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PERFORMANCE EXCELLENCE
IN THE WOOD PRODUCTS INDUSTRY

# LUMBER SIZE CONTROL

## Part 2: Size Analysis Considerations

*T.D. Brown*

Lumber size control is one of the more complex parts of any lumber quality control program. When properly carried out, lumber size control identifies problems in sawing-machine centers, sawing systems, or setworks systems. It is a key component of all good lumber quality control programs. In processing both large and small logs, lumber size control is an essential element in maximizing recovery.

Size control has two aspects: measurement and analysis. Measurement is discussed in OSU Extension publication EM 8730, *Lumber Size Control: Measurement Methods.* Lumber size is one part of the manufacturing process that can be quantified very well. Even though it requires time to take the measurements, given current technology, the benefits of size control far outweigh the cost of the time required.

> ***Size control programs have realized…***
>
> from $300,000 to $1,000,000 per year in additional lumber value.

Information obtained from a size control program is a powerful management and production control tool. As the mechanical condition of a sawing-machine center or sequential flow pattern becomes apparent in detail, maintenance priorities can be determined more easily. It is easier to attach dollar values to proposed machine improvements if size control information is the basis for decision making. Results of lumber size analysis are valuable for justifying new equipment and for setting specifications for that equipment when it is installed.

The goal of a size control program is to minimize the sum of kerf, sawing variation, and roughness. Also, the effect of minor changes in saw kerf or feed speed can be determined immediately. Developing an effective size control program requires hard work, understanding, and patience, but the payoffs are considerable. A mill manager who minimizes the amount of wood cut per saw line without losing grade recovery will maximize the dollar return. Companies that have implemented size control programs, and have reduced rough green sizes and kerfs as a result, have realized from $300,000 to $1,000,000 per year in additional lumber value depending on the amount of improvement and the mill's production level.

OREGON STATE UNIVERSITY
EXTENSION SERVICE

*Terence D. Brown, Extension forest products manufacturing specialist, Oregon State University.*

Most sawmills spend a great deal of time collecting size control data. Looking at raw data can help make immediate corrections to obvious problems. Beyond that, it is the *analysis* of raw data that creates the greatest benefit of a lumber size control program.

There is some benefit just in collecting the data because that process keeps maintenance personnel and machine operators "on their toes." However, there are times when size data are collected but allowed to sit for days without being processed into meaningful information. It is true that data analyzed in this way are still important as historical perspective, but they lose their immediate benefit of evaluating current processing capabilities.

### Uses of size control information

Size control information has two primary benefits. The first and most important is the ability to use the sawing variation information to troubleshoot machine center problems. Because of the sawmill's dynamic nature, it is difficult to maintain control of sawing-machine centers over a long period. Sawing variation information obtained from the data analysis can be used to isolate problems and to identify the most likely places to look for solutions. This diagnostic application is by far the greatest value of any size control program.

The second benefit is being able to estimate the appropriate rough green target size for the machine center. It is important to understand that no current mathematical model can estimate the rough green target size of a particular machine center with any degree of certainty. Most attempts involved highly complex modeling that did not prove useful. Shrinkage variation due to drying and planer variation can be as much as the sawing variation. To account for all those sources of variation in a meaningful way currently is not practical.

## Components of target size

Whenever we discuss lumber size control, many people think only about reducing sawing variation. There always will be some variation. Therefore, attaining the least amount of sawing variation is only one part of cutting lumber to the smallest rough green size possible. We must look at all the factors that affect rough green target size.

The best way to visualize target size components is to work backward from final product size. If the lumber has been surfaced to establish its final size, the first component of target size is planing allowance. The next component is shrinkage allowance (if the lumber is dried), and the last component is sawing variation. Figure 1 illustrates how each of these components builds upon the other to establish the rough green target size.

The largest size in Figure 1 is oversize lumber—which should never occur in a mill with a well-run size control program. The days of throwing in a "fudge factor" to protect against undersize lumber have long passed. In today's world, timber is expensive.

