LUMBER SIZE CONTROL

Terence D. Brown
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[Graph showing distribution of lumber thickness.]
INTRODUCTION TO LUMBER SIZE CONTROL

Lumber size control is a systematic procedure that, properly carried out, identifies and locates problems occurring in sawing-machine centers, sawing systems, or setworks systems. It is a key component of all good lumber quality-control programs. In both the large-log sawmill, where board feet may sometimes be sacrificed to recover grade, and in the small-log sawmill, where boards must be sawn to the smallest green target size possible without losing grade from planer skip or undersizing, a size-control program can optimize decisions on breakdown, edging, and trimming, and is essential for maximizing board-foot recovery (Brown 1982).

The information obtained from a size-control program is a powerful management and production-control tool. As the specific mechanical condition of a sawing machine center becomes apparent, maintenance priorities can be more easily determined. It is easier to attach dollar value to contemplated machine improvements when size-control information is the basis for decision making than when it is not; and when modernization of equipment is being planned, the results of lumber size analysis are valuable for setting specifications for sawing equipment.

The goal of a size-control program is to minimize the sum of kerf, sawing variation, and roughness (Bennett 1974). With a good program, the effect of minor changes in saw kerf or feed speed can be immediately determined. A mill manager who minimizes the amount of wood cut per sawline without degrading the material will maximize the dollar return. Companies that have implemented programs and reduced rough green target size have realized value increases from $100,000 to $300,000—sometimes more—per year.

Developing an effective size-control program requires hard work, understanding, and patience. This publication is designed to help. It gives, first, the theory behind the practice and the necessary initial procedures; and, second, a step-by-step account of how to establish a program.

PROGRAM PRELIMINARIES

A size-control program may end in failure if the proper initial steps are not taken, especially if statistical methods are to be used. A quality-control supervisor should be selected who understands the basic concepts of size control as outlined in this publication.

All sawing-machine and quality-control personnel must begin to think in terms of decimals. If, for example, the edger is cutting within 1/32 inch (+) of target, workers should know that the standard deviation is 0.015 inches. It may be helpful to give results in both fractions and decimal form for a time. A card with fractions and their decimal equivalents is a good reference.

**Useful Decimal Equivalents**

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Decimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/32</td>
<td>0.03</td>
</tr>
<tr>
<td>1/16</td>
<td>0.06</td>
</tr>
<tr>
<td>3/32</td>
<td>0.09</td>
</tr>
<tr>
<td>1/8</td>
<td>0.13</td>
</tr>
<tr>
<td>5/32</td>
<td>0.16</td>
</tr>
<tr>
<td>3/16</td>
<td>0.19</td>
</tr>
<tr>
<td>7/32</td>
<td>0.22</td>
</tr>
<tr>
<td>1/4</td>
<td>0.25</td>
</tr>
<tr>
<td>9/32</td>
<td>0.28</td>
</tr>
<tr>
<td>5/16</td>
<td>0.31</td>
</tr>
<tr>
<td>11/32</td>
<td>0.34</td>
</tr>
<tr>
<td>3/8</td>
<td>0.38</td>
</tr>
<tr>
<td>13/32</td>
<td>0.41</td>
</tr>
<tr>
<td>7/16</td>
<td>0.44</td>
</tr>
<tr>
<td>15/32</td>
<td>0.47</td>
</tr>
<tr>
<td>1/2</td>
<td>0.50</td>
</tr>
</tbody>
</table>

17/32 — 0.53
9/16 — 0.56
19/32 — 0.59
5/8 — 0.63
21/32 — 0.66
11/16 — 0.69
23/32 — 0.72
3/4 — 0.75
25/32 — 0.78
13/16 — 0.81
27/32 — 0.84
7/8 — 0.88
29/32 — 0.92
15/16 — 0.94
31/32 — 0.97

Determining the program scope

A size-control program cannot be introduced until mill management decides how it will be organized and how many people will be involved. Mill managers should not tackle a large program if there are two few people to carry it out. For instance, if the production foreman will be the quality-control supervisor, it is better to begin with a small program. Likewise, if a mill is cutting 100 Mbf or more per shift, it is unrealistic to expect a full-time supervisor to monitor all quality-control activities from woods to shipping while monitoring each sawing-machine center. In the final analysis, quality control is the job of everyone on the mill floor.

If the goal of a size-control program is to monitor machine-center performance over a long period for trends in size accuracy, only a few boards need be measured every day or two; however, if the goal is to monitor sawing performance for problems originating from the machine or its operator, measurements must be made frequently—at several points on at least eight boards from a sawline on each machine center at each shift. A record of sawing performance must be kept if the information is to be used to adjust target sizes, and the sawing machine centers must be brought to an acceptable level of performance and continually controlled. As target sizes are reduced, it
becomes increasingly important to assure sawing accuracy.

**Equipment needs**

Only one piece of equipment is mandatory for a size-control program: a dial or digital caliper capable of measuring lumber in thousandths of inches. Lumber is no longer adequately measured with tapes because wood is too expensive to be cut consistently only within 1/32 (0.031) inch of target size. Many well-controlled machine centers are cutting within 0.015 to 0.020 inches of target. Moreover, statistical analysis requires measurement in hundredths or thousandths of inches.

Items such as depth gauges, micrometers, and statistical and programmable calculators or microcomputers are also extremely useful equipment. Let's look at each of these in more detail.

