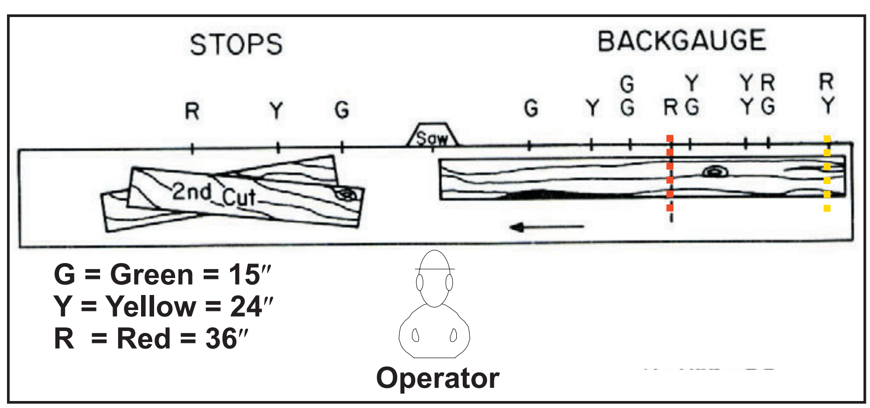

Figure 18.—Using the backgauge, the crosscut operator can minimize end trim loss by cutting a 36-inch (red) and 24-inch (yellow) section from the remaining board length.

Electronic backgauges with colored lights automatically calculate and display the location of backgauge marks. A manual system consisting of a channel bar with drilled holes, colored taper pins (e.g., golf tees) to set the backgauge marks, used in conjunction with a spreadsheet program to calculate backgauge mark locations, also will work well.

Backgauge combinations must be determined while balancing conflicting needs. On the one hand, the goal should be to minimize gaps between pegs on the backgauge. At the other extreme, we must be careful when combining lengths to avoid cluttering the backgauge and complicating its use. When introducing the backgauge, one approach to simplify its use is to use only two combinations of part lengths. Some combinations that include low priority parts, such as short lengths, can be excluded even though their inclusion would more completely fill in the backgauge. The most needed lengths should be paired with each other first to make them appear more frequently on the backgauge.

Trim Allowance

Other practices at the crosscut saw need to be examined carefully for possible improvement. It is human nature for the crosscut sawyer to add a little bit extra to the trim allowance to make sure the part is long enough, not realizing that quite often sufficient trim allowance has been added by the front office in building the cutting bill. It is very important that the crosscut operator stick to the assigned length, cutting the length specified on the cutting bill. For example, adding on ½ inch to a 25-inch rough length will cost the mill 2 percent yield.

Each plant needs to re-examine what trim allowance is needed. The standard 1 inch over the final finished part length needs to be questioned. If the rough target length can be reduced, yield can be improved. Many rough mills have been able to reduce trim allowance to ¾ inch for panel stock and to ½ inch on solid parts for moulding. Of course, if your lumber has severe sidebend, angled cuts will result (even if you place horns against the fence) and it may not be possible to reduce the trim allowance.

Lack of cutting accuracy or the failure to consistently cut the assigned length sometimes causes problems in minimizing trim allowances. Saw stops need to be in good shape, capable of easily being locked into place and not sliding. Stops that are bent or loose should be replaced. A dirty or poorly maintained infeed table and rollers can cause excessive friction that results in problems when positioning boards against the fence. The operator should not have to compensate for defective equipment - doing so usually lowers yield. In addition, the failure to achieve repeatable lengths can cause ragged panel ends in gluing operations "downstream." In some gluing operations, these uneven ends can push on adjacent panels and make them uneven, resulting in a panel that is too short. Unfortunately the solution in some plants might be to add even more trim allowance to the panel parts.

Grouping of Lengths

It is common practice for rough mills to group parts of similar length together for cutting. This is usually necessary due to space considerations and the lack of sorting capacity. It is important for rough mills to recognize that this practice hurts yield and should be limited as much as possible. One rule of thumb is to establish a length below which grouping will not be used, such as 30 inches. The rationale is that we can use all lengths of short parts in the cutting bill to help maintain yield, and grouping of short parts is especially costly in terms of yield. For example, grouping together 20- and 21-inch parts results in 1 inch excessive trim for the 20-inch part or 5 percent yield. In contrast, grouping 50- and 51-inch parts results in only a 2 percent loss in yield due to the excessive trim.

Determining Overage Allowance

The overage allowance refers to the extra number of parts manufactured to replace the defective parts created in the normal sequence of machining operations. The overage allowance should be carefully examined and can be complicated by several factors. The first is that it is difficult to obtain an accurate count of parts, so a few parts might be added to ensure the required quantity is met. An additional complication is the tendency for operators to cut more parts than are needed, since having to later make up for a shortage is time-consuming. Operators often are not aware that overage is already built into the cutting bill.

Overages are required to account for parts lost in subsequent machining operations. One of the major causes of part loss is that parts are needed to test machine setups at the beginning of new runs. Part sizes that will be undergoing more and complex machining

Table 4.—Proposed method of calculating preliminary overage allowance (Ross 1984).

Part Type	Setup allowance	Production first 100 parts	Production next 900 parts	Production over 1000 parts
Simple interior parts	3 Pieces	+ 3% of 1st 100	+ 2% of next 900	+ 1% over 1000
Simple exterior parts	3 Pieces	+ 3% of 1st 100	+ 3% of next 900	+ 2% over 1000
Complex exterior parts	5 Pieces	+ 5% of 1st 100	+ 4% of next 900	+ 3% over 1000

operations need more setup pieces. If a good system can be established, using parts that contain defects as set-up pieces can boost rough mill yield significantly.

A second major cause of part loss is rejected parts where machining operations: a) expose hidden defects; b) cause breakage or torn grain; or c) produce mismachined profiles, faces, edges, etc. More rejections occur when higher numbers of parts are needed and when more complex machining is required. End use also will affect the definition of what is defective, since hidden frame parts located on the inside of furniture can contain defects that cannot be tolerated in an exposed part that will receive a high gloss finish. Taking all these into consideration, overage allowance must consider setup, quantity, complexity, and end use.

It is easy to see that using a fixed percentage to determine overage is wasteful. Ross (1984) has recommended preliminary overage allowances grouped according to end use and complexity. Three different types of parts are identified: simple interior parts, simple exterior parts, and complex exterior parts.

Simple interior parts are those in which five or less straightforward operations are performed on wood that is easily machined, and where minor defects may be tolerated. An example would be interior frame parts.

Simple exterior parts also have only a few straightforward operations to be performed on wood that is easily machined. But minor defects are not tolerated, and defects are likely to occur in the machining operations. An example would be mouldings.

Complex exterior parts are those in which a larger number of operations are to be performed, and/or where part design results in fragility of the part or difficulty of machining, or where the species used is difficult to machine. An example would be sash or a complicated crown moulding with a check prone wood.

These groupings are used to calculate an initial estimate of the overage allowance, as shown in Table 4. It is expected that manufacturers will adjust these values to fit their general production needs and to fit specific situations that periodically arise.

A few examples will illustrate the use of Table 4. The differences in overage allowance as affected by the type of part to be cut will be examined first. Using 500 parts as the base number of parts required, the calculated overage allowances are as follows:

Simple interior parts: 3 + 3% of 1st 100 + 2% of next 400 = 3 + 3 + 8 = 14 parts
Simple exterior parts: 3 + 3% of 1st 100 + 3% of next 400 = 3 + 3 + 12 = 18 parts
Complex exterior parts: 5 + 5% of 1st 100 + 4% of next 400 = 5 + 5 + 16 = 26 parts

In this example, the number of parts required for the overage allowance increases from 14 to 26, depending on the part type.

Next, consider the impact the size of the production run has on the size of the calculated overage allowance. For simple exterior parts as shown in Table 5, the size of the overage allowance required is greatly impacted by the quantity of parts required by the production run. When the overage allowance is expressed as a percentage of the

Table 5.—Calculated overage allowance as a function of production run size.

Production run quantity	Overage allowance	Percentage allowance
10	3 + 0.3 = 3*	30
100	3 + 3 = 6	6
1000	3 + 3 + 27 = 33	3.3
10000	3 + 3 + 27 + 180 = 213	2.1

*Overage allowance was rounded to nearest whole number.

run quantity (right column in Table 5), the negative yield impact associated with small run sizes becomes obvious; the overage allowance (specifically the setup allowance) becomes a large percentage of the total production run. This illustrates the reason why many manufacturers are using computer technology to reduce the number of parts required for machine setups.

Other Considerations

We have discussed many of the details that can impact yield at the crosscut saw. Crosscut saw operators also have an oversight role in the rough mill that has not been mentioned. As the first operators in the rough mill to handle the lumber, they can be potential sources of information regarding lumber quality, lumber width, and lumber moisture content. This can be very important in small shops where there may not be automatic tally of these factors.

Bottlenecks may occur “downstream” from the crosscut saw, such as at the straight-line ripsaws and the salvage saws. It may be tempting to control the bottleneck by having the crosscut saw operator cease production of certain parts until the bottleneck eases, but that approach will likely hurt yield. A better approach is for the rough mill foreman to smooth flow by adjusting cutting bills, lumber grade brought to the mill, lumber length, and width of lumber brought to the mill. These adjustments will have a less drastic, negative impact on yield.

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Ross, V.R. 1984. **Yard, kiln & rough machine standard practice manual.** Asheville, NC: Hardwood Dimension Manufacturers Association.

Yield Improvement in Manual Ripsaw Operations in the Crosscut-First Rough Mill

The ripsaw cuts boards parallel to the grain, usually sawing along the board length. In the traditional crosscut-first operation, the objectives of manual ripsaws are to: 1) manufacture parts of specified width; 2) remove manufacturing defects and those wood characteristics unacceptable in the final product; and 3) produce a straight edge suitable for gluing. These objectives need to be achieved while minimizing the amount of waste generated and sent to the hog (or grinder).

As the ripsaw operation is the major defecting process in a crosscut-first rough mill, the volume of wood loss (some may be usable but is wasted) is greater than elsewhere in the rough mill. There usually are recovery opportunities that can be found in the wood waste placed on the hog belt. This section examines the practices and tools that can improve yield recovery at the manual ripsaw operation.

Ripsaw Practices to Improve Yield

Operators can have a large impact on the yield produced at the straight-line ripsaw. The practices recommended here can improve yield for those operations that are successful in getting their operators to implement them.

<u>Minimize edge trim.</u> Excessive edge trim is a major contributor to reduced yield at the ripsaw. Edge trim should be no more than the thickness of the saw blade. The initial edge at the ripsaw can be just sawdust in rough mills that have well-maintained saws and flat stock. Ideally, the amount of wood removed should be just enough to clean up the edge of the board. Sharp and properly tensioned saw blades do not need to be buried in the wood to produce a good cut. However, kickback of the edging strips may occur when using poorly maintained saws or when warped or skip dressed boards are sawn, so each situation must be considered carefully.[2]

<u>Place kerf inside the defect.</u> The saw cut should be made through the edge of the defect, not through the clear wood adjacent to the defect. Obviously, consideration must be given to the acceptability of sloping grain that is common around knots. Accurate ripping, possible with the tools described later in this chapter, can result in considerable yield improvements and material cost reductions.

<u>Fixed widths and random width parts should be ripped together.</u> Ripping only fixed-width parts (also called solids or specific widths) result in a large amount of waste because multiples of the desired part width will seldom equal the board width. Yield will be improved if random-width parts for panel glue-up can be ripped from the same length board sections as the fixed-width parts. An alternative to ripping random-width parts would be to have a range of multiple widths being cut from the same length stock.

Some ripping examples are presented to illustrate some of the yield improvement ideas that have been introduced. Keep in mind the two main objectives of the ripsaw operation are to remove defects and size parts to required widths, but that each saw kerf contributes significantly to the amount of waste produced.

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[2]Usually, kickback occurs when the pieces being cut lose contact with the feed system and come into contact with the rotating saw blade. Actions to minimize the risk of kickback injury include:

- Stand to the side, not directly behind the saw infeed.
- Maintain all kickback control features: anti-kickback fingers; corrugated feed chain surfaces; pressure rolls and springs; and replace or recut worn feed chains and chain race.
- Set saw to the correct height, and maintain alignment of the saw arbor.
- Properly adjust the pressure rollers for lumber thickness and keep them clean.
- Maintain correct saw blade tension and watch for uneven or high teeth.
- Be aware of warped and thin lumber, lumber with wane, and narrow strips.
- Consider additional kickback guards.