In Figure 1, each component of rough green target size appears as a layer added to the previous one. By minimizing the thickness of each layer, the rough green target size will be as small as possible. Let's look at these components and discuss how each can be minimized.

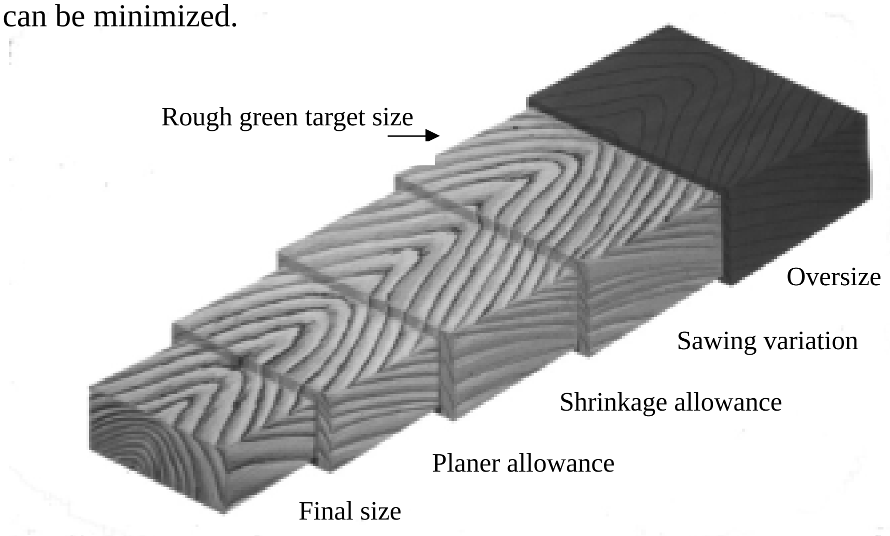


*Figure 1.—Target size components.*

## Planer allowance

The amount of wood removed by both top and bottom heads combines as total planer allowance. To fully understand how total planer allowance affects green target size, we need to know how a planer works. The amount of lumber removed by the top and bottom planer heads is seldom the same, even though we assume that it is roughly the same. (Although this discussion focuses on board thickness, the same principles hold true for board width; it's just that different planer heads are involved.)

We must know how the top and bottom heads interact to plane lumber to understand why this is true. Normally when planing dimension lumber, a small amount of *skip* (i.e., surface area left rough, or *unsurfaced* area) is acceptable from a grade standpoint. Sometimes a planer setup person intentionally sets the bottom planing head to produce a small amount of skip on the bottom side of the lumber so that any thin lumber still can be surfaced by the top planer head. The bottom planer allowance is established by lowering the bed plate of the planer infeed below the top of the bottom planer head knives (Figure 2). This bottom head allowance is fixed from one planer run to the next. The amount actually planed off depends on how accurately the lumber was sawn and on how rough the lumber surface is.

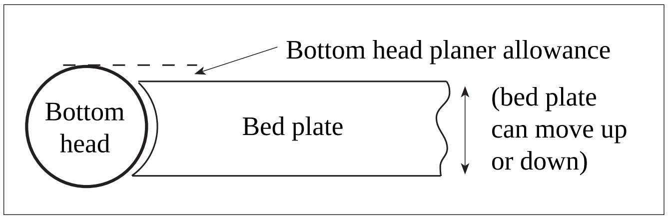


*Figure 2.—Bottom head allowance (side view).*

Let's assume the bottom head planer allowance has been preset to 0.030 inch and the lumber has been sawn without a lot of surface roughness. If the wood has not cupped or warped during drying, the board may have a good chance of coming out with a smooth surface or with very little skip. If, however, the board is wide (8, 10, or 12 inches) and has any amount of warp or roughness, the bottom planer allowance might need to be increased to 0.060 inch.

The gap between the top head of the planer and the bottom head will be the finished lumber size. In the case of 2-inch dry dimension lumber, that is 1.500 inches. The thickness of lumber removed by the top head (top head allowance) will vary depending on the thickness of the lumber being planed and the fixed bottom head allowance. Figure 3 illustrates the relationship between bottom and top head planer allowance.