**DIAL CALIPPERS**

There are basically two types of dial calipers: those measuring 0.1 inch and those measuring 0.2 inches in one revolution of the dial (Figure 1). The former have a zero only at the top of the dial, while those that measure 0.2 inches have a zero at both top and bottom, which is sometimes confusing. For that reason, a dial caliper that measures 0.1 inch in one revolution is preferable.

Another desirable feature is a top pinion rack rather than one located on the bottom of the slot (Figure 1A). A bottom rack is prone to collect sawdust and cause the pinion gear to skip, throwing the dial out of calibration. It may be desirable to file the "ears" off the calipers to keep them from snagging clothing or skin.

The caliper selected should be no larger than necessary; the most common are 6-inch, 8-inch, or 12-inch types. Twelve-inch calipers are bulkier and heavier but may be needed if large cants are to be measured. Leather belt cases can be made in order to make the calipers easier to carry.

**DIGITAL CALIPPERS**

Digital calipers have the advantage that lumber sizes can be read directly from the display. However, they must be kept clean by periodical spraying of the electronic sensing bar with a solvent–lubricant that removes pitch.

**DEPTH GAUGE**

A depth gauge is a valuable tool when a double–arbor edger is being checked and is also useful for measuring planing allowances. A gauge can be constructed by mounting a dial indicator on a flat plate with the indicator probe extending through the plate (Figure 2). The gauge is set at zero when the probe is level with the bottom of the plate.

**FIGURE 1.**

DIAL CALIPPERS: (A) TOP-RACK TYPE (EARS FILED OFF) AND (B) BOTTOM-RACK TYPE. A CALIPER WITH A TOP RACK IS LESS LIKELY TO BE THROWN OUT OF CALIBRATION.

**FIGURE 2.**

A DEPTH GAUGE CONSTRUCTED BY MOUNTING A DIAL INDICATOR ON A FLAT PLATE. WHEN THE PROBE IS LEVEL WITH THE BOTTOM OF THE PLATE, THE GAUGE SHOULD READ ZERO.
MICROMETERS

Micrometers are useful for measuring such things as saw teeth and saw plates. Their use is optional.

PROGRAMMABLE CALCULATORS AND MICRO-COMPUTERS

Before 1975, few calipers were used for measuring lumber in a sawmill, and sawing variation was usually expressed as the range in thickness of boards coming from a machine center. As the drive for maximizing recovery from logs grew and the need for precision increased, statistical size-control methods were introduced. Today, production and quality-control personnel do not need a background in statistics to use such methods because inexpensive statistical calculators ($20–$40) and programmable calculators ($300–$1,000) or microcomputers ($1,500–$3,000) are available for determining sawing variation with the press of a button. One of the best investments for a mill implementing statistical size control is a programmable calculator, such as the Hewlett Packard HP-41CV, or a microcomputer, such as an IBM-PC or IBM–compatible computer. The simpler the size-evaluation process is made, the more likely it is that the program will be effective.

For mill managers who want to obtain maximum value from a size-control program, a microcomputer which runs size-control software is a must. Some software programs not only analyze size data but provide graphics and have the capability to trace trends over time. Some systems also automatically collect data by means of digital calipers and data-storage devices.

Measurement methods

Lumber may vary in thickness or width as much as an inch or more, as is the case when a saw snakes, or as little as a few thousandths of an inch. Evaluating the amount of variation during the sawing process is essential not only for determining rough green target size but also for evaluating machine–center performance.

Variation in thickness or width along the length of a board is called "within-board standard deviation" ($S_w$) and variation from one board to the next "between-board standard deviation" ($S_b$) when the variation is calculated by statistical procedures. Together, $S_w$ and $S_b$ make up total-process standard deviation ($S_t$).

The way lumber size is measured depends on the objectives of management and the amount of time available. Obviously, as more measurements are taken on a single piece of lumber, more information becomes available for evaluating machine–center function. Isolating problems and identifying them as either saw related or setworks related is impossible unless several measurements are made on each board. The same is true for problems of edge–to–edge wedging and end–to–end taper.

SINGLE-POINT MEASURING

Some quality-control programs have been developed from data based on one measurement per board, but only limited information is obtained from this method. Figure 3 is an example of a data sheet for single–point measurement of two five–board samples. About all that can be determined is that the range in thickness is 0.040 inches in Sample 1 and 0.050 inches in Sample 2. With a simple calculator that has a standard deviation ($\sigma$ or $S$) key, and with methods discussed in the section Evaluation with a Statistical Calculator on page 5, between-board standard deviation and average thickness ($X$) can also be determined, with these results:

<table>
<thead>
<tr>
<th>Sample 1</th>
<th>Sample 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\bar{X} = 1.702$ inches</td>
<td>$\bar{X} = 1.692$ inches</td>
</tr>
<tr>
<td>$S_b = 0.018$ inches</td>
<td>$S_b = 0.023$ inches</td>
</tr>
</tbody>
</table>

However, it is not possible to determine if end-to-end taper or edge–to–edge wedging occurred, or how much thickness varied along the length of each board. Better quality–control programs use a multiple–point measuring method.