You should contact your ripsaw manufacturer for more detailed information

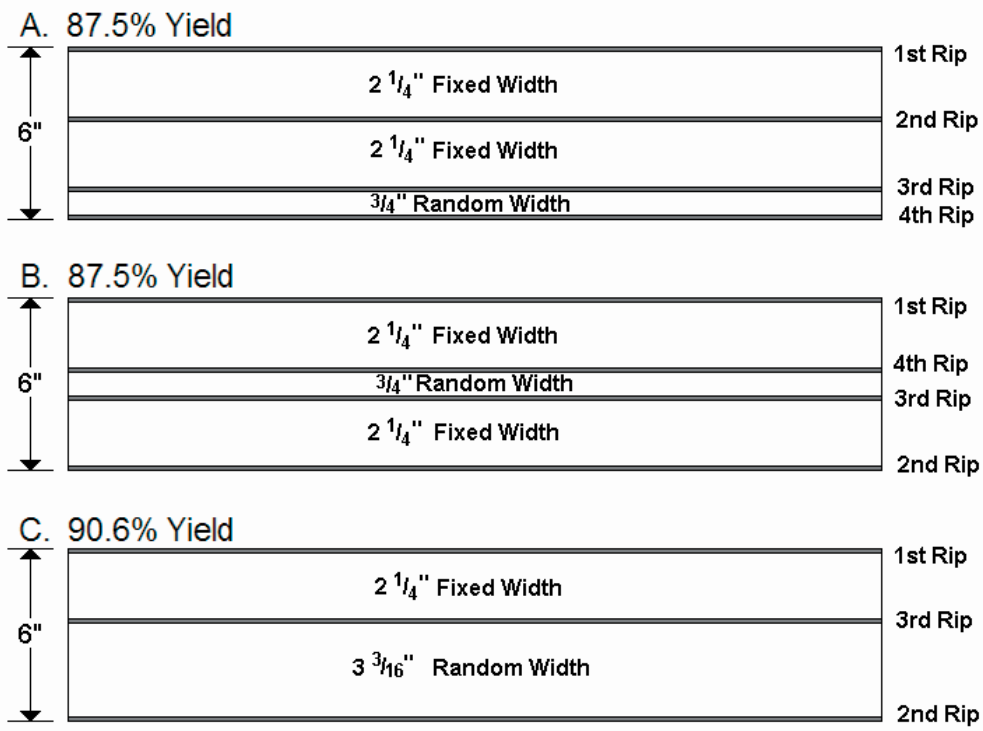

Figure 19.—Three different methods of ripping a clear board section to produce 2¼-inch fixed-width and random-width strips.

Example 1: The stock to be ripped is a clear, 6-inch wide section (see Fig. 19). Fixed-width parts 2¼ inches wide and random-width strips are required from this particular length. This board section may be ripped in several different ways, as shown in Figure 19 (A,B,C). Considering Figure 19A, the first rip straightens the outside edge. The second cut produces one 2¼-inch fixed-width part, while the third cut produces another. The fourth and final cut straightens the outside edge on the remaining narrow, random-width strip that will be edge glued into a panel.

A slightly different approach to ripping this same board section is shown in Figure 19B. Before any parts are removed, the two outside edges are straightened with the first and second rips. This method is somewhat safer than that shown in Figure 19A since it avoids ripping a narrow random width by itself. In both examples the same part volume is produced resulting in a part yield of 87.5 percent for both cases ([2¼ + 2¼ + ¾] ÷ 6).

There is still another approach (Fig. 19C) that can be used to rip this board. In sawing random-width parts at the ripsaw, an effort should be made to avoid the generation of narrow, random-width strips. Narrow strips can be out of square, and the effort in handling and gluing narrow strips may exceed the cost benefit gained from the yield improvement. At many mills, the minimum acceptable random width strip is limited to 3/4 inch for these reasons. Some operations avoid generating narrow strips by ripping a wider random-width strip, as shown in Figure 19C. Yield of parts is increased to 90.6 percent, a 3 percent yield increase over examples 13A and 13B.

It is important to remember that each saw kerf reduces solid wood to sawdust. It may not be necessary to machine both edges of fixed-width solid parts since it will be further machined by the moulder. Considering the example in Figure 19C, additional yield can be obtained by not ripping the outside edge of the fixed width part (omitting rip 1). This assumes that the board is reasonably straight to start with. By not ripping the edge, we can shift the position of the fixed-width part and increase the width of the random-width strip by the kerf thickness (3/16 inches) to 3 3/8 inches. The yield of usable parts is now 93.7 percent, and we have reduced the number of rip cuts required.

Example 2: It is more often the case that the board sections to be cut at the ripsaw will not be clear as

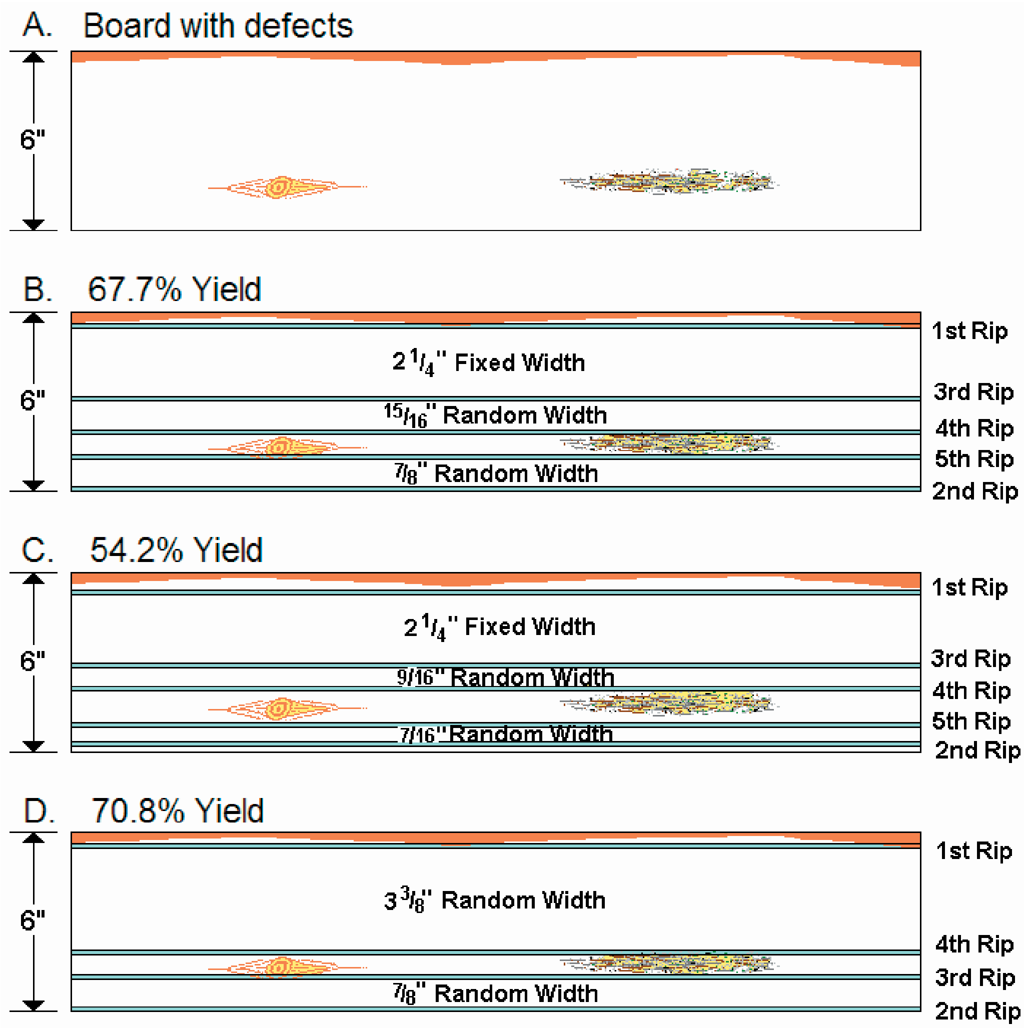

Figure 20.—Three methods of ripping a board with defects.

in the previous example, but will contain defects that need to be removed. The board section passed on to the ripsaw from the crosscut saw in Figure 20A is 6 inches wide and contains several defects. This board contains a knot, an area of stain, and wane along one edge. Again, a 2¼-inch-wide fixed-width and random-width parts are to be cut. As shown in Figure 20B, the first rip removes the wane and straightens the edge. The second rip straightens the other edge. The third rip produces the 2¼-inch fixed-width part, while the fourth and fifth rips remove the defects and generate two random-width strips. The yield for this ripping solution is 67.7 percent.

Figure 20B illustrates good ripping practices—the edging strips were minimized and the kerf was placed into the defect, maximizing the amount of good, clear wood available. Figure 20C, on the other hand, illustrates poor ripping practices as exhibited by the very wide edging strips produced and the placement of the kerf totally outside the defect area, wasting usable wood around the defect. The two random-width strips are probably too narrow to use economically and safely. In the properly ripped board (Fig. 20B), 67.7 percent of the board is converted to useful parts, while the poorly ripped board (Fig. 20C) results in only a 54.2 percent yield.

For completeness, example 20D illustrates how ripping wider random-width parts in lieu of fixed-width parts can increase yield and reduce the number of narrow strips produced. For some rough mills, this cutting strategy is a viable option, but for those that do not have a large glued-up panel market, this approach may not be feasible.

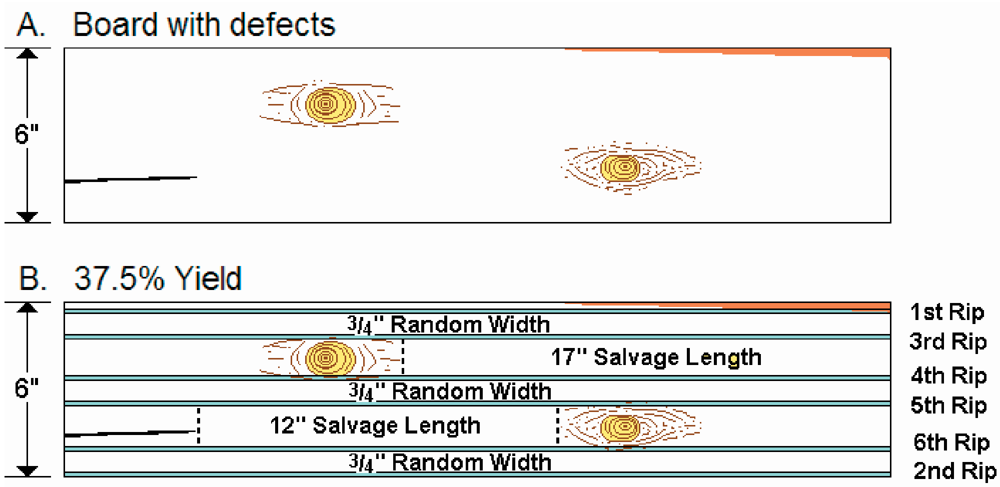

Figure 21.—Board section containing many defects from which only random-width strips can be ripped. Salvageable areas also are shown.

Example 3: Figure 21A presents a board in which the location of the defects may not permit any fixed-width parts to be cut. As shown in Figure 21B, the first two rips straighten the outside edges and remove the wane located on one edge. The subsequent rips bury the saw into the defect area and produce three minimally acceptable random-width strips (each 3/4-inch wide) with straight edges ready for edge gluing. Strips containing defects can be sent to the salvage saw, typically a small crosscut saw used to remove defects and produce shorter parts. Possible salvage saw cuts are shown as dashed, vertical lines.

Operators must know what defects are acceptable. It is essential that ripsaw operators (both infeed and off-bearer operators) know and understand their end-product requirements. Without an adequate understanding of acceptable defects, two very different types of mistakes can occur, both of which will impact yield. The failure to remove defects will result in a defective part that may be further processed and even used in an assembly before the defect is found, resulting in rework or rejection of the assembled product. At the other extreme, it is more likely that without adequate instruction, the tendency of the ripsaw operators will be to reject small defects and blemishes that may be acceptable in certain parts, and instead produce C2F parts in all cases. For the inexperienced or unsure operator, producing a clear part is the safest course of action as it will always exceed quality standards. But the cost of this unnecessary quality will be reflected by reduced yield and the volume of wood on the hog belt.

During defect removal at the ripsaw, it is important that the operator keep the salvage saw operation in mind. Although the ripsaw operator should remove all objectionable defects from parts, not all defects need to be removed from salvageable material. Material containing defects can be passed to the salvage saw (typically a crosscut saw after the ripsaw) that can efficiently recover sizes in the cutting bill. For example, the crosscut sawyer may have previously placed defects into an intermediate-length board section (usually a good practice). The alert ripsaw operator, after sawing the intermediate-length parts, will recognize that a short part can be obtained and will allow the salvage saw to recover it by removing the defect. The ripsaw operator should not lose sight of the opportunity provided by the salvage saw for the recovery of shorter parts.

The need for operators to be trained and to understand quality criteria seems so fundamental, yet often operators are not adequately trained. The first step in training operators is for management to establish and document quality criteria. Writing it down establishes a base line that will serve for future reference. The objection is raised that there are too many shades of gray in establishing quality criteria because not all defects fit into the established grade definitions. However, if obvious cases of unacceptable defects or acceptable blemishes are classified, the process of establishing quality criteria will develop a better understanding of product need at all levels—first with management and then with operators.

In establishing quality standards, it is important that operators understand that these standards vary not only according to species, but also according to the design and finish of the product, and to customers' needs. Management must communicate these quality standards to the operators on a regular basis. One tried and true communication method is the use of sample boards with representative defects illustrating different grades. A newer method involves interactive computer programs with text and photos that can be accessed by a computer located on the floor. With computer technology there is the advantage of accessing a lot of information that can be updated easily; the disadvantage is the information is not visible at a quick glance.