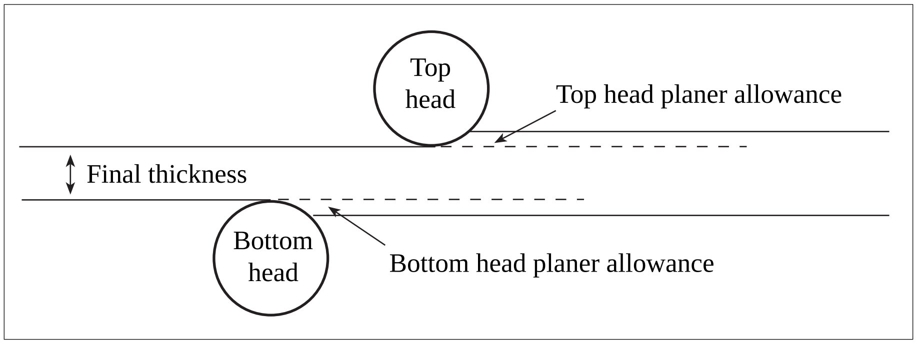


*Figure 3.—Relationship between top and bottom planer allowance (side view).*

For example, the desired final size out of the planer is 1.500 inches. If a board 1.580 inches thick enters the planer, and the bottom planer allowance is 0.030 inch, then the top head will remove 0.050 inch. If the lumber is 1.560 inches entering the planer, then the top planer will remove 0.030 inch.

It is vital that the total planer allowance used in calculating rough green size be the actual settings used at the planer. Let's take the above example of a 1.560-inch board entering the planer with a 0.030-inch bottom allowance. In this case, an equal thickness of lumber will be removed by the top and bottom heads. The board, in fact, could be 1.540 inches in thickness and still have a tiny amount of wood—approximately 0.010 inch—removed by the top head. In reality because of sawing variation, lumber is not going to have a uniform thickness coming into the planer, and this piece probably would leave the planer with unsurfaced areas.

Suppose the planer setup person had a bad day and set up the bottom head so that the bottom planer allowance was 0.070 inch. In this case, the board that was 1.560 inches thick entering the planer would never be touched by the top head and would come out of the planer totally unsurfaced on the top face. The lumber had plenty of wood to surface cleanly if the bottom head allowance had been set correctly.

If a quality control (QC) person hears from the planer mill that the lumber is being cut too thin, the first thing to do is check how much wood the bottom planer head is removing. If, after planing, the lumber is surfaced cleanly on the bottom and shows all the skip on the top, then the problem is planer setup, not green target size in the sawmill or shrinkage due to overdrying the lumber.

The goal is to minimize the amount of lumber the planer removes while still maintaining grade. This can be done only by presenting flat, smoothly sawn lumber to a planer that has been set up correctly. Total planer allowances range from 0.120 inch for dry southern pine to 0.010 inch for green Douglas-fir. This does not imply that southern pine manufacturers are doing a poorer job; it is more a reflection of species differences and drying characteristics. In either case, more surface smoothness and greater sawing accuracy tend to enable smaller planer allowances.

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>
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## Shrinkage allowance

The next "layer" that needs to be minimized is shrinkage. The more the wood shrinks during drying, the thicker it must be sawn initially in the sawmill. Any quality control program should minimize shrinkage during drying. It is absolutely pointless to spend time, energy, and money to make the machine centers in the sawmill saw accurately, then pay little attention to the drying process. For a sawmill to gain the most benefit from its size control program, it must do high-quality drying.

Wood does not shrink until moisture content reaches approximately 30 percent. This is called the *fiber saturation point*. At the fiber saturation point, all water has been removed from the wood fibers' cell cavities (lumens), but the wood fibers' cell walls still are fully saturated. When the wood's surface reaches the fiber saturation point, it begins to shrink and continues shrinking in an almost linear fashion until the wood is completely dry (i.e., contains no water at all). Most dimension lumber can be graded officially as dry if its moisture content is below 19 percent, or below 15 percent if graded (KD15).