<table>
<thead>
<tr>
<th>MACHINE: SINGLE LINEAR BEAU</th>
<th>MEASURED BY: BETTY</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPECIES/GRADE: Ponderosa Pine</td>
<td>DATE: 9/12/84</td>
</tr>
<tr>
<td>TARGET SIZE: 1 3/4</td>
<td></td>
</tr>
</tbody>
</table>

**SAMPLE 1**

<table>
<thead>
<tr>
<th>BOARD NO.</th>
<th>TIME 9:15 AM</th>
<th>TIME 6:30 PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.70</td>
<td>1.40</td>
</tr>
<tr>
<td>2</td>
<td>1.32</td>
<td>1.60</td>
</tr>
<tr>
<td>3</td>
<td>1.68</td>
<td>1.92</td>
</tr>
<tr>
<td>4</td>
<td>1.61</td>
<td>1.91</td>
</tr>
<tr>
<td>5</td>
<td>1.72</td>
<td>1.64</td>
</tr>
</tbody>
</table>

**SAMPLE 2**

A SIZE-CONTROL DATA SHEET FOR SINGLE-POINT MEASUREMENT.
MULTIPLE-POINT MEASURING

A thorough analysis of the data from a multiple-point measurement system can provide much information about a machine center with no statistical analysis whatsoever. In such a system, each board is measured at more than one place along its length, preferably at three or four points along one edge. Within-board standard deviation, usually an excellent indicator of how well the saw is cutting, and between-board standard deviation, usually an excellent indicator of how well setworks are performing, can then be determined. Multiple-point measuring is the only way that both of these sources of variation can be identified and evaluated.

The data developed for size analysis should be used to determine as much about a machine center as possible before beginning a statistical study. Note the thickness measurements in Figure 4 for each of the samples of five boards measured at six points along their lengths. There is a definite indication of end-to-end taper in Sample 1. Further, because care was taken to track the entering and trailing ends through the resaw, it can be seen that the trailing end was wide. The taper was noted in the comment section of the data sheet, and maintenance was performed on the linebar between shifts, so that when Sample 2 was taken, the problem was corrected. This technique works equally well with as few as three measurements per board. It identifies problems that would otherwise go undetected. Correcting the taper problem also improved sawing accuracy between Samples 1 and 2. With the techniques outlined on pages 5 and 6, the following size data can be computed:

<table>
<thead>
<tr>
<th>Sample 1</th>
<th>Sample 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \bar{X} = 1.710 \text{ inches} )</td>
<td>( \bar{X} = 1.691 \text{ inches} )</td>
</tr>
<tr>
<td>( S_W = 0.021 \text{ inches} )</td>
<td>( S_W = 0.010 \text{ inches} )</td>
</tr>
<tr>
<td>( S_B = 0.023 \text{ inches} )</td>
<td>( S_B = 0.023 \text{ inches} )</td>
</tr>
<tr>
<td>( S_T = 0.031 \text{ inches} )</td>
<td>( S_T = 0.025 \text{ inches} )</td>
</tr>
</tbody>
</table>

It can be seen that the within-board standard deviation decreased from 0.021 inches to 0.010 inches, a direct result of eliminating the taper problem. But eliminating that problem was unrelated to the setworks ability to repeatedly set to the same size. This is apparent only from between-board standard deviation, which remained unchanged at 0.023 inches for both samples. Because within-board variation decreased, the total-process standard deviation was reduced from 0.031 inches to 0.025 inches.

Data analysis shows that although the target size for this resaw was 1.68 inches, actual average thickness was 1.71 inches for Sample 1 and 1.69 inches for Sample 2. In other words, the machine center was oversizing. Further evaluation of Samples 1 and 2 shows that one board in each was thicker along its entire length than other boards of the sample. By troubleshooting this problem, which could be setworks related, the between-board variation could be reduced further.

Another example of the use of multiple-point data can be found in an evaluation of the Figure 5 data for a twin band saw being evaluated for accuracy and edge-to-edge wedging. The data show that end-to-end taper is not a problem, but edge-to-edge wedging is. In Sample 1, the bottom edge is narrower than the target size of 1.70 inches; in Sample 2, the top edge is narrower. Sample 1 came from Pocket 1, between the linebar and the first saw, and Sample 2 from Pocket 2, between the first and second saws. The data indicate that the first saw may not be parallel to the linebar, a problem that would need to be corrected.

FIGURE 4.
A SIZE-CONTROL DATA SHEET FOR ONE-EDGE MULTIPLE-POINT MEASUREMENT.
EVALUATING SIZE DATA WITH A STATISTICAL CALCULATOR