<u>Minimize edge allowance.</u> The traditional amount of extra width added to moulder stock for sizing rough mill parts is ¼ inch. Reducing this allowance should be considered. Some manufacturers have reduced moulder allowance from 1/4 inch to 1/8 inch for shorter moulder stock (≤ 24 inches) and to 3/16 inch for longer stock (>24 inches). Consider a part whose rough size is 1 3/4 inches and is machined at the moulder to a width of 1 1/2 inches; i.e., an edge allowance of 1/4 inch. Reducing the allowance from 1/4 inch to 1/8 inch recovers an additional 1/8 inch for every part machined. What this means, in effect, is that for every 13 pieces cut, one 1 5/8-inch rough part will be gained simply due to the reduction in edge allowance (7% improvement in utilization). For parts whose allowance can be reduced only to 3/16 inch, the utilization gain will be about 3.5 percent—or an extra part for every 27 sawn parts.

Edge allowance also can be effectively reduced by using the splitter saw at the moulder to separate multiple-run parts. This substitutes one thin kerf produced at the moulder for two (often wider) ripsaw kerfs. Finally, consideration should be given to ripping interior parts to net size (that is, no edge allowance is required, as there is no need to mould these parts).

<u>Avoid producing oversized parts.</u> It is common to find rough mill parts 1/16 inch wider at the ripsaw than specified by the route sheet. This may be done by the ripsaw operator to ensure that the parts are wide enough to meet the moulder requirements and thus avoid a shortage caused by parts that are too narrow. This is a prime example of how important it is for everyone to understand how they can influence cost and profit. For example, a ripped 2-inch-wide part, manufactured only 1/16 inch over size, represents a 3 percent yield loss. The underlying cause may be equipment problems, such as a loose fence at the saw. The equipment needs to run properly so the operators can confidently cut to the required specifications.

<u>Workstation Design and Tools to Improve Ripsaw Yield.</u> The practices to improve yield at the straight-line ripsaw have already been discussed. Of equal importance is a well-designed workstation that includes tools to assist operators in the successful implementation of these practices. The ripsaw station should have sufficient lighting to allow correct defecting. The workstation should be designed so minimum operator effort is required to bring a board section to the saw table so that the operator can maintain a smooth working rhythm. Pallet stock should be positioned consistently in a location that can be reached easily by the operator. The use of scissor lifts to raise palletized stock will help eliminate bending, reduce back fatigue and injury, and increase productivity.

Operators of ripsaws that are coupled directly to the crosscut saws often will spend time and effort retrieving board sections from a belt feed or a jumbled pile at the base of a gravity slide. Excessive pile ups at the base of gravity slides sometimes can be reduced by cutting different length lumber or shorter lumber at the crosscut saw. The former will result in the production of a different mix of section lengths while the latter will reduce the productivity of the crosscut saw, allowing the overwhelmed ripsaw time to catch up.

Additional Tools to Aid Ripsaw Yields

<u>Lasers.</u> A laser, aligned with the saw blade, will project the saw's path onto the board at the ripsaw infeed table. Installed above the saw and projecting a straight line of light onto the board, lasers help operators to feed the board into the ripsaw accurately and quickly (Fig. 22).

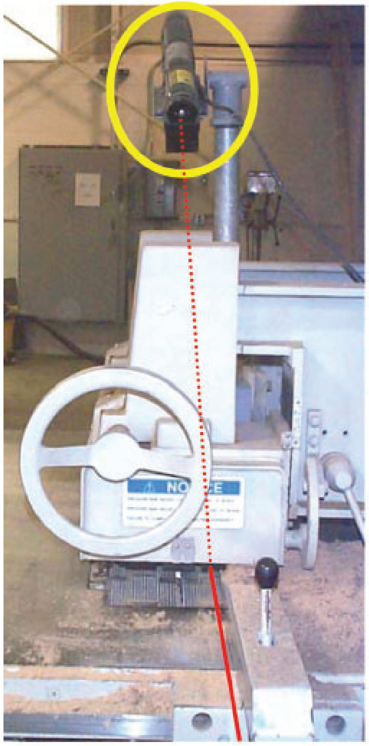

Figure 22.—A laser projection unit mounted above a straight-line ripsaw projects a laser line onto boards placed on the infeed table enabling the ripsaw operator to see where the sawline will fall on the board.

Use of this widespread technology assists operators in accurately locating and excluding defects from parts, minimizing edge strips, accurately burying the saw kerf into the defect area, and maximizing the width of random-width parts. Although the greatest benefit of lasers is derived when cutting longer parts, many operations benefit from their use with all part lengths.

Floating rip fence. The floating rip fence facilitates the sawing of random-width parts and fixed-width parts at the same time. Typically, a counterweight and cable allow the fence to be easily moved to control the width of the cut. The ability to rip random-width parts for glue-up in addition to fixed-width parts from lumber greatly enhances ripsaw yield.

Pop-up fence. Sometimes referred to as a disappearing fence, the edge of the pop-up fence is aligned with the saw blade so relatively straight boards can be edged without producing an edging strip. Pop-up fences often are recommended only for lengths less than 36 inches since the amount of crook in longer boards will not clean up. The pop-up fence may consist of a spring-loaded, hinged plate on the ripsaw table whose edge acts as a fence when it is used to edge a board. If a board needs to be defected or ripped to a width using the conventional fence, the board is placed on top of the pop-up fence. The weight of the board presses the pop-up fence flat with the surface of the ripsaw table. Other pop-up fences are designed to be operated using a foot pedal.

Flip-stops. As described above, it is sometimes better to rip a wide random-width part rather than produce a fixed-width and narrow random-width strip because yield will be higher and the random-width strip may be too narrow to use. This may be difficult to put into practice since the fence stop will prevent the fence from moving to a position that will allow a cut wider than the fixed width. Attaching a hinged flip-stop to the conventional stop will give additional flexibility to the ripsaw. When the operator determines that producing a wider random-width part is the better option, the flip-stop can be raised, allowing the fence to move back further, and the wider, random-width strip to be sawn.

Thin kerf saws. Conventional ripsaw blades typically have kerfs that range from 5/32 to 3/16 inches (0.15625 to 0.1875 inches). Yield losses at the ripsaw are affected by the width of the saw kerf. Yield losses due to ripsaw kerf typically range from 7 to 12 percent. Many operations have found yield savings by using saws with thin kerf saw blades with thicknesses ranging from 0.080 to 0.125 inches. For example, consider Figure 20D on page 33, in which a 6-inch-wide board has three kerfs. If each kerf was 3/16 inch, then 9.4 percent of the board yield is lost as sawdust. On the other hand, if a thin kerf saw (0.100 inch kerf) is used, the yield loss due to kerf is only 5 percent. Average yield savings at straight-line ripsaws attributable to the use of thin kerf saws are expected to be about 2 to 3 percent. Using thinner saws usually requires two things: more attention to saw maintenance and large saw collars to provide extra stability. It is important to note that many operations have not had success implementing thin kerf technology probably because they were unable to provide the high degree of saw maintenance required.

Gang Ripsaw Practices in the Rip-First Rough Mill

Several different lumber gang saw optimizing systems are available. These systems have different capabilities and costs, and some are found more commonly in certain industry segments than in others. They all have in common the following basic functions:

- Optimization capability
- Board measurement
- Arbor configuration and board positioning
- Gang sawing

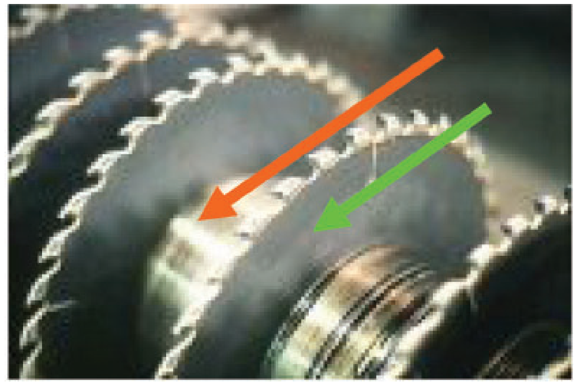

Figure 23.—Gang ripsaw arbor with saws and pockets (spaces) between saws.

Optimization Capability

Optimization is the adjustment of variables to obtain the best result, which in rough mill cut-up operations may be the highest yield or the highest value. Many optimizers have the capability of optimizing either for yield or for value. Thus the pattern selected to cut each board is usually an attempt to optimize either yield or value. The sawing solution determined by the optimizer that is cutting for yield may be different than the optimizer cutting to maximize value. Sawing to maximize the value of parts will generally sacrifice or waste clear wood. Whether this is good or bad depends on the operational goal of the rough mill and plant.

Board Measurement

The various technologies used for board measurement result in a broad range of capability. Board width is the most important parameter required by the gang saw and is the minimum amount of data collected at the measurement station. The simplest approach is to determine the board's width at a single point. The width measurement is then used to match the available combination of arbor pockets that most closely fits the board width in the case of yield optimization, or that produces strips of highest value during value optimization.

More complex camera systems can be used to measure width along the length of the board (Fig. 23). These systems can evaluate board taper and edges with wane and use the effective board width in evaluating cutting solutions. When there is little variation in width from one end of the board to the other (small amounts of wane and taper), good results can be obtained using single point board width determination. With lumber that has significant amounts of width variation, however, optimization at the gang saw may be better accomplished with systems that evaluate board width all along the board length, rather than single point measurement.

Yield Optimization at the Gang Saw

Arbor Configuration and Board Positioning. Obtaining a high yield from a fixed-blade gang ripsaw depends on correctly designing (setting up) the sequence of arbor pockets (saw spacings; Fig. 23). Ideally, for each board, it is desirable to have available adjacent arbor pockets whose combined width (including saw kerf) matches the width of the board (Fig. 24). An example will show how arbor design can be important for yield. Assume a 7¾ -inch-wide board that will be ripped with an arbor that has 2-, 2¼-, 2¾-, and 3-inch wide pockets available. A saw kerf of 3/16 inch will be assumed. Figure 24 illustrates an arbor designed with the following sequence of arbor pockets: 2, 2, 2¼, 2¼, 2¾, and 3 inches. Also shown in Figure 24 are potential locations that the board might be fed into the saw (A, B, C, D).

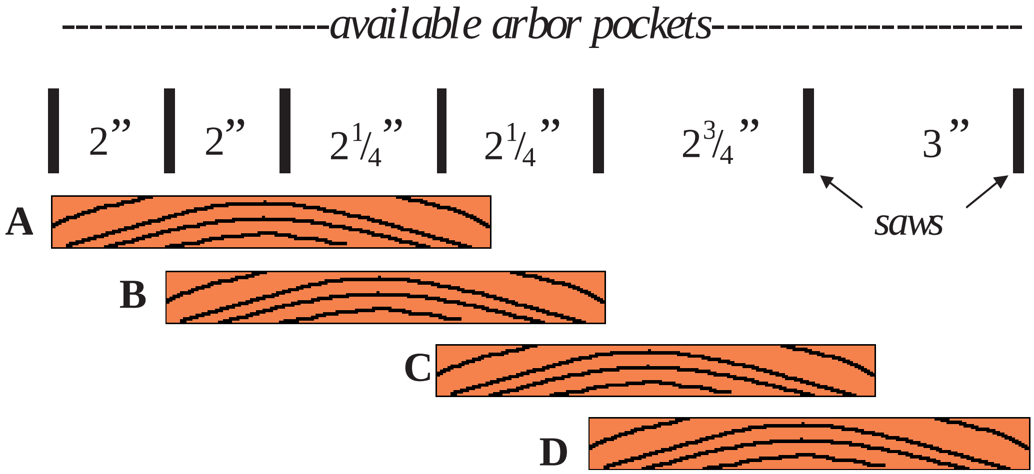

Figure 24.—Six arbor pockets and seven saws (3/16-inch kerf) are shown with four possible positions that a 7¾-inch-wide board might be fed.

Depending on the board location, the yield results can vary by nearly 20 percent as shown below:

A=2 + 2 + 2¼ + 4 (3/16) = 7″ or 80.6% strip yield

B=2 + 2¼ + 2¼ + 4 (3/16) = 7 ¼″ or 83.9% strip yield

C=2¼ + 2¾ + 3 (3/16) = 5 9/16″ or 64.5% strip yield

D=2¾ + 3 + 3 (3/16) = 6 5/16″ or 74.2% strip yield

Other pocket combinations into which the board may be fed result in lower yield or exceed the board width of 7¾ inches. The results of any of these potential placements indicate that this arbor design does not fit this board well. Given these choices, our optimizer would have chosen B and achieved an 83.9 percent yield at the gang saw. This is a respectable yield and we might be satisfied since the yield is higher than 80 percent, often given as a minimal acceptable yield from a gang saw. But consider this lost opportunity. Had the arbor been slightly different, we could have boosted yield, as shown in Figure 25.

E = 2 + 2 ¼ + 2 ¾ + 4(3/16) = 7¾″ or 90.3% strip yield

By simply swapping the position of the 2¼- and 2¾-inch pockets on the arbor resulted in a 6.4 percent yield increase (Fig. 25). This example illustrates the importance of arbor design. Further, consider the potential impact arbor design could have on yield if there are a significant number of 7¾-inch-wide boards.

There are thousands of combinations possible when designing the sequence of saw spacings of an arbor. Many gang optimizers offer arbor design programs as part of the software package, and software is available from universities to assist in arbor design.