Some mills have a problem with drying variability. In trying to dry all lumber below 19 (or 15) percent, some lumber might be near 5 percent. Lumber at 5 percent moisture content shrinks more than lumber at 15 percent. The excessive shrinkage causes the mill's QC department to set target sizes in the mill thicker or wider than would otherwise be necessary.

A wide range in moisture content may be due to natural causes but, if excessive, more likely it is because drying kilns are not under good control. The bottom line is that poor drying practices can result in larger-than-necessary green target sizes just as poor sawing can.

## Sawing variation

Sawing variation is the last target-size component. Sawing variation information is useful not only for estimating target size but, more important, in troubleshooting machine center problems.

Sawing variation is an indicator of how accurately a sawing-machine center cuts lumber. Total sawing variation, $S_T$, has two components: *within-board sawing variation* and *between-board sawing variation.* Being able to distinguish between the two allows quality-control personnel to troubleshoot machine center problems.

### *Within-board variation*

Within-board variation, $S_W$, is a measure of how the thickness or width varies along the length of a board. The three types of within-board variation are *snake*, *wedging*, and *taper.* Snake is the variation along one face of the board relative to the opposite face (Figure 4).

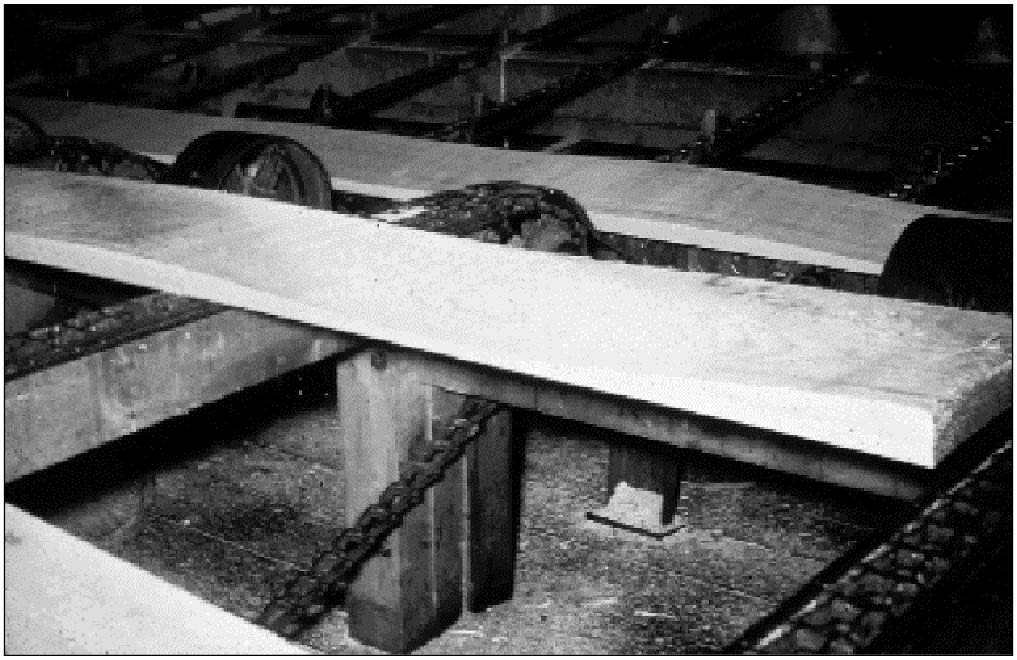

*Figure 4.—Extreme within-board variation ("snake").*

One of the primary causes of saw snake is overfeeding a saw during cutting. Even when snake does not result but within-board variation is above acceptable limits, overfeeding can be the cause.

Edge-to-edge *wedging* is a tapering of thickness from one edge of the board to the other; it may not extend the entire length of the board. Alignment and feeding problems in the machine center typically also cause wedging.