Values for eight boards measured at four points along their lengths, given in the portion of a data sheet shown in Figure 6, are used in the following example of evaluation of size data with a statistical calculator. The results obtained by the means below are: $X = 1.707$ inches, $S_W = 0.016$ inches, $S_B = 0.021$ inches, and $S_T = 0.026$ inches.

```
<table>
<thead>
<tr>
<th>BOARD</th>
<th>MEASUREMENTS</th>
<th>$\bar{x}$</th>
<th>$s$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.70 1.73 1.71 1.72 1.715 0.018</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.67 1.72 1.70 1.71 1.700 0.022</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1.69 1.72 1.70 1.68 1.698 0.019</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1.74 1.73 1.75 1.72 1.735 0.013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1.70 1.68 1.66 1.67 1.678 0.017</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1.71 1.72 1.72 1.74 1.723 0.013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1.60 1.69 1.68 1.68 1.686 0.015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1.71 1.75 1.74 1.72 1.750 0.016</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

FIGURE 6.
A PORTION OF A DATA SHEET SHOWING VALUES FOR EIGHT BOARDS MEASURED AT FOUR POINTS ALONG THEIR LENGTHS.

DETERMINING AVERAGE THICKNESS ($\bar{x}$) AND STANDARD DEVIATION ($s$) FOR EACH BOARD

- Enter the four measurements for Board 1 into the statistical register of the calculator.
- Key $\bar{x}$ to obtain the average thickness.
- Key $S$ or $\sigma$ n−1 to get standard deviation.
- Repeat for each board.

Values derived for each board should agree with those shown in the two right-hand columns of Figure 6.

DETERMINING OVERALL AVERAGE THICKNESS

The equation for determining average thickness for all boards is $X = \bar{x} X/n$, where $\bar{x} X$ is the sum of all board averages and $n =$ the number of boards measured.

- Enter the eight values for average board thickness into the statistical register.
- Key $\bar{x}$.
The result is overall average thickness:

\[ \bar{X} = 1.707 \text{ inches.} \]

DETERMINING WITHIN-BOARD STANDARD DEVIATION

The equation for determining within-board standard deviation is \( S_W = \sqrt{\frac{\bar{X}^2}{2}} \), where \( \bar{X}^2 \) is the mean of the squared standard deviations from average thickness or width.

• Enter the \( S \) value for Board 1.
• Key \( X^2 \).
• Enter the value into the statistical register.
• Repeat for each board.
• Key \( \bar{X} \) to obtain the variance of all boards.

\[ S^2 = 0.0002578. \]

Note that small values for \( S^2 \) should not be rounded off, even to three decimal places, or \( S_W \) will be incorrectly calculated.

• Key square root, \( \sqrt{ \}. \)

The result is within-board standard deviation:

\[ S_W = 0.016 \text{ inches.} \]

DETERMINING BETWEEN-BOARD STANDARD DEVIATION

The equation for determining between-board standard deviation is \( S_B = \sqrt{S(\bar{X})^2 - (S^2_W/n)} \), where \( S(\bar{X}) \) is the standard deviation of the average thickness of each board, \( S_W = \) within-board standard deviation, and \( n = \) the number of measurements per board.

• Enter the eight values for average board thickness (Figure 6, \( \bar{X} \)) into the statistical register.
• Key \( S \) or \( \sigma \) n-1.
• Key \( X^2 \).

\[ S(\bar{X})^2 = 0.000492 \]

• Enter the \( S_W \) value previously calculated (0.016).
• Key \( X^2 \).

• Divide by four, the number of measurements per board.

\[ S_W^2/n = 0.000064 \]

• Enter the value for \( S(\bar{X})^2 \) and subtract from it the value for \( S_W^2/n \) (0.000492 - 0.000064).
• Key square root, \( \sqrt{ \}. \)

The result is between-board standard deviation:

\[ S_B = 0.021 \text{ inches.} \]

Sometimes \( S_W^2/n \) will be larger than \( S(\bar{X})^2 \), causing a negative value to appear. When this occurs, the between-board standard deviation is close to zero (Petersen 1980). One cannot take the square root of a negative number; therefore, assume that \( S_B = 0 \).

DETERMINING TOTAL-PROCESS STANDARD DEVIATION

The equation for determining total-process standard deviation is \( S_T = \sqrt{S_W^2 + S_B^2} \).

• Enter the \( S_W \) value (0.016).
• Key \( X^2 \).
• Enter the \( S_B \) value (0.021).
• Key \( X^2 \).

• Enter the value for \( S_W^2 \) and add to it the value for \( S_B^2 \) (0.000256 + 0.000441).
• Key square root, \( \sqrt{ \}. \)

The result is total-process standard deviation:

\[ S_T = 0.026 \text{ inches.} \]

EVALUATION WITH A PROGRAMMABLE CALCULATOR

Versatile and reliable programmable calculators are available for evaluating size data. Figure 7 is a printout of the data from Figure 6 and the sawing-variation information derived from it by means of a Hewlett Packard HP-41CV calculator.
BOARD 1
1.70  1.73  1.71  1.72  AVE. BOARD SIZE = 1.715
BOARD 2
1.67  1.72  1.70  1.71  AVE. BOARD SIZE = 1.700
BOARD 3
1.69  1.72  1.70  1.68  AVE. BOARD SIZE = 1.698
BOARD 4
1.74  1.73  1.75  1.72  AVE. BOARD SIZE = 1.735
BOARD 5
1.70  1.68  1.66  1.67  AVE. BOARD SIZE = 1.678
BOARD 6
1.71  1.72  1.72  1.74  AVE. BOARD SIZE = 1.723
BOARD 7
1.66  1.69  1.68  1.68  AVE. BOARD SIZE = 1.678
BOARD 8
1.71  1.75  1.74  1.72  AVE. BOARD SIZE = 1.730

SIZE DATA
OVERALL AVE = = 1.707 IN
WTMN BD STDEV = 0.016 IN
BTWN BD STDEV = 0.021 IN
TOTAL STDEV = 0.026 IN
OLD TRGT SIZE = 1.700 IN
NEW TRGT SIZE = 1.668 IN

FIGURE 7.
A PRINTOUT OF INFORMATION ON BOARD SIZE DERIVED FROM DATA IN FIGURE 6 BY AN HP-41CV CALCULATOR.

Establishing the target size

The rough green thickness or width of lumber is targeted from the desired final size, the planing allowance (if any), shrinkage (if lumber is to be dried), and sawing variation. Any thickness or width in excess of the amount required for adequate surfacing of the lumber is called "oversize."

The target size of rough green lumber is determined by the equation

\[ T = \frac{(F + P)}{1 - \%SH} + (Z \times S_t), \]

where

- \( T \) = rough green target size,
- \( F \) = final size,
- \( P \) = planing allowance (both sides),
- \( \%SH \) = percentage of shrinkage allowance (green to final moisture content),
- \( Z \) = the undersize factor, and
- \( S_t \) = total-process standard deviation.

Let's look at each component in more detail.

CRITICAL SIZE FACTORS

FINAL SIZE

Final size is the thickness or width to which lumber eventually will be sized. It is the basis for adjusting all other components.

PLANING ALLOWANCE