A good arbor can be designed by hand. The main objective is to develop as many different pocket combinations as possible on the arbor. This will depend on the width of the parts required and the width of the arbor. Wide part requirements (and thus wide pockets) will result in fewer pockets on the arbor and therefore reduce the number of pocket combinations possible. Conversely, a gang saw with a wide arbor will be able to hold more pockets than a gang saw with a narrower arbor. With these thoughts in mind, the following arbor design guidelines are suggested:

- Use at least three or four different widths on the arbor; more is usually better
- Evaluate lumber widths to determine the most frequently occurring widths
- Design combinations of arbor pockets to closely match the predominant lumber widths (be sure to include kerf in the calculations)
- Determine the percentage of the total area of the cutting bill in each part width
- As a starting point, use two arbor pockets for part widths containing more than 25 percent of the

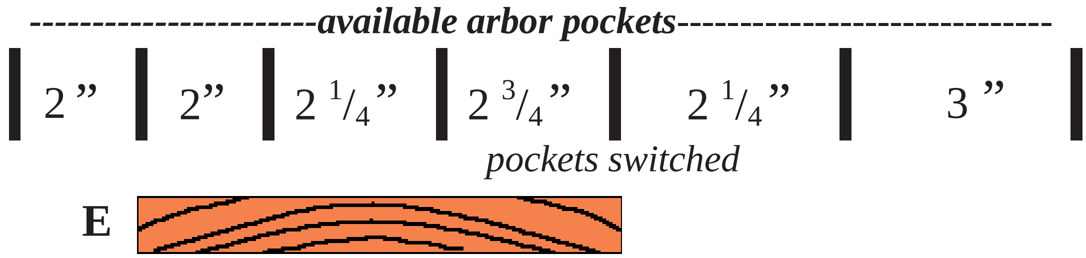

Figure 25.—Feeding a 7¾-inch-wide board into a well designed arbor resulting in a maximum strip yield.

total cutting bill area, and consider three arbor pockets for part widths greater than 50 percent. Often widths comprising less than 1 percent of the total cutting bill area can be omitted on the arbor and obtained by salvage operations

- Do not repeat the same sequence of pocket combinations if possible (in order to create different pocket combination alternatives for the optimizer)
- Use thin kerf blades to increase the amount of arbor space available for pockets which may allow a more efficient arbor design. Compared to a conventional saw kerf of 0.156 inch, a thin kerf saw (with 0.100 inch kerf) will save 0.056 inch in kerf per saw blade, resulting in an increase of more than ½ inch of arbor space on a 10-blade arbor.

Value Optimization at the Gang Saw

The previous example focused on recovering yield from the board by maximizing the amount of strip volume produced. In some situations, it is more desirable to maximize the value of the strips produced by the gang saw. The following example will illustrate a case where the value-driven solution differs from the previous yield-based solution. Assume each of the different strip widths have been assigned the value shown:

2-inch wide:	$1
2¼-inch wide:	$2
2¾-inch wide:	$4
3-inch wide:	$5

As expected, the wider strips are more valuable than narrower strips. The resulting strip value and yield for the five previously described solutions are presented below. If the gang saw optimizer is selected to maximize value, then the selected solution is D with a maximum value of $9, while the maximum yielding E solution has a value of only $7.

	Strips Produced	Strip Value ($)	Strip Yield (%)
A	2, 2, 2¼	1 + 1 + 2 = 4	80.6
B	2, 2¼, 2¼	1 + 2 + 2 = 5	83.9
C	2¼, 2¾	2 + 4 = 6	64.5
D	2¾, 3	4 + 5 = 9	74.2
E	2, 2¼, 2¾	1 + 2 + 4 = 7	90.3

More complex technology is incorporated in vision-assisted optimizers that often use video cameras and other scanning technologies (x-ray, laser) to identify and locate defects (Fig. 26). This allows the gang saw optimizers to extend the value concept to maximize the total value of the parts that can be obtained from each board. This

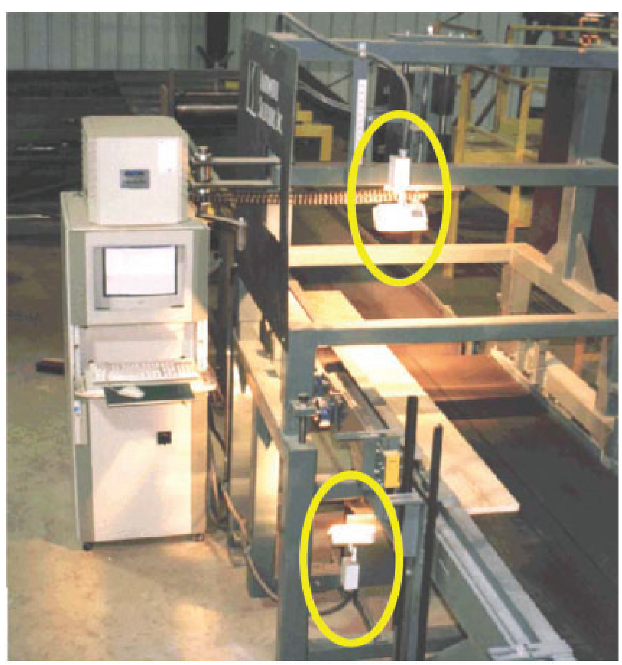

Figure 26.—A system for scanning both sides of a board along its length as it approaches the infeed to an optimizing ripsaw.

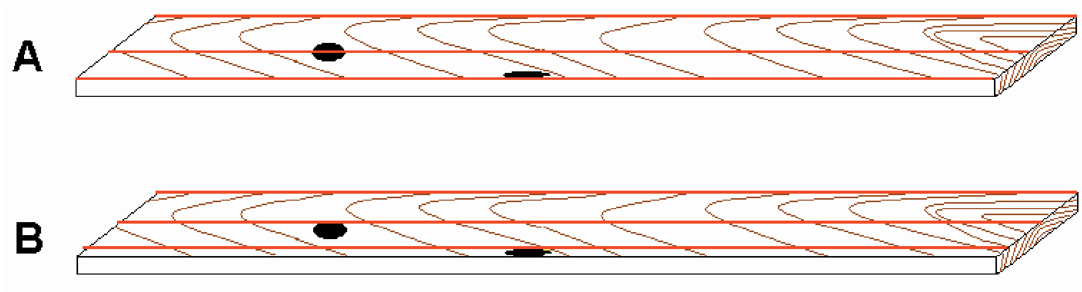

Figure 27.—Different methods of ripping. In A the board has been ripped to maximize strip yield. In B the board is ripped to maximize part yield, obtaining a long, clear strip by placing the knot wholly in the other strip.

approach uses vision technology to identify major defects on one or both sides in addition to the board size and shape. Part sizes from the cutting bill and part values are used by the gang saw optimizer to determine the best combination (best either in terms of yield or value) of parts to cut from the board. The optimizer predicts where the defects will be located when the strips are processed at the chop saws, and determines the maximum obtainable value or yield of parts (in most cases this estimated solution is not shared with the automatic chop saw).

Value cutting usually will force the recovery of wide and long parts, sacrificing yield in order to obtain more valuable parts. Whether this is desirable or not depends on the objectives of the rough mill and the grade of lumber being cut. For instance, a casket manufacturer that requires a large number of long and wide parts is justified in force cutting for value from a reasonably high grade of lumber, but trying to do so from a low grade of lumber likely will result in a large amount of waste.

Another difference between optimizers whose goal is to fill the board with useful strips and those with the goal of predicting the parts available when the strips are chopped is the manner in which defects are handled. Optimizers that evaluate only the size and shape of the board do not take into account where the defects may be located in the strip that exits the gang saw. This type of optimization may result in a defect, such as a knot, being split in half by the saw and thus becoming a defect in each of the two strips (Fig. 27A). On the other hand, if the defect was identified and located by a vision-assisted optimizer, the opportunity exists for the knot to be placed in only one narrow strip (Fig. 27B). Of course, this concept depends heavily on how well the defect detection system correctly identifies and locates defects. With a less-than-perfect vision, the final yield from a board may differ from that predicted by the gang optimizer since the human grader who marks defects in front of the chop saw may see more (or fewer) defects than the vision-assisted optimizer.

One disadvantage unique to gang-rip-first cut-up systems is the inability to efficiently cut boards containing crook (side bend). Gang ripping of full length boards containing a significant amount of crook can result in large yield losses. Research has shown that about one in four kiln-dried boards have ½ inch or more of crook. One-half inch of crook in a 10-inch wide board will result in a 5 percent yield loss. Given that 90 percent of today's hardwood lumber is narrower than 10 inches, this means one-fourth of all boards will lose at least 5 percent yield due to crook. Losses due to crook will be much higher with narrower lumber. To avoid losses due to crook, many gang rip optimizers can identify crooked boards and reroute them to an offline crosscut saw to cut the boards in half lengthwise before being ripped. Rough mills that have both gang-rip first and crosscut-first cut-up lines should be vigilant in their efforts to route crooked boards through the crosscut-first system.

The boards leave the optimizer and travel to the gang saw infeed. They must remain separated to keep the determined solution with the proper board. The purpose of the positioning infeed is to convey the board and position it in alignment with the saws recommended by the optimizing computer. Some systems use a movable fence to position the board in front of the correct set of gang saw pockets. Other infeed systems use belts to position the board. These belts swivel the board to feed it into the gang saw by aligning it at an angle, which might be an advantage if the board has excessive crook or taper. Pinch rollers then clasp the board and hold it in place as it feeds into the saw.

Gang Sawing

Three types of optimizing gang saws are commonly found: fixed-blade gang saw with movable fence (often called fixed arbor, best feed), fixed-blade gang saw with movable outer saw, and all-blades-movable saw.

The fixed-blade gang saw with a movable fence is the predominant gang saw found in furniture gang-rip-first rough mills. Even the most optimized arbor design will not completely eliminate the waste edging strips produced on a fixed-blade gang saw. For operations that utilize a fixed-blade gang saw, the generation of waste edging strips is particularly problematic. These waste edging strips represent a visible measure of the level of gang saw performance (specifically the efficiency of the arbor design). Extra labor is typically required to remove the strips and feed them to a guillotine or saw where they are cut into pieces that can be managed by the waste conveyor.

One limitation of the fixed-blade gang saw is that it cannot generate random-width parts. The solution to this problem and that of the waste edging strips is to use a dual arbor gang saw in which one arbor is equipped with two movable blades. The movable blades are capable of moving to the outer edges of each board to: 1) generate a random width strip, and 2) eliminate or reduce the size of the waste edging strip. Although there were problems with the initial implementation of this technology, its application today is much improved. The advantage of using a dual arbor gang saw that has both fixed and movable blades is the potential to saw random-width strips from the lumber and thus increase yield. This is a particularly good arrangement for a manufacturer with strong product potential in panels and a handful of fixed-width sizes. However, one must be careful in implementing the production of random-width strips from the gang saw so that the amount of random-width parts produced does not exceed the glue room's capacity to glue them into panels. Another caution is the random widths must not be too close (typically 1/8 to ¼ inch) to the width of the fixed-width strips in order to differentiate strip widths at the chop saw and parts at the sorter.

All-blades-movable saws have historically been found in the millwork industry where the ripped stock is generally moulded and not edge glued. However, many of today's saws with movable blades are capable of producing a glueable edge, unlike earlier moving blade saws. With this limitation removed, most value-added industries can take advantage of the higher gang saw yields that result with movable blade saws. Because the gang saw has movable blades, the optimizer can position the saw blades based on board width, part widths, and defects when they are accurately identified and located by scanning. These gang saws are capable of placing the saw blades at the best location for each board. This relieves personnel of the burden of daily arbor design required for fixed blade gang saws. As with a fixed-blade gang saw, the optimized decision made by a movable-blade gang saw can be based on maximizing the yield or the value of the ripped strips produced. The saw operators and mill supervisors must understand the function of the saw's computer-based optimization software to correctly evaluate and adjust optimization parameters.

Gang saw output will have significant impact on productivity throughout the rough mill. The capacity of most gang saws is such that they can swamp downstream operations. In such situations, it makes good sense to slow down the gang operation either by slowing the feed through the saw or by encouraging the gang operator to carefully observe the optimizer's decision and override it if a better sawing decision is obvious. One manner in which the gang saw can overwhelm the chop saw markers is by producing a large amount of narrow strips. Narrow strips sometimes are needed by the cutting bill, but often are added to the arbor to make up for the deficiencies of what would otherwise be a low-yielding arbor. This may or may not be justified; it will slow down the volume of wood processed by the chop saws because the volume of wood marked per strip is reduced. In addition, these narrow strips tend to jam the chop saw infeed and the saw itself.

In some cases, gang saw productivity is reduced due to narrow lumber. Narrow lumber is more and more common and is a challenge to the gang saw in terms of productivity and yield. In gang sawing narrow lumber, there are fewer pocket combinations available that produce an acceptable yield compared to gang sawing wide lumber. The use of moving saw blades, either as a dual arbor or an all-blade-movable saw, to produce a combination of random- and fixed-width strips, is a method of improving the yield from narrow boards. In operations that use moving saw blades but do not cut random-width parts, an effort should be made to ensure that part width combinations are available that match the lumber width.