End-to-end *taper* is a progressive decrease or increase in thickness from one end of the board to the other. Typical causes are feeding and alignment problems in the machine center.

When these types of variation occur, quality-control personnel should look to these potential sources of the problem. Not all within-board variation can be attributed to these causes, but they are good places to start.

### *Between-board variation*

Between-board variation, $S_B$, measures how the average thickness or width of a board varies from one board to the next coming from the same saw line or machine center.

If lumber with excessive between-board variation comes from the same saw line (Figure 5, page 8), then setworks or set repeatability should be examined. If the variation is coming from different saw lines, then saw spacing—either fixed or setworks-based—and individual saw kerf should be evaluated as potential causes.

It is important to realize that what may appear to be a between-board variation problem in a particular machine center may, in fact, be unrelated to that machine center. The reason instead may be that a cant that had been processed by a machine center earlier in the work flow was processed through the edger or resaw. The outside board may be a different size because the entire cant was badly manufactured earlier by the other machine center.

### *Total sawing variation*

Total sawing variation, $S_T$, is the mathematical relationship of within-board and between-board variation. With planer allowance and shrinkage allowance, it is used in the equation to estimate rough green target size.

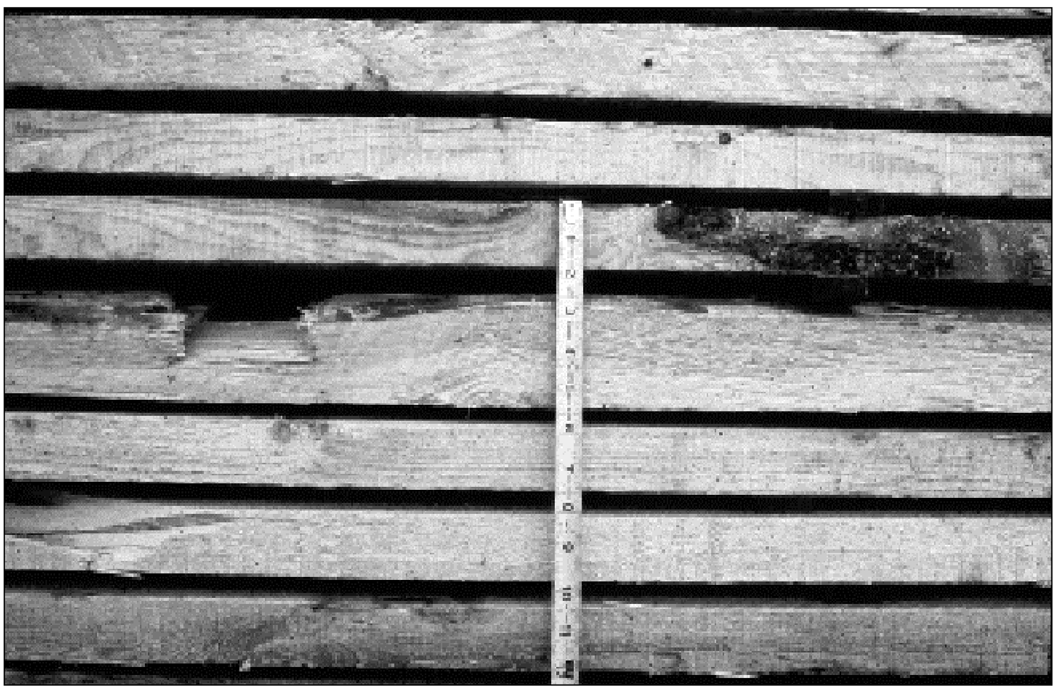

*Figure 5.—Excessive between-board variation.*

## Statistical linkages

Sawing variation is a much easier concept to grasp for most sawmill personnel than the statistical term *standard deviation*. However, all size-control software uses the term standard deviation. We typically talk about within-board, between-board, and total sawing variation, but in fact we really are talking about within-board, between-board, and total sawing standard deviation.