Except for the small amount of lumber that is "saw sized," almost all softwood lumber is surfaced before being sold; therefore, when establishing rough green size, enough wood must be added to allow for surfacing. When evaluating target size by means of statistics, the planing allowance is the total amount of fiber removed by opposing planing heads at the top and bottom or sides, or by sanding belts in abrasive planers or lumber sanders.

It is assumed that approximately equal amounts of fiber will be removed from the sides or from the top and bottom of a board (Figure 8A). In

FIGURE 8.
TWO BOARDS PLANED WITH AN ALLOWANCE OF 0.125 INCHES. (A) FIBER REMOVED EVENLY FROM TOP AND BOTTOM. (B) FIBER REMOVED UNEVENLY.
most mills with size-control programs, the bottom head is set to clean up the bottom of the lumber or to leave "hit and miss" skip, and the top head takes off the remaining amount of fiber. The side heads are set up in the same way, and the planer may not remove equal amounts from each side (Figure 8B). Oversize comes off the top head or side head. If target size is to be evaluated statistically, the planer must be set up so that approximately half of the total planing allowance is taken off each side, as shown in Figure 8A. This requires careful communication between the sawmill and planer mill. When lumber is sanded, equal amounts of fiber are generally removed from each face automatically. Good communication will assure this.

SHRINKAGE

When lumber is to be air or kiln dried, enough fiber must be included in the rough green size to allow for shrinkage that begins when wood dries below approximately 30% moisture content. Shrinkage continues in an essentially linear relationship with moisture content down to 0%. It is important to know the approximate moisture content to which the wood will be dried. If it is to be kiln dried, the air flow, drying schedule, and condition of the kiln greatly influence the range of moisture content in a charge of lumber.

Wood shrinks most in the tangential direction, although true tangential shrinkage will not occur in either the wide or narrow face of the lumber unless lumber is quarter sawn or flat sawn. However, if tangential shrinkage is the basis for determining the amount of shrinkage, percentages have been established for the amount that will occur between 30% and 0% moisture content in common commercial softwood species sawn in North America (derived from USDA Forest Service Handbook 1974).

<table>
<thead>
<tr>
<th>Species (cont.)</th>
<th>Average shrinkage (%) (cont.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pine</td>
<td></td>
</tr>
<tr>
<td>Eastern white</td>
<td>6.1</td>
</tr>
<tr>
<td>Southern pines (major species)</td>
<td>7.6</td>
</tr>
<tr>
<td>Southern; Virginia; pond</td>
<td>7.1</td>
</tr>
<tr>
<td>Lodgepole; ponderosa; jack</td>
<td>6.5</td>
</tr>
<tr>
<td>Sugar</td>
<td>5.6</td>
</tr>
<tr>
<td>Western white</td>
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Assume that the lumber being dried is ponderosa pine. Its shrinkage value is 6.5 if lumber is dried to 0% moisture content. If the final average moisture content is 10%, which is two-thirds of the original 30% moisture content, the 6.5% shrinkage must be multiplied by two-thirds. This relationship can be represented by the following equation (after USDA Forest Service Wood Handbook 1974):

\[
\% \text{ shrinkage} = \left(\frac{30 - \text{final moisture content}}{30}\right) \times \text{average } \% \text{ shrinkage.}
\]

For the ponderosa pine example, percent shrinkage = \left(\frac{30 - 10}{30}\right) \times 6.5 = 4.3.

Of course, shrinkage is highly variable; within a single load of lumber each piece will shrink differently, not only because of different final moisture content but also because of varying grain orientation and density. Shrinkage amounts for any one species may vary from those shown above. Lumber dried below average moisture content will shrink more, and that dried above average moisture content will shrink less. For this reason, some mills use the lowest moisture content that will occur in a kiln load for determining shrinkage values. Obviously, if kilns are well maintained and moisture content well monitored, the range of moisture content will be smaller and the average moisture content can be higher without many pieces of lumber being underdried. More important, generally with a higher average moisture content, less shrinkage will occur, and the smaller the rough green target size can be.

After being dried, lumber must have enough thickness or width so that it can be planed to final
size without degrade due to planer skip or undersizing. An amount of thickness equal to the amount lost in drying must be added to the sum of final size and planing allowance. If, for example, the final dressed size is 1.50 inches and the total planing allowance (both heads) is 0.08 inches, the thickness of lumber after drying should be 1.58 inches. The relationship that determines the required size before drying (less sawing variation) can be expressed as

\[
F + P \over 1 - (\%SH)
\]

If the lumber shrinks 3% (0.03), the thickness required before drying is

\[
1.58 = 1.58 = 1.63 \text{ inches.}
\]

1 - 0.03 0.97

Note that the amount of shrinkage, 3%, must be expressed in decimal form, 0.03.

If the lumber is to be surfaced green, the denominator of the fraction becomes 1 - 0 or 1, as shrinkage is not a factor.

If all lumber coming from the mill could be sawn with no variation in thickness or width down the entire length of a board, or with no variation from one board to the next, nothing more would be needed to determine rough green target size. For this reason, \((F + P)/(1 - \%SH)\) determines the critical size (CS). But because lumber cannot be cut perfectly, amounts of fiber must still be added to account for sawing variation. The target size equals the critical size factors plus an undersize factor and total-process standard deviation: \((T) = CS + (Z + St)\).

**UNDERSIZE FACTOR**

The undersize factor \((Z)\), used in the equation for calculating target size, is a statistical value that predicts the number of surfaced boards that will, in places, be smaller than the desired final dimension.

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**SAWING VARIATION**