Operator Process Control Responsibilities

The misconception of computerized optimization systems is that the systems will operate correctly without human intervention. But in reality, the operator must verify that the saw has been set up correctly and is functioning properly. The operator must perform a number of process control quality checks to ensure the following:

- Accuracy of board width and length. The actual dimensions of the incoming lumber needs to be compared to the measurements obtained by the optimizer. If the measurements do not agree, the sensors or cameras that measure dimension need to be calibrated.
- Accuracy of ripped strips. The width of ripped strips needs to be measured using calipers that measure to 0.001 inch. Strips that are not sawn to the specified width may indicate that the incorrect arbor spacers were used in building the arbor, or that movable saw blades are not correctly adjusted.
- Accuracy of laser line or video imaging system alignment. For the board (or movable saws) to be in the correct position, the laser lines or video cameras must be in correct alignment and calibration.
- Size of edging strips. When the gang saw is set to maximize the yield of strips, wide edging strips suggest a poor arbor design on a fixed-blade gang saw, or too few widths available on the all-blades-movable gang saw.
- Best side up or down. With single-sided video camera systems capable of identifying defects, operators must turn the best face toward the cameras for C1F parts. The worst face must be turned toward the camera when cutting C2F parts.
- Crooked lumber. The operator needs to divert crooked lumber from the gang ripsaws as its first cut.

Because the breakdown of the lumber package usually occurs at the gang saw infeed, it is a convenient location to evaluate the lumber moisture content. This can be done by checking each board with an inline moisture meter, or using a systemized method of spot checking and recording moisture contents of a sample portion of the incoming lumber with a hand-held moisture meter. Moisture content needs to be evaluated to ensure that the lumber meets product moisture content specifications. Failure to do so will likely cause problems in machining, gluing, assembly, and finishing.

Optimizing Crosscut and Chop Saw Operations

During the 1990s, many rough mills adopted semiautomatic optimizing lumber crosscutting or strip chopping systems to improve processing efficiency and profitability. As part of these systems, humans locate defects and mark their edges with a fluorescent crayon. Then a scanner detects the leading and trailing ends of the board and the fluorescent crayon marks. In fully automated optimization, which is more common in the softwood industry, the scanner detects defects without marks. The use of optimizing crosscut and chop saws leads to yield increases and cost savings for many rough mills. Lumber yield increases of 4 to 10 percent have been achieved by some rough mills after adopting optimizing saws (Anonymous 1998, Davidson 2001, Moss 1999a, b). Other rough mills report less substantial and generally disappointing results after installing optimizing saws. It is not unusual to attend meetings of secondary manufacturers and hear stories of optimizing saws that have been retired. An indisputable benefit from optimizing saws is improved safety because the operator is removed from the saw. But most rough-mill managers also expect an increase in lumber yield and productivity. Reduced operator/marker training time and increased cutting consistency throughout the day and week are other benefits attributed to optimizing saws. Some component manufacturers also may realize greater scheduling flexibility and find it feasible to process fewer part quantities.

Whether optimizing saws deliver these benefits depends primarily on how the saw is used and whether sound process and quality control practices are adopted. Yield benefits are derived from optimizing saws when more part sizes and grades are cut simultaneously than would be possible with a manual saw. Yet some rough mills install new saws without installing additional sorting stations and/or storage space for parts.

More Lengths Produce Higher Yield

A study of the yield effect of processing more lengths at one time revealed that cutting 15 part lengths together rather than in three groups of five lengths each increased yield by 10 to 12 percent (North Carolina State University 1996). In another study in which additional lengths were added to a cutting bill (one at a time), adding a fifth length increased yield by 4 percent and each additional length resulted in a smaller yield increase. When the number of lengths increased from four to eight, the total yield increase was about 10 percent (Mullins 1998).

Some rough mills may have sufficient sorting space but fail to use it upon realizing that when lumber and strip markers put more marks on a board (as is necessary when multiple part grades are used), the productivity (lineal feet per shift) of the saw and marker is reduced. Some mills with insufficient sorting capacity will increase yields by manually sorting strip widths then processing only one or two widths at a time through the optimizing saw. This allows the processing of additional lengths per width on saws with limited sorting capacity, but increases costs for material handling. Ideally, if a gang saw rips an average of four widths simultaneously, the sorting station should be designed to cut an average of eight different lengths per width. This would require 32 part-sorting stations assuming that only one part grade is recovered per part size! Few optimizing saws are installed with a sorting station that has this much capacity.

Basic Considerations for Saw Operators

Many operating guidelines for defect/grade markers working with optimizing saws are similar to those for operators of manual crosscutting/chopping saws. Operators and supervisors should read Length Cutting on a Manual Crosscut Saw (Mitchell 2003) for an overview of how marking/cutting decisions affect lumber yield. Usually, most of the cuts made on a crosscut saw in a crosscut-first rough mill are made to cut the piece of lumber into the lengths needed for the current part order, but most of the defecting is accomplished on the straight-line ripsaw. By contrast, in a rip-first rough mill most of the defecting occurs on the chop saw. In both cases, it is the second cutting operation that performs the majority of the defect removal.

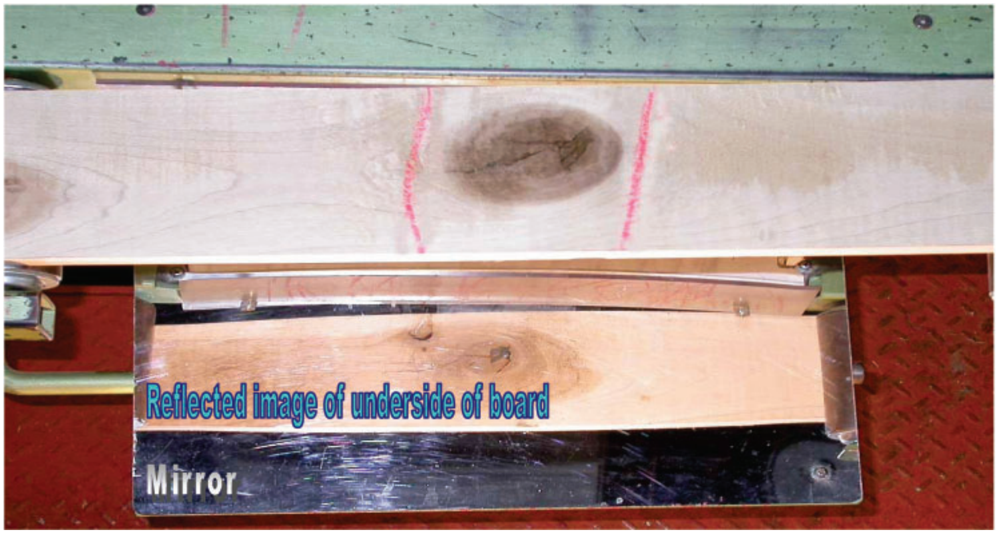

Figure 28.—The view of both the top and underside of a board as seen by the defect marker using a well positioned mirror.

The Mitchell article (2003) includes the following key concepts:

- To obtain the best yield, the cut-off saw's defect marker in a crosscut-first rough mill should not try to remove all defects; most defecting can be done in the ripping operation that follows. A rule of thumb for many mills is that only those defects that occupy at least one-half of the board's width should be removed on the crosscut saw.
- If long cuttings are especially important and valuable, defecting on the lumber cut-off saw should be minimized. If longer cuttings are not particularly difficult to obtain or valuable, defecting with the cut-off saw can be increased.
- The defect marker at the crosscut or chop saw should inspect both sides of the board or strip. When cutting C2F parts, place the worst face of the board or strip up for easy viewing. When cutting C1F parts, orient the best face up. The use of mirrors positioned so that the marker can see the underside of the board or strip can be very effective (Fig. 28). It takes several days (and usually a temporary slowdown) before a new defect marker becomes accustomed to the mirrors, but speed and accuracy gradually increase. Ultimately, mirror use will improve marking speed, marking quality, or both.
- The first cut is made to square the end and remove end checks. However, a single end split of more than an inch or two should be left for the ripsaws to remove. This distinction cannot be made if an optimizing saw is set up to automatically end-trim each board by a specific amount. For boards with multiple end checks, markers must designate longer first-end trim lengths than would be made by a manual saw operator because the marker cannot re-evaluate the board end after the first cut to determine whether another trim cut is needed to complete the removal of checks or splits. Therefore, more substantial end trims are taken to reduce the risk that the first and last parts cut from the board or strip will be rejected. This results in a greater loss in yield on optimizing saws associated with end trim. Alternatively, if larger end trims are not taken, more parts will be rejected, resulting in even greater yield losses and operating costs.
- To determine the optimal length to remove to maximize yield, markers should regularly evaluate the end appearance of stacked "good" parts and trim (waste) sections removed from the boards/strips for checks (Fig. 29). The trim amount should differ for different species. For example, check-prone species such as oak, alder, and beech must be trimmed more than other species. Trim amounts also can vary

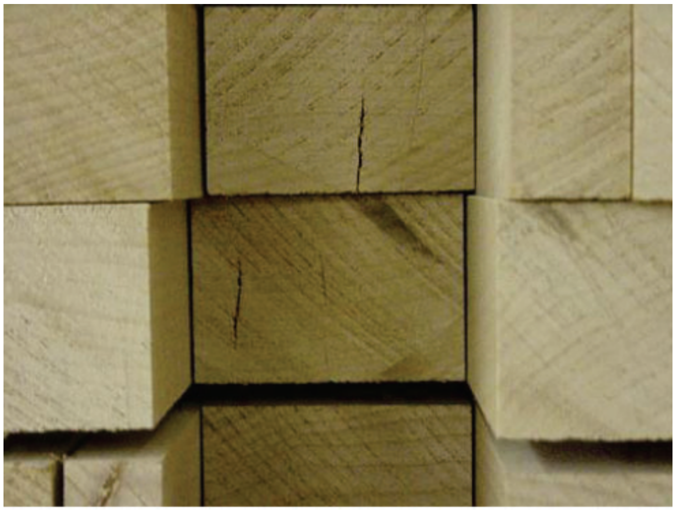

Figure 29.—Red alder dimension parts that were not end-trimmed as much as necessary to remove checks. These parts will need to be recut, otherwise they will be rejected further along in the processing sequence.

depending on the quality of the wood provided by different suppliers. The marking team and their supervisors should strive to refine end-trim practices and emphasize the importance of the end-trim decision.

- Usually, spike knots, fuzzy grain, and badly distorted or cross-grain should be removed at the crosscut saw in a crosscut-first rough mill. These defects affect much of the width of the board and, in the case of spike knots and cross-grain, can cause structural failures in the piece as it goes through subsequent machining operations such as the moulder. It is more difficult to evaluate spike knots and fuzzy grain when flow through the marker station is fast paced. It is common for strip markers to process 20,000 lineal feet during an 8-hour shift compared to a manual chopping operation that more typically processes 5,000 or fewer lineal feet. It also is difficult to detect tiny defects when there is a fast-paced flow rate of boards/strips through the marker station. Presurfacing lumber to make defects more visible before the crosscut or ripsaw increases yield and reduces the number of rejected parts.
- Mark defects so the marks touch the edge of the defect. There are occasions when even minor errors in mark placement (e.g., ¼ inch) can result in a significant loss in yield. For example, a longer part that would fit between defects is not recovered because the marks indicated that available clear length was insufficient.
- The average mark placement error measured at three rough mills was about 1.7 inches (Maness and Wong 2002, Fig. 30). On a 10-foot board, this means a yield loss of 1.4 percent per defect mark if the misplaced marks are placed further from the defects than is optimal. This is typical since markers are particularly conscious of the need to minimize the number of rejected parts. It has been observed that a new marker often will mark closer to defects than will an experienced marker who processes lumber and strips at a faster pace than the novice.
- Removing boards/strips from delivery conveyors, forwarding boards/strips onto the saw's infeed, and distributing boards between marker stations should not be time- or energy-consuming tasks for markers -- their time and attention should be oriented toward the marking task. Deep-piled station infeed conveyors slow the rate at which a marker can refill his/her marking table (Fig. 31). The marker's job is made even more difficult if he/she must sort through or remove waste edgings produced at the ripsaw. Modifications in workstation design often improve both the quality and productivity of the defect-marking task.

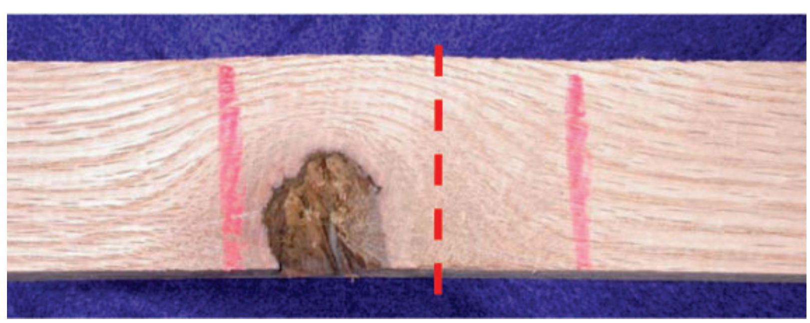

Figure 30.—The mark to the right of this defect is more distant from the defect than it needs to be in most cases. The dashed red line superimposed on the picture shows a better position for the mark that will still remove most of the cross-grain but not waste as much wood.

Figure 31.—Boards piled up at marker station cause the person doing the marking to spend time and energy straightening them out before they can be pulled into marking position.