***Standard deviation…***

is a statistical term that expresses the amount of variability in a process.

### *Standard deviation*

Standard deviation is a term that statisticians use to express the amount of variability in a process. The greater the variability in thickness or width of lumber coming from a machine center, the greater the standard deviation, be it within-board, between-board, or total sawing. The formulas to calculate standard deviation are discussed on pages 21–22.

Usually, data on the sizes of lumber produced by a given sawing-machine center will, when plotted on a graph, form a bell-shaped curve (Figure 6). This type of curve, or *distribution* of data, is considered a *normal distribution*; in other words, in most cases most machine centers produce lumber with these size variations.

A normal distribution can be used to make some predictions of how all lumber cut on a machine center is being cut, based on smaller sample sizes. Not all pieces sawn on a machine center will be normally distributed, but they will be close enough to be treated that way. In Figure 6, the curve on the left has a larger total standard deviation, $S_T$, than the distribution on the right. That is, the range of thicknesses of boards from the machine center on the left is greater than the range from the machine center on the right. (Note that average thickness is the same for both machine centers.)

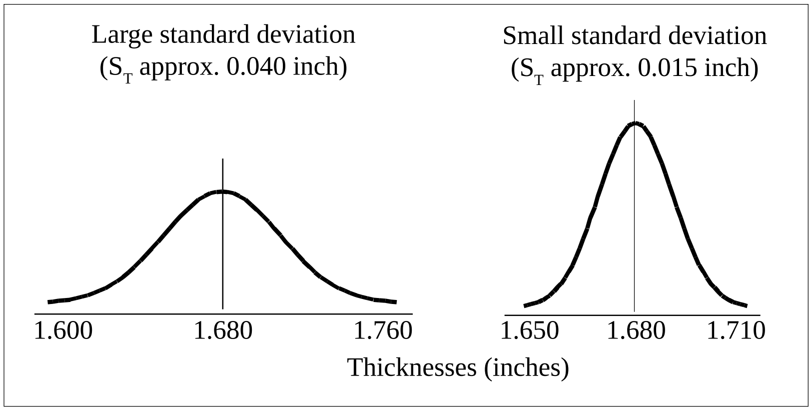


*Figure 6.—Two size distributions with different standard deviations.*

***Estimating standard deviation given the thickest and thinnest boards***

If you know the thickest, thinnest, and average thickness in a sample of boards—and you assume these data are part of a normal distribution—it is possible to estimate the total standard deviation of the distribution. A handy statistical shortcut states that the thicknesses of 95 percent of all boards cut on a machine center will be between two standard deviations above and two standard deviations below the average size. Stated another way, the total standard deviation will be one-fourth of the range between the thinnest and thickest pieces of lumber measured.

Figure 7 shows a distribution with a range of 0.120 inch between the thickest and thinnest measurements. Estimated total standard deviation is one-fourth the total range, or 0.120 ÷ 4 = 0.030 inch. It's that simple to calculate, and it gives mill personnel a much better understanding of the relationship of standard deviation to the thickest and thinnest boards from that particular machine center.

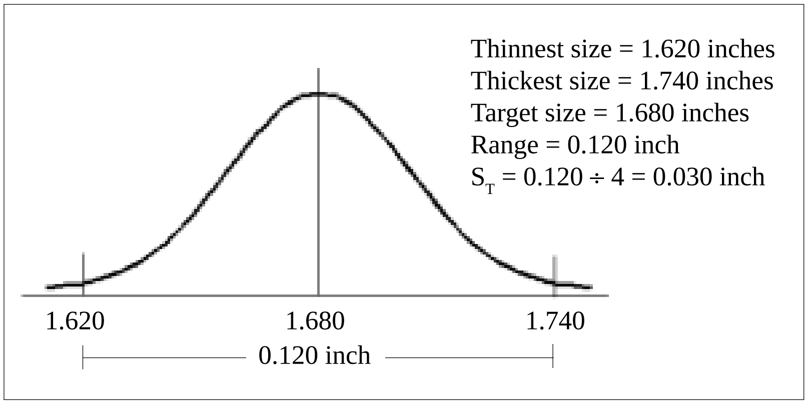


*Figure 7.—Estimating standard deviation from distribution end points.*

For those who use true statistical control charts in quality-control programs, the upper and lower control limits on the control charts are calculated as three standard deviations above and three standard deviations below the average of the pieces being measured. The total of six standard deviations from the thickest to the thinnest boards covers 99.9 percent of all boards cut on a machine center, not the 95 percent used in the preceding example.