A bar chart of the average thickness (or width) of boards is commonly used to show how well a saw is cutting lumber (Figure 9A). It is possible to represent the same information by drawing a line through the midpoint of each of the bars (Figure 9B) and then eliminating them (Figure 9C). Average thickness in Figure 9 ranges from 1.62 to 1.78 inches, with most thicknesses falling at 1.70, which was probably the rough green target size of the linebar resaw. The left side of the bell-shaped curve, the portion representing thicknesses from 1.70 to 1.62 inches, is of particular concern. From the shrinkage example, it was determined that for final size 1.50 inches, planing allowance 0.080 inches, and shrinkage allowance 3%, the rough green target thickness must be at least 1.63 inches (the critical size). A smaller target size would
not surface cleanly, even without sawing variation. As sawing variation increases, target thickness must also increase so that the thinnest point on the lumber is at least as thick as the critical size. When the critical size is superimposed on the curve for thickness distribution in Figure 9C, the bell-shaped curve shows that some boards are less than 1.63 inches in average thickness. These boards may contain planer skip or may be undersized when surfaced. How many undersized boards are there? To answer this, standard deviation must be determined.

**STANDARD DEVIATION**

In simple size-control programs, sawing variation may mean nothing more than the range between thinnest and thickest pieces; but if a quality-control supervisor is to determine the amount of undersized boards, such as those represented in Figure 9C, or a rough green target size that will allow some undersizing, range will not be sufficient. Instead, standard deviation, the statistical indication of the spread of thickness or width around the target size, must be determined. The relative shape and end points of the curve, as shown in Figure 9B, can be determined without drawing bar charts. All that is needed are the values for overall average thickness and total-process standard deviation.

You can then estimate from a small sample of boards (5 to 100) the number at a specific machine center that will be undersized or contain skip. This is made possible by choosing a Z value corresponding to the percentage of undersized boards you will allow.

Target size is also easily estimated from final size (1.50 inches), planer allowance (0.080 inches), percentage of shrinkage (3%), sawing standard deviation (0.040 inches), and the undersize factor. Substituting these values in the target-size equation (page 7), we have

\[
T = \frac{1.50 + 0.080}{1 - (0.03)} + (1.65 \times 0.040) = 1.70 \text{ inches.}
\]

Figure 9C shows that for target size 1.70 inches, total standard deviation 0.040 inches, planing allowance 0.080 inches, shrinkage allowance 3%, and final size 1.50 inches, 5% of the lumber below the 1.63-inch critical size will be undersized or have planer skip.

Figure 10 illustrates use of the equation for determining the target size for linebar resaws in two mills. The only difference between Mill A and Mill B is sawing variation, a relatively poor 0.060 inches in Mill B and an excellent 0.015 inches in Mill A. Both mills allow 5% undersizing. In both mills, no more than 5% of the boards will have skip. Yet every board cut on the resaw in Mill B must be 0.080 inches thicker than those in Mill B. In Mill A, the rough green target thickness must be 1.73 inches; in Mill B, it need be only 1.65 inches.

![Figure 10](image-url)

**SIZE DISTRIBUTION OF LUMBER FROM A LINEBAR RESAW IN TWO MILLS. NOTE HOW THE DIFFERENCE IN ACCURACY AFFECTS TARGET SIZE.**

**SURFACE ROUGHNESS**

No discussion of the components of target thickness is complete without considering surface roughness, which can be caused by machine alignment and vibration, saw instability, filing practices, and operator performance. In some cases, surface roughness is a major component of within-board variation, especially in the range from 0.010 to 0.015 inches. If the hills and valleys caused by roughness are narrower than the width of the caliper blades, roughness may not show in thickness measurements; a piece of lumber may show little within-board variation and still be rough. Because of this, some mills have developed a roughness index by determining how much bottom-head planing, e.g. 0.030 inches, is re-
quired to cleanly surface the lumber. A roughness index should be included in the process used to establish a planing allowance.

**Practical considerations**

It is important that estimates of target size not be accepted as absolute. Even though the statistical approach just described is a far better way to estimate rough green target size than previous approaches, it is only a guide. In most instances, target sizes derived statistically will be conservative. For several reasons, actual undersizing will be less than that predicted for a given target size. First, most mills assume a shrinkage value based on maximum tangential shrinkage and minimum moisture content, but all boards will not shrink the maximum amount nor reach the same moisture content. Shrinkage, like sawing variation, varies in a bell-shaped pattern. Unfortunately, quantifying shrinkage distribution is not cost effective with present technology. Therefore, we many times use the worst case in evaluation of target size. Second, the planing allowance and within-board standard deviation interact. In the method just described—the one used most by industry—thickness or width is added to account for planing allowance and to allow for sawing variation (standard deviation). In actuality, some within-board variation in sawing will be removed by the planer. Within-board standard deviation and planer allowance are therefore not additive. Third, sample size has an effect. Ideally, the number of measurements would always be sufficient to assure that within-board or between-board standard deviation are representative of all boards coming from a machine center. Lack of time may prevent this. Fourth, because 5% of a planer run of boards shows skip does not mean that the boards will be graded below "2 and BTR" grade since that grade allows occasional skip.

Although standard deviation ($S_w$, $S_b$, $S_t$) is useful for determining rough green target size, it is currently more useful for diagnosing machine-center problems and for promptly identifying loss of sawing accuracy so that corrective action can be taken. Whether target size is determined by means of statistics or mill tests, once it is established, the sawing accuracy must be kept at the same level or improved over time. Lumber size-control will assure this.