Marking Accuracy

In a study of defect recognition and marking performance at six rough mills, there were significant differences in accuracy among defect markers (Maness and Wong 2002). Lumber grade, the marker station's throughput rate, and the complexity of the cutting bill affect accuracy. Poor accuracy (20 to 30 percent error rate) was associated with mills that process lower grade lumber at higher speeds using more complex and variable cutting requirements (Fig. 32). Good marking accuracy (<10 percent error rate) was associated with mills processing higher grade lumber at a slower production rate through the marker station.

Markers in the same rough mill seem to have relatively similar defect identification scores compared to markers from different mills. Correct recall of the number, location, and types of defects on boards presented to two operators at each of three rough mills showed variations in defect detection scores of 2.5, 4.5, and 7.0 percent between operators within each mill (Huber et al. 1985). Potential lumber/strip markers can have visual perception difficulties (that may be correctable) that diminish the quality of their marking decisions. Regular eye exams, quality checks, and periodic training can improve marking accuracy as can ensuring that the station has sufficient lighting, particularly where mirrors are used.

Important Characteristics of the Optimizing Saw

Characteristics of the semiautomatic optimizing crosscut/chop saw are just as important as the ability of the defect marker in achieving the saw's full potential. Buyers of optimizing saws rated 13 saw attributes that are equally important: cut-to-length accuracy (typical accuracy in 2003 is ± 1/32 inch), ease of clearing jammed boards, length measuring design, mark detection design, overall production speed, waste handling, sorting accuracy, ease of use, board drive design, maintenance reliability, service reliability, warranties and assurances, and degree of damage to wood products (North Carolina State University 1996). Systems with the highest feed speeds typically have the largest scanning error rates (Maness and Wong 2002). Also, there is an inverse relationship between the number of grade marks missed by the lumber/strip scanner and the number of phantom or nonexistent marks that are recognized; it is difficult to find and maintain the scanner sensitivity adjustment at the optimal setting (Maness and Wong 2002).

Several other important features that can vary among optimizing saws include: a) the part priority modes of the saw; b) whether the saw can center parts in clear areas; c) whether the saw can be set to automatically end trim

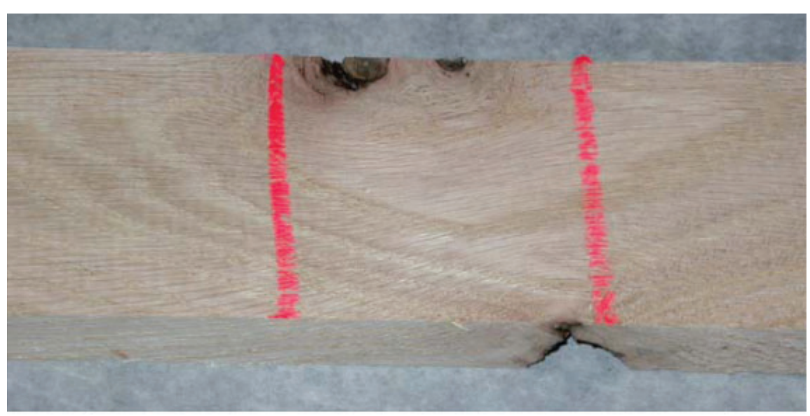

Figure 32.—The right-side mark on this strip appears to be mislocated by a very short distance such that the hole on the edge and bottom of the strip may not be completely removed by the chop saw. The use of a mirror can help the operator better judge the extent of the underside defect.

lumber/strips by a given amount on the leading end; d) whether the saw can cut longer, lower grade but higher value parts by combining two sections of the marked board; and e) whether the saw can automatically place new parts on the saw's computer when a part-quantity requirement has been achieved. Each of these features, if present, should have a positive impact on yield but many are misused by markers/operators/supervisors who haven't received adequate training.

Evaluate Sawing Performance Regularly

Machine (saw and scanner) characteristics and problems must be understood and tracked on a daily basis by mill personnel (supervisors, lead operators, maintenance personnel, and defect markers) to optimize the performance of the existing system. An obvious and important conclusion of the rough mill study was that there are many sawing system errors that go undetected (Maness and Wong 2002). Quality control tests of system accuracy should be conducted daily. Measures that should be tracked include grade marks missed by scanner, phantom marks created by scanner, the percentage of pieces cut too short and too long (Maness and Wong 2002), and part rejection rates.

Defect marking personnel should be responsible for many of these measurements so they feel ownership of the quality of the system's products and learn to be vigilant to more common problems so they can recognize those situations in which they are more likely to occur.

A maintenance specialist and the rough-mill supervisor or assistant supervisor should have an extensive knowledge of the optimizing saw and know how to diagnose and repair problems. The markers also should be given training in troubleshooting problems. When you purchase a new optimizing saw, the saw's supplier will offer training sessions — take advantage of every such training opportunity since the payback will be large.

The most common problems that are encountered with optimizing saws include:

- Miscut parts in which the first part cut per board or strip is the wrong size caused by belt or other form of mechanical slippage such as crayon buildup on the feed rollers
- Miscut parts in which a given part is consistently too long or too short due to miscalibration of the computer's encoder
- Sawcuts that are offset from crayon marks by a consistent distance along the length of the board or strip caused by the camera being the wrong distance from the wood piece
- Sawcuts that are offset from crayon marks by a nonuniform distance along the length of the board or strip due to mechanical slippage or poor calibration of the camera
- Missed crayon marks due to a dirty or blocked camera lens
- Missed marks due to low quality crayon marks caused by rough lumber or crayons that are very old and have been overexposed to the sun. New fluorescent spray systems may eliminate this problem.

The Greatest Opportunity… and Greatest Current Failing

The greatest opportunity to improve the performance of the automated optimizing crosscut or chop saw lies in using the simulation capacity of the saw's computer. The simulation software included with the saw can evaluate different cutting orders using different lumber grades and/or saw parameters. Employees who use the simulation software will become valued experts with their understanding of how part production and yield respond to changes in the cutting bill and the part values input into the saw's computer. The consistency attributed to the optimizing saw often is lost when personnel with limited expertise adjust the value settings for different part lengths to emphasize production of a particular length. The resulting impact on yield and part-length recovery is seldom understood. By using data on board/strip lengths and widths measured by the scanner(s) located on the saw's infeed, valid simulations can be conducted and supplier-based differences in lengths and widths can be determined. The size data is critical information that should be used to plan production for maximum yield and profit.

Train and Retrain

Many optimizing saw markers/operators trained on saw setup, marking specifications, and process control forget what they have learned by the time the new equipment is installed in the rough mill. Also, new operators often are not trained on more complex operational strategies and the higher level functions of the optimizing saw, or they are unable to absorb this information. Thus, it is important to conduct retraining sessions even with experienced operators in which the more detailed and complex strategies and features of the optimizing system are highlighted.

Maintain Balance and Focus

In answer to the question "What distinguishes your best strip marker from an inexperienced strip marker?", the typical response is, "productivity through the marking station." It is common for rough-mill managers to conduct in-depth feasibility studies and justifications that include yield standards before investing in optimizing technologies but quickly shift focus to production rates after installation. A combined emphasis on lumber yield, part quality, and mill productivity needs to be in place if a rough mill is going to realize the benefits projected in the feasibility analysis.

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SECTION 3:
THE PANEL LAY-UP, FINGERJOINTING, AND MOULDING OPERATIONS

Panel Lay-up Operations

Most wide furniture parts, such as table tops and bed or chest panels, utilize edge-glued panels in their product. These panels can be constructed either of fixed width or random width components, although use of the latter is more common. The panel lay-up operation as a function of the rough mill consists of manufacturing a gluable edge, color matching, grain matching, and panel sizing.

Making a Gluable Edge

The first and most important step in panel lay-up is producing a smooth edge that will perform successfully in a glue line. Poor machining or poor moisture control can result in a surface that will cause glue bond failure. It is common practice that the edge to be glued is produced either with a straight line ripsaw or with a gang saw. Regardless of which saw type is used, edges must be:

- Surfaced smoothly and straight from end to end
- Square with the part face and back
- Parallel with the opposite edge
- Free of loose fibers
- Not burnished by sawing

Having a well maintained rip or gang saw is crucial to forming a surface suitable for a glue joint. Improper saw lead can result in a rough surface characterized by deep arcs left by the saw blade. Ideally, the edge to be glued should be straight from end to end so adjacent strips touch completely along their length. An opening along the glue joint may indicate a problem with the feed chain tracking. Open glue joints or gaps at the ends are unacceptable. A gap that occurs at mid-length between two adjacent strips is a "hollow joint" that may be acceptable if slight and can be forced closed by the subsequent gluing process. Forcing the hollow joint closed will build stresses into the glue line proportional to the amount of force used, and thus the width of the gap allowed should be limited. The rule of thumb for the allowable hollow joint gap at mid-length of two freshly sawn 40-inch pieces is 0.005 inch. Although wider gaps can be forced together with sufficient pressure, the resulting glue joint may experience early failure. Joint preparation is most critical with continuous flow glue machines because accumulated errors in width will be too large for this process to close. The same degree of error is better tolerated with the more forgiving clamp carrier.

The saw alignment must be perpendicular to the saw bed (anvil) so the part edges are square with the face and back. Out-of-square edges will cause gaps between parts when they are assembled for gluing. These gaps often are forced closed by the use of excessive pressure in the press that can crush the wood cells and squeeze too much glue out of the "high spot." At the same time, inadequate pressure is applied to the "low spot," resulting in too large of a gap for the formation of a high strength bond.

Planed lumber works best to provide stability as the part travels through the ripsaw. Rough, unplaned lumber may rock and roll in the ripsaw, resulting in an uneven edge and possibly kicking back either the part or the ripped edging strip.

Opposite edges of the part that are to be glued should be parallel. Occasionally an operation will try to improve yield by sawing without the fence, producing an edge that is at an angle to the opposite edge. The resulting wedge shaped parts may not be stable in clamps and it is difficult to apply uniform pressure across the glue joint.

Sharp saw blades should be maintained at the ripsaw. A dull saw will generate excessive heat that may visibly burn or scorch the wood. A less obvious problem is the dull saw may burnish or polish the wood. The sawn surface may have a lustrous sheen but does not appear burned. However, glue cannot wet and penetrate this inactivated surface and as a result, a poor glue joint will form.

A dull saw also can accentuate inherent wood problems such as tension wood, an abnormal growth response in leaning hardwoods. Cutting tension wood with a dull saw often will result in fuzzy grain, wood fibers that are not completely severed during the cutting process. These partially attached fibers can interfere with panel assembly resulting in a poor adhesive bond. Problems related to fuzzy grain are greater if the wood has a high moisture content.

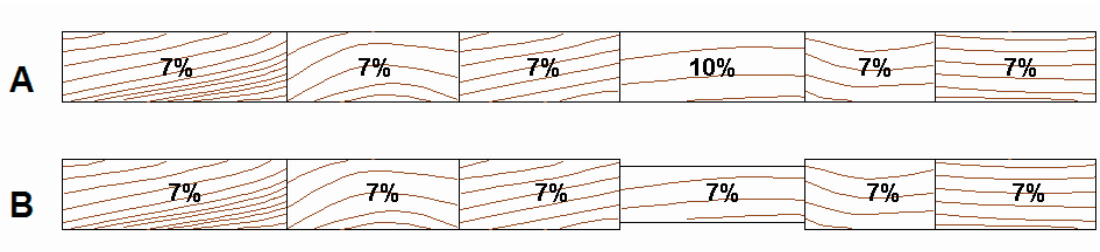

Figure 33.—Development of sunken board in a panel containing one board of high moisture content. A) Panel and moisture content of components as glued, pressed, and surfaced; B) Panel after high moisture content part has reached equilibrium, resulting in shrinkage of that part. Note the exaggerated shrinkage shown.

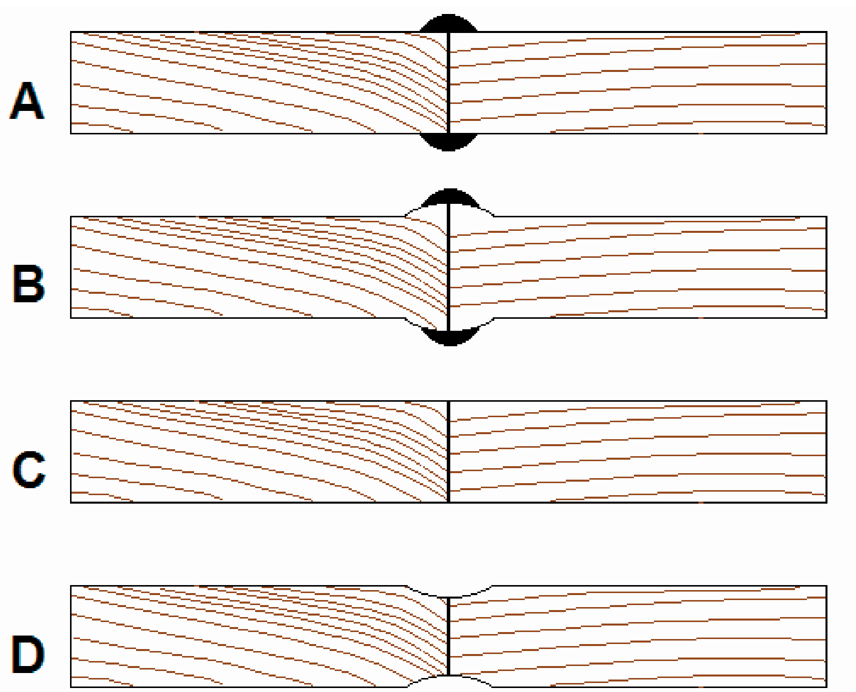

Figure 34.—A plausible cause of sunken joints in panels: A) A bead of adhesive is squeezed out over the glue line when pressure is applied; B) Moisture in the adhesive swells the wood near the glue line after pressing; C) If the panel is surfaced before it has conditioned to a uniform moisture content, the swollen wood near the glue line is removed; D) As wood near the glue line continues to dry and shrink, a slight depression along the length of the glue line develops.