**CARRYING OUT THE PROGRAM**

The key to successful quality control is a supervisor who thoroughly understands the program and who can communicate goals and results effectively to both management and workers on the mill floor. All personnel should know the purpose of the procedures that follow. Once size information becomes available for each machine center, a graphical representation of results, such as that shown in Figure 8A, should be posted or given to each worker. If machine problems are found through size data, the quality-control supervisor should inform the production worker and maintenance crew. When problems long suspected are identified, workers will begin to have confidence in the method.

**Step 1: Choosing the machine center**

If it is not desirable to begin size analysis on all sawing-machine centers, start with the machine that is suspected of cutting most poorly. A single-saw machine center, such as a linebar resaw, is the simplest to begin with because no interactions take place between a set of band

saws or gang of circular saws. Only one surface is cut by a linebar resaw, and the parallel surface will probably have been cut by another machine center. Don't be concerned about interactions between machine centers; they are not of practical concern to many mills. When multi-saw machine centers are being evaluated, separate the size measurements of boards by pocket or line to help in machine diagnosis. Results can be combined later if necessary.

**Step 2: Establishing measurement technique**

Generally, a minimum of four measurements should be taken from each piece of lumber—one near the leading end, one near the trailing end, and the other two spaced evenly between. Measurements should be taken in the same general location on each board.

If the mill desires to monitor edge-to-edge wedging, measurements must be taken opposite each other along each edge of a board. Three measurements per edge are satisfactory, but four
per edge are better. When end-to-end taper is monitored, entries for the leading end of the lumber into the machine center should be consistently recorded either first or last to allow for consistent evaluation of the data.

Skill with the calipers is necessary for consistent size measurements. The thumb wheel should not be used to tighten the blades of the caliper against the lumber; instead, the blades should be firmly pressed against the lumber with the fingers of one hand while the calipers are held with the other. The blades are wiggled slightly from side to side while pressure is exerted on them to eliminate some of the variation created by surface roughness. With very little practice, the procedure becomes automatic. The calipers should be cleaned periodically with a lubricant, such as WD–40, especially if there is pitch on the lumber being measured.

How accurate should measurements be? Some mills measure to hundredths of inches, others to thousandths. Either is acceptable. Repeated measurements taken by the same person at the same location on a board will vary as much as 0.005 inch, and measurements taken by different people will vary more. Because of this, measurements of lumber in thousandths of inches may be accurate only to the nearest hundredth. A worthwhile exercise for personnel taking measurements is to mark at least four locations on ten boards and to take two or three sets of data at these locations, then to determine the variation between sets. This will indicate the accuracy of the measurer. If a quality-control supervisor wants to carry the process one step further, he or she may calculate sawing variation with each set of measurements to determine the effect of the measurer on the results.

**Step 3: Constructing a data sheet**

A data sheet should be constructed that is simple to use and to interpret while providing the most information possible about a machine center. Items that must be included are:

**NAME OF THE MEASURER**

Measurers are identified so that they can be consulted later if necessary.

**DATE AND TIME OF DAY (SHIFT)**

Date and time of day are critical for record of frequency of measurements and for finding size trends over time. Problems that vary with time of day can then be identified.

**SPECIES AND GRADE**

The species and grade being cut must be recorded as they may affect machine-center performance.

**TARGET THICKNESS**

Target thickness is included for comparison with the actual size being cut.

**SAW-LINE LOCATION**

The sawline must be identified if multi-saw machines are being evaluated.

**MEASUREMENTS**

Space should be provided for recording measurements of leading and trailing ends, top and bottom edges.

**COMMENTS**

Space should be allowed for comments concerning irregularities.

You may wish to include other items such as allowable tolerance (for evaluating the range of thickness for a given board), a machine diagram (if a code is to be used for determining sawline location), and length (if lumber of varying lengths is being measured).

Pages 4 and 5 show sample data sheets for lumber being measured on one edge only (Figure 4) and on both edges for edge-to-edge wedging (Figure 5).

**Step 4: Making preliminary estimates**

Data obtained from a 100-board sample can be used with data in Table 1 to determine how many
### TABLE 1.
NUMBER OF MEASUREMENTS PER BOARD (n) AND THE NUMBER OF BOARDS NEEDED FOR A STATISTICALLY ACCURATE ESTIMATE (95% CERTAINTY) OF GIVEN BETWEEN-BOARD (S_b) OR WITHIN-BOARD (S_w) STANDARD DEVIATION (AFTER WARREN 1981).

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boards are needed for a statistically accurate estimate (95% certainty) of machine-center performance. Initially, about 100 boards should be taken from the machine center being evaluated so that the quality-control supervisor will have some assurance that preliminary values calculated for within-board and between-board standard deviation represent the cutting accuracy for all boards. All boards should be of the same target thickness or width.

After the initial evaluation, the quality-control supervisor may decide that the machine center is not sawing with the desired accuracy. If immediate adjustment is made, for problems related to wedging or taper, for example, another 100-board sample should be taken to determine the amount of improvement. If gradual improvements are to be made, a second phase of measurements should begin. In this phase, relatively few boards are taken from the machine center; generally, eight to ten boards per shift are sufficient for determining sawing accuracy over a short period. Such sampling may not satisfy the statistical requirements of the 100-board sample but is more realistic for the daily production environment. The values obtained for within- and between-board standard deviation from a small sample can be extremely useful in tracking sawing accuracy over a long period. When daily data are combined, ten-board samples taken over ten periods will provide the same statistical accuracy as a 100-board sample taken at one time, and size data accumulated over time gives a better indication of the sawing capabilities of the machine center. Use a 100-board sample to establish the sawing accuracy of the machine center and an eight- to ten-board sample to evaluate changes in sawing accuracy from one period to the next.

**Step 5: Determining sample size and frequency**

To be statistically correct, use the preliminary estimates of $S_W$ and $S_b$, and the data in Table 1 in choosing the number of boards to measure and the number of measurements per board. If five- to ten-board samples are being taken at each shift, accumulate data until you have satisfied the requirements of Table 1. The smaller the values for $S_W$ and $S_b$, and the closer the values, the fewer the boards needed for statistical accuracy.

From each machine center under study, at least eight boards should be taken at each shift for as many target sizes and sawlines as possible.

It may be impractical, however, to evaluate all target sizes and sawlines each day. If a particular sawing-machine center is a problem, it may be desirable to take measurements at that center more often than at others.

**Step 6: Establishing operating standards and target size**

A size-control program based on multiple-point measurements and statistical analysis is most valuable for evaluating machinery performance. In order to learn if the values for $X$, $S_W$, $S_b$, and $S_t$ are acceptable, you must compare them with machine standards based on a target size set by the company. The primary reason for setting standards is to produce lumber that will not be oversized or downgraded because of undersizing or planer skip. To establish optimum machine tolerances and target sizes in an existing mill, follow these procedures:

**LOOK FOR UNDERSIZING AT THE PLANER**

Be sure that no undersizing is occurring because the planer is taking too much wood. More than likely, oversizing will be a greater problem than undersizing because the planing allowance at the bottom head or side head may be excessive, yet the boards will not show skip. This can be dealt with as standards are set and target sizes are adjusted. A reduction in planing allowance could allow for an immediate reduction in target.

**COLLECT AND ANALYZE SIZE DATA**

Collect and analyze the data to determine sawing variation. After several weeks to a month, a definite pattern will appear in the values ($X$, $S_W$, $S_b$, or $S_t$) for a specific machine center. If they are not consistent, adjustments must be made at the machine center until consistency is established. This need alone indicates the importance of a dedicated maintenance program. Without one, size-control is not possible.

**EVALUATE TARGET SIZES**

Once consistent sawing-variation data are being produced, evaluate the target size. The evaluation may be based on the relationships
explained on pages 7-11 and on mill experience, or on mill experience alone. Whatever the method, the target size should meet the goals of the mill. In a grade-cutting mill, some oversizing may be allowed as a cushion so that high-grade items are not degraded because of undersizing and skip, but in a dimension mill, oversizing must be reduced to a minimum. The more accurate the sawing, the closer the target size can be to the minimum acceptable level, or critical size. A target size thus established should become the standard for the machine center. The values for $S_w$, $S_b$, and $S_t$ that are used to established the target sizes can be used as baseline standards for future analysis.

DEVELOP SIZE POLICY

When target sizes are established and standards are set for each machine center, develop a course of action to take when standards are not being met. A policy consistent with good size control is one in which the machine center is shut down for repairs at the first break or shift change after unacceptable deviation is found. If boards are produced for a longer time, the amount of undersizing may be excessive. A maintenance program must be committed to this level of support. The only alternative is to increase target thickness or width and destroy the value of the quality-control program.

PROVIDE MEANINGFUL INFORMATION

As size data and information are generated, the information should be put into a form useful to the quality-control supervisor, management, and mill worker. Graphic display is easy to understand. Figure 11 shows the results of one month's evaluation of Sawline 1 of a twin-band resaw. It can be seen that on January 10th and 21st sample average thickness fell below the 1.70-inch standard and that total-process variation was greater than 0.025 inches. Notice that after January 23rd, average thickness is more consistent and sawing variation is significantly decreased and remaining at a low level. If a machine is able to cut with such accuracy on all sawlines for an extended time, and if maintenance personnel are committed to the standards, the target size might be further reduced.

LITERATURE CITED


SLIDE TAPES

The following tapes are available from the Forestry Media Center, College of Forestry, Oregon State University, Corvallis, OR 97331-5704.

BROWN, T., and T. LUBA. Establishing and organizing a lumber quality control program. 15 minutes, 78 slides, $95. 826.1 S–T

BROWN, T., T. LUBA, and S. MELLEM. Establishing a lumber size control program. 16 minutes, 80 slides, $95. 826.2 S–T
A lumber size–control program in a sawmill is very profitable if it leads to reduced sawing variation and reduced rough green target sizes. This publication describes the processes for establishing an effective program: determining the program scope, choosing the machine centers to be evaluated, establishing measurement techniques, evaluating information on sawing accuracy, determining sample size and frequency, and establishing operating standards and target sizes.

Keywords: lumber size–control, within-board standard deviation, between-board standard deviation, total-process standard deviation, target size, shrinkage, critical size, planing allowance, multiple-point measuring, single-point measuring, machine-center diagnosis.
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