Common Gluing Problems

Machining may initially produce a gluable edge, but moisture content changes before or after the wood is glued can result in an unacceptable glue line or glued product. Many, if not most of the problems with edge-glued panels originate with changes in moisture content. Consider the description and cure for several of the more common gluing problems.

Sunken or raised board. This occurs when boards of varying moisture content are glued into panels and then surfaced flat. A high moisture content board eventually will lose moisture and shrink to a smaller thickness than adjacent boards that were at a lower moisture content initially (Fig. 33). To avoid this, boards should be at the same moisture content, or within 2 percent, when glued.

Sunken joints. Water from the glue swells the wood adjacent to the glue line. Planing the panel before the moisture has had time to distribute throughout the panel will remove more wood near the glue line than further away. Although the surface appears smooth immediately after planing, future movement of moisture away from the glue line to a uniform distribution will cause wood shrinkage near the glue line, leaving a shallow channel or sunken joint (Fig. 34). To correct this, before being surfaced panels should have a conditioning period, the length of which depends on thickness, temperature, and the end product.

Figure 35.—An example of a panel in which the component parts are poorly matched in terms of color and grain pattern.

Open joints. Assuming the wood is at the correct moisture content initially, open joints often are caused by moisture content changes that occur in the machined wood part during delays between machining and gluing. Parts to be glued are typically dead piled, leaving the end grain exposed. Changes in moisture content and dimension occur more rapidly (about 5 to 10 times faster) on end grain surfaces than other surfaces. An overnight delay between machining and gluing can result in moisture pickup (or loss) within parts. This problem occurs more frequently in winter when the relative humidity in the rough mill is lower, resulting in greater dimensional changes in the ends of the cut parts. Extra pressure at the gluing operation may be required to close the visible gaps that result. Although the gap is temporarily closed, it is likely to open with future moisture changes. To avoid this situation, adopt the policy that what is sawn today should be glued today. Such practice also will minimize contamination by wood dust, dirt, or oil. In addition, yield losses from moisture problems can be lessened if the equilibrium moisture content in the part storage room is carefully controlled.

Cupped panels. Cupped panels can arise from differences in tangential and radial shrinkage. Boards that are not perfectly flatsawn or quartersawn will not maintain perpendicular edges with changes in moisture content. Although this may be very slight in each board, gluing several similar boards together can result in a warped panel. To prevent this, the direction of annual rings in adjacent boards should be alternated to maintain panel stability.

Grain Matching

Concerns about panel warping often bring limits to the maximum part width allowed in the panel. Many operations limit the width of the individual component to 3 or 4 inches to minimize the individual strip's ability to cup the panel. Unfortunately, there is often no effort to alternate the annual rings (as described above). The net result is that wide boards are ripped and then simply glued back into their original orientation with no increase in dimensional stability, but with a lot of added costs. Anecdotal evidence from some operations suggests that for some species and products, the width of strip that can be safely incorporated into a panel can be increased if the initial moisture content matches the end-use moisture content.

Color Matching

A panel constructed of components of similar color is more attractive and has a higher value than a panel constructed of randomly placed parts. For some operations, the appearance requirement of the end product necessitates the color matching of component panel parts. Color matching may be as simple as separating heartwood from sapwood, or it may involve the careful matching of various shades of color and grain appearance (Fig. 35). Human operators are capable of manually sorting parts into as many as four color groups. Possible limitations include: 1) differences in color perception ability between operators, and 2) reduced accuracy caused by operator fatigue as the day wears on. Recently, equipment has been developed to automate the color sorting process and alleviate the shortcomings

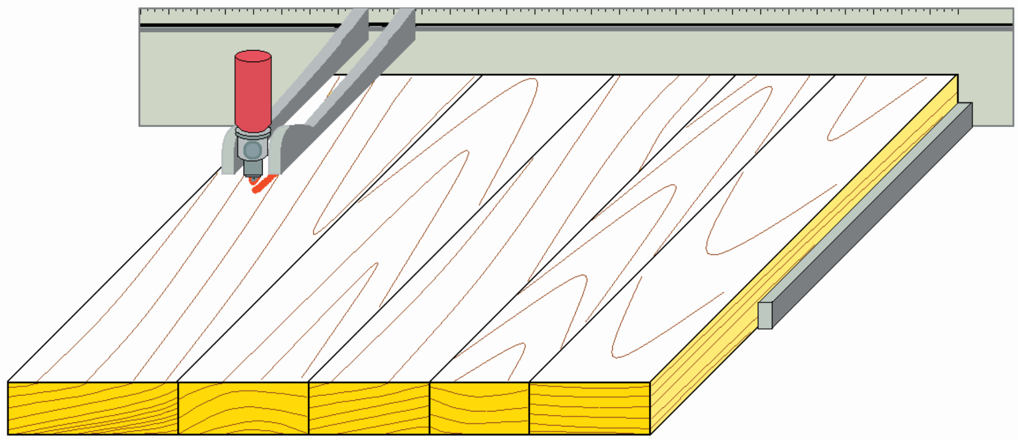

Figure 36.—A paint striper marking the desired panel width.

of manual color sorting. With automated color sorting, the challenge is to ensure that even the “off” color components are placed in a marketable panel product.

Panel Sizing

Panel sizing often is overlooked or done poorly. Too often panels are built ½ to ¾ inches wider than required. It is important to remember that ½ inch of waste in a 25-inch wide panel represents 2 percent of the panel yield. Assembled panels should be within 1/8 inch of the rough panel dimension. There are at least four techniques to minimize waste generated during panel lay-up:

1. Optimize your panel lay-up with automation. Available technology will measure the widths of several boards and automatically select the best combination of those available to lay-up a panel of desired width. Although it has the ability to build a panel to within 1/8 inch of the target panel width, some operations find that they need to increase the tolerance if they only produce a limited number of fixed-width parts (perhaps with a fixed-width gang ripsaw). Also note that to obtain color matched panels when using an automated panel lay-up machine, color presorting must be performed and thus a more complex parts inventory system will be required.

2. A template might be used to limit the size of the panel during lay-up. A wide variety of templates may be devised. A marking system can be used by the ripsaw tail person who uses a template and a magic marker or paint striper to indicate on the board where it should be cut (Fig. 36). The board then is passed to the ripsaw operator for cutting. Alternatively, some operations utilize a two-sided partition that boxes the panels as they are placed on the cart or pallet. One side of the partition is marked to indicate the target panel width. The tail person and the ripsaw operator communicate by hand signals to indicate how much width is needed to finish out a panel.

3. Use a wide part as the final edge when laying up the panel, and then size the assembled (but not glued) panel using either a matching saw or a straight-line, chain fed ripsaw equipped with a panel gauge. The trimmed overage then can be used as the first piece of the next panel (Fig. 37).

4. Rerip the glued panels and save the trimmed strips for later use. The cautionary note is that strips must actually be saved and reused to accrue a yield benefit. In addition, the increased costs associated with inventory tracking and material handling must be less than the yield benefit realized.

With sawmills improving their board thickness tolerances, rough mills now have thinner stock to use for panel lay-up. As a result, manufactured panels may be too thin, resulting in losses at the finish planer. Additional care in panel lay-up and lumber manufacture will be required to prevent these panel losses.

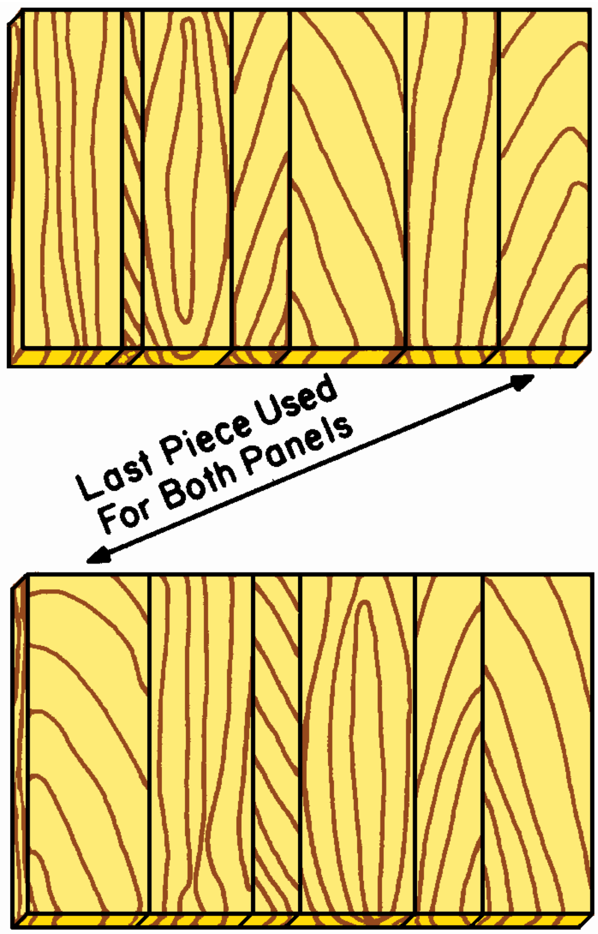

Figure 37.—Using overage from preceding panel for first piece in next panel.

The ability to manufacture random-width parts for glued panels can increase rough mill yield by about 5 percent compared to fixed-width only part production. Many factors, including lumber and part grade, fixed part size, and panel specifications, can dramatically influence the actual yield increase each plant may attribute to using random-width parts in panels. Higher yields are accrued when the moisture content of the lumber and parts is carefully controlled. It is important to keep in mind that one wet piece of lumber can affect multiple panels. Moisture related problems are the biggest cause of diminished yields in panel operations.

Improving Rough Mill Yield by Fingerjointing

Fingerjointing (FJ) is the process of joining short pieces of stock (FJ blocks) of the same width into longer pieces (FJ blanks). The hardwood industry uses FJ blanks to produce mouldings, interior furniture parts, substrates, and flooring. Fingerjointing potentially can help a manufacturer increase rough mill yield by allowing chop saw operators to cut random lengths along with the fixed lengths from strips. Cutting only fixed lengths dramatically reduces the chop saw operator's ability to utilize the entire amount of clear wood between defects. Several manufacturers have begun fingerjointing and have reported as much as a 10 percent improvement in yield. However, before buying a fingerjointer, a manufacturer should consider markets, production levels, and the quality of the blocks needed for the fingerjointing process.

Fingerjointed Product Markets

In 2003, the strongest FJ product market in the hardwood industry is for poplar moulding blanks. Unfortunately, there is only a limited market for FJ stock in other species. Oak is beginning to be used for FJ flooring and is occasionally used in mouldings and exterior furniture parts. Hard maple is sometimes used for stools, bench tops, and bowling alleys. The rest of the FJ market is comprised mostly of interior furniture parts using species such as soft maple, sycamore, and aspen. The market for interior furniture parts is small and growing slowly. The furniture industry has been slow to use FJ stock on a large scale for interior parts for fear that the FJ material is not as strong as solid material. Only a few manufacturers are using FJ stock for exterior parts because consumers have been slow to accept the use of FJ material for exposed parts.

Fingerjointing Production Considerations

Production planning should be considered before a company purchases a fingerjointer to increase yield. Some of these machines can run as much as 50,000 to 60,000 lineal feet per 8-hour shift, while others may only run 3,000 or 4,000 lineal feet per 8-hour shift. Assuming the average width of the blocks are 3 inches, a FJ machine that will produce 60,000 lineal feet per 8-hour shift will consume 15,000 board feet of blocks during a shift. If the production of FJ blocks raises yield from 55 to 65 percent, a rough mill that produces 30,000 board feet of net parts per day will realize a daily net gain of 5,400 board feet. If the block volume generated in-house was the entire FJ input, the utilization rate for a high production FJ machine would be only 36 percent. To fully utilize a high production FJ machine, the rough mill may need to supplement their own FJ blocks with outside FJ blocks (Fig. 38) or move some of the production from current products to FJ products. Alternatively, the company may buy a machine that has lower production levels. Low production machines usually cost less, which would better fit the capital investment budgets of most manufacturers.

Figure 38.—Fingerjoint blocks are recovered wood sections that are too short to meet length requirements specified in the cutting bill.

Fingerjointers are made in a variety of configurations - some machine the joint across the tangential surface of the stock while others machine the joint across the radial surface. Each design is used for different finish criteria and one design may be more acceptable than the other based on aesthetics in different parts of the world.

The design of the FJ tooling needs to be considered. Tooling can be purchased to produce joints that range from as short as ¼ inch to as long as ¾. The blocks being fed into the fingerjointer are trimmed to square them before the finger is cut in each end. The amount of stock removed for the squaring process and the length of the joint will determine how much loss occurs during machining.

The amount of loss can be calculated:

FJ yield loss = [(trim allowance * 2 ends) + joint length] / average block length.

Figure 39.—Two sets of fingerjoint blanks that show how joint length can vary.

Figure 40.—Nonparallel edges and unequal block widths can lead to offset fingerjoints that generally must be rejected.

For example, removing 3/16 inch from both ends in blocks that have a 3/8-inch joint length with an average block length of 16 inches, the yield loss due to FJ machining would be calculated as:

FJ yield loss = [(3/16 inch * 2) + 3/8 inch] / 16 inches = 4.7% loss

Some manufactures find it difficult to change to a smaller joint length and hold the same quality specifications. Usually, the longer the joint length, the easier it becomes to properly join the pieces together (Fig 39).

Several companies are selling their shorts (generally stock that is less than 12 inches) to FJ manufacturers. This benefits both companies. The seller can improve yield while not incurring the overhead costs of a new machine or the necessity of developing new markets. On the other hand, the buyer usually pays less for the stock than if he were to produce it in-house. There are a few companies that are hiring other manufacturers to fingerjoint their blocks together so they don't have to buy a machine. These companies then incorporate the fingerjointed parts into their products.

Fingerjoint Block Requirements

The edges of the blocks that are to be fingerjointed must be parallel and the same width at each end. FJ blocks that do not have parallel edges will result in offsets from one piece to the next when they are fingerjointed together (Fig. 40). Offsets make machining the FJ blanks through other machines (e.g., moulders) difficult to do without generating rejects. A company interested in producing FJ blocks should consider that straight-line ripsaws do not do as good a job ripping stock parallel as do gang ripsaws. If the stock is going to be straight-line ripped, great care must be taken to make sure these blocks are ripped correctly. Thickness also is a concern. Most fingerjointers only have a thickness tolerance of about 1/16 inch (.0625 inch). Any FJ blocks (a.k.a. shorts) outside this tolerance are very difficult, if not impossible, to fingerjoint correctly. In order to meet thickness requirements, a manufacturer must have a rough surfacer capable of controlling stock thickness within a 1/16-inch allowance. Thickness and width requirements are so critical that a company with a newly installed FJ operation might have to change its entire production line and equipment if not able to meet these standards.

Fingerjointing can increase the yield of most rough mills, but before purchasing a fingerjointer a great deal of planning and research are needed to make sure that the FJ investment achieves the desired result.

Figure 41.—A manual feed, mid-size, four-head moulder.

Improving Rough Mill Yield at the Moulder

An estimated 2 to 5 percent of material is lost during production at the moulder. These losses have a major impact on the yield and raise the overall cost of materials. These losses, because they are smaller than losses at the primary rough mill cutting stations, are mostly overlooked by rough mill managers and personnel. Losses at the moulder are almost always related to one of the following:

- moulder allowance
- the process of setting up the machine
- defects that occur during the machining process
- natural defects where the stock was not properly fed into the machine
- defects not properly removed in the rough mill

While it is very unlikely that a 0 percent rejection rate could ever be achieved, a meager 1 percent improvement in recovery at the moulder of a firm that produces $6 million annually in sales could lead to a net savings approaching $60,000 per year. When a part is rejected at the moulder, it is almost impossible to reshape or cut the material into another product, so the loss is usually total.

Moulder Allowance

Perhaps the easiest way to decrease waste at the moulder is to reduce moulder allowance. Moulder allowance is the amount of material left on the edges of the stock from the rough mill for sizing purposes at the moulder. For many years, the industry standard has been ¼ inch. In recent years, several companies have started using as little as 1/8 inch. Part of the reason some companies have been successful using less allowance is because of the increase in gang ripping. A gang ripsaw produces a more uniform width than straight line ripping, thus requiring less stock for the moulder. A general rule of thumb when gang ripping is to use a 3/16-inch allowance for lengths longer than 36 inches and 1/8 inch when moulding pieces shorter than 36 inches. Some factories may find that they can use an 1/8-inch allowance on pieces longer than 36 inch in some instances. Take heed! An increase in the number of rejects generated should not be tolerated for the sake of reducing moulder allowance.

Setup Piece Losses

Another material saving opportunity is to eliminate pieces lost during setup. Traditionally, rough mills have been satisfied losing a certain amount of material during the setup portion of moulder operations. However, in today's industry new technologies such as mechanical/digital readouts and instruments that measure a tool's cutting circle are available on new machines. Upgrades (retrofits) for older machines also are available. By using these devices, most, if not all, of the setup-related losses can be eliminated. This process, referred to by the industry as "axial constant," works by predetermining the location of the spindles on the moulder prior to production and manufacturing of knives.

Those companies that chose not to use a system like this should work to reduce the cost incurred in setup operations by using inexpensive material (e.g., non-clear pieces) for their setup pieces. This can have a major impact on material cost in a plant.

Machining Defects

In normal moulder operations, there can be and normally are losses due to the machining process. These losses are generally referred to as rejects. Again, while a zero rejection rate may be impossible to achieve, machining defects can be reduced so they do not have a significant impact on yield. Machining defects, their causes, and typical cures are:

- Raised grain—The roughened surface in wood characterized by the harder summerwood raised above the softer springwood, but not torn from it. This happens when the knives are too dull to properly cut the fibers. The fibers of the summerwood are forced down into the springwood by the cutting action of the knives causing the springwood to be compressed. These fibers may not decompress until there is a slight change in the moisture content of the wood, causing the springwood to push the latewood above the surface of the stock. This defect is more prevalent in certain species like basswood and aspen. If this material already has been installed and/or finished when the raised grain appears, it can ve very expensive for the manufacturer to replace. This defect is less likely to occur in lumber with 6 to 10 percent moisture content; also, keeping the knives sharp will help prevent this defect from occurring.

- Fuzzy grain—Loosened ends of fibers that are raised above the surface of the stock after machining. This usually happens when running wet wood. The best circumstance would be to mould stock from 8 to 10 percent moisture content. Keeping the knives sharp and increasing the hook angle and the sharpness angle on the knives can greatly improve the situation, particularly if you are having to machine stock wetter than what is ideal.

- Tearout or chipped grain—Characterized by pits or voids below the plane of cut, resulting from the fibers being pulled from the wood instead of being cut. The defect occurs more frequently around knots, grain swirls, and stock where the average moisture content is below 7 percent. Making the hook and sharpness angles more blunt, keeping the knives sharp, feeding the stock with the direction of the grain, moving chipbreakers closer to the cutting circle, taking a smaller cut, slowing down the feed rate, and installing the knives in the cutterhead as close to the circumference of the head as possible can reduce the frequency that this defect occurs.

- Chip bruising or chip marks—Characterized by shallow dents in the surface of the stock. This defect is caused from chips that are lying on the end of the knife tip being embedded in the finished surface of the stock by the rotating cutterhead, resulting in a dent. The most effective way to reduce or eliminate this defect is to provide better vacuum from the dust system so chips are sucked away from the knife tip. Sharpening the knives and changing the chip size/type by increasing or decreasing the feed and the depth of cut also can have a positive effect.

- Glazed surface—Characterized by burnishing the surface of the stock to the point that it will not finish properly. This is caused from having too many knives in the finished cut. This usually is a problem for jointed machines where the machine is running at too slow of a feed rate. Increasing feed rate, removing knives from the cut, or not jointing the knives can fix this. Sharpening the knives also can help.

- Burn marks—Characterized by an extreme case of glazing where there is so much heat generated by the knives that it actually burns the fibers on the surface of the material. This is normally caused from the stock not being fed continually through the machine. This defect also can occur on hardwoods like oak and maple during normal operation. Increasing feed rate, grinding relief angle on knives, removing knives from the cut, and sharpening the knives can eliminate this defect. It may take one or more of these actions to completely remove the defect.

- Chatter—Characterized by inconsistent knife marks. This is usually caused from the stock improperly held as it is fed through the machine; however, it also can be due to spindle bearing wear, loose dovetail slides, or unbalanced cutting tools. Normally, repositioning the pressure shoe and chip breaker so that there is the right amount of consistent pressure across the work piece can eliminate this defect.

- Snipe—Characterized by a deep cut a few inches from the end of the stock on the top, bottom, or edges of the part. A snipe on the inside edge of the stock occurs when the right side of the cutterhead is not positioned tangentially to the outfeed fence or the fence is not set close enough to the cutterhead. A snipe on the outside edge of the stock occurs when the chip breaker is not close enough to the cutterhead or an inadequate amount of pressure is applied by the chipbreaker. The guide fence also could be set out of position. A snipe on the top of the stock on the front end usually is caused by the pressure shoe or chipbreaker being positioned too far from the cutterhead, or the chipbreaker not touching the surface of the stock. A snipe on the bottom is a result of the cutterhead not positioned tangentially to the outfeed table or the outfeed table not positioned close enough to the cutting circle of the head. All fences and hold-downs should be set to within 1/8 inch of the cutting circle.

A rejected load of mouldings can create more anxiety in a woodworking plant than any other yield-related issue. One rejected load can wipe away an entire year of profits for some companies. In order to prevent this situation, all tolerances and specifications should be explicitly written on the purchase orders and then precisely followed by all moulder personnel. There are several associations such as the Wood Components Manufacturers Association and the Wood Moulding & Millwork Producers Association, that publish standards for buying and selling moulded products. The number of knife marks per inch (KMPI) also should be specified on every purchase order where moulder products are sold. These marks can be counted by measuring an inch on a piece of moulded stock and then counting the number of marks contained within the inch. There also is a formula for calculating the number of knife marks per inch that will be created at a certain feed rate.

$$\text{KMPI} = \frac{(\text{Spindle rpm}) * (\text{\# knives in the finish cut})}{(\text{12 inches per foot}) * (\text{feed rate in feet per minute})}$$

Example:

$$16.7\ (\text{KMPI}) = \frac{(\text{6000 rpm}) * (\text{4 knives in the finish cut})}{(\text{12 inches per foot}) * (\text{120 feet per minute})}$$

Naturally Occurring Defects

There also may be defects left in the stock from the rough mill that require the parts to be oriented in a certain way when they are fed through the moulder. For instance, parts that may specify C1F with a sound back can have defects left in them from the cutting operations that are acceptable only on one surface. Due to the profile required, the parts may have to be turned a particular way in order to get the clear side on the correct surface. Manufacturers who are running jointed machines (running high speed) and manufacturers who run shorter stock (less than 48 inches) may not have time to orient these parts properly at normal operating speeds. At this stage in the manufacturing, yield should not be sacrificed for production. All effort should be given to either have the parts oriented properly prior to moulder operations or provide extra personnel at the moulder when production time is a concern.

Figure 42.—A moulded piece in which a hidden defect in the wood was exposed by the moulder machining process causing the piece to be rejected.

Defects Not Properly Removed in the Rough Mill

Defects that should have been removed at the crosscut and/or ripsaw in the rough mill but were not, either because they were not visible (e.g., interior defects), not seen (e.g., the operator did not flip over the wood piece to view its underside), or not completely removed by the defecting cut (i.e., miscut) may lead to additional losses at the moulder (Fig. 42).

Again, the rejection rate at the moulder probably can never be zero, however, significant improvement normally can be made. In most woodworking plants, materials account for 45 percent or more of the cost of operations, so a small recovery improvement at the moulder can significantly reduce production costs in a plant.

Mitchell, Philip H.; Wiedenbeck, Jan; Ammerman, Bobby. 2005. **Rough Mill Improvement Guide for Managers and Supervisors.** Gen. Tech. Rep. NE-329. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 60 p.

Wood products manufacturers require an efficient recovery of product from lumber to remain profitable. A company's ability to obtain the best yield in lumber cut-up operations (i.e., the rough mill) varies according to the raw material, product, processing equipment, processing environment, and knowledge and skill of the rough mill's employees. This book discusses several key principles that can help manufacturers understand and solve yield and production problems. This publication is inspired by the 1981 publication "Rough Mill Operator's Guide" written by Edward K. Pepke and Michael J. Kroon. Computer-based technologies and new rough mill layouts and equipment are prevalent in today's rough mills, therefore, they are given considerable emphasis in this contemporary version of the Pepke-Kroon guide.

Keywords: rough mill; yield; efficiency; training; hardwood; rip; crosscut

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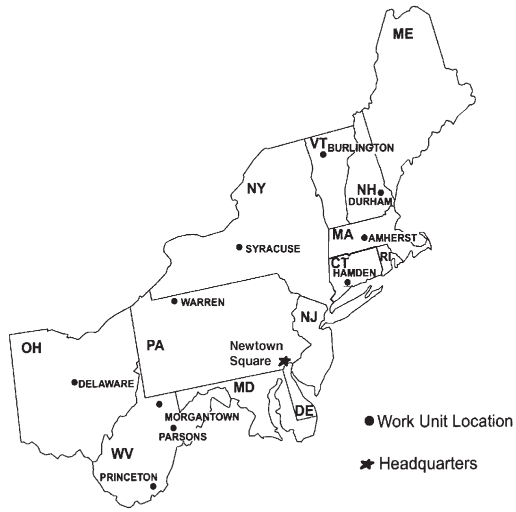

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