Because we typically use small samples, however, the statistical shortcut of 95 percent is more appropriate. In the example below, the thickest and thinnest measurements in a sample of, say, 10 boards would not in all likelihood be the smallest and largest sizes cut on that machine center. In the example above, if we were to use control chart upper and lower control limits, which assumes 99.9 percent coverage, we would have divided the 0.120 range in thickness by six, not four. This would have resulted in an estimated total standard deviation of 0.020 inch, not 0.030 inch. In my opinion, because samples tend to be small, this would leave the impression that the standard deviation was smaller than it in fact probably was. Ultimately, this could lead to reducing a target size by more than it should be.

*Table 1. Sawing-accuracy benchmarks for softwoods.*

| Machine center | Total standard deviation ($S_T$) |
|---|---|
| Headrig/carriages | 0.030–0.050 inch |
| Band resaws | 0.020–0.030 inch |
| Board edgers | 0.020–0.040 inch |
| Rotary gangs | 0.005–0.015 inch |

### *Estimating thickest and thinnest boards given the standard deviation*

To estimate the thickest and thinnest boards in a sample, we calculate in the opposite direction from the example above. Figure 8 shows a distribution with an average size of 1.680 inches and a total standard deviation of 0.040 inch. The upper value (i.e., thickest board) is calculated:

$$1.680 + (2 \times 0.040) = 1.680 + 0.080 = 1.760 \text{ inches.}$$

Likewise, the lower value (thinnest board) is calculated:

$$1.680 - (2 \times 0.040) = 1.680 - 0.080 = 1.600 \text{ inches.}$$

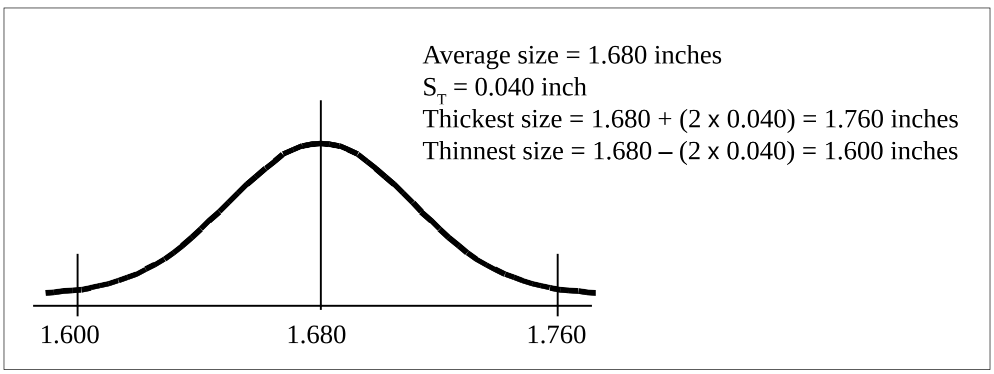


*Figure 8.—Estimating thickest and thinnest boards from the standard deviation.*

## *Critical size*

Figure 6 (page 9) illustrates two different thickness distributions. Both distributions have an average thickness of 1.680 inches, but the difference in their standard deviations indicates very different thickness ranges. Does either distribution mean that undersize boards will come out of the planer? It is impossible to tell without additional information. To see whether undersizing is predicted by any distribution, we need to use another tool: *critical size*.

***Critical size…***

is the minimum size that lumber can be cut and still stay within grade size by the end of the process.

Simply put, critical size is the minimum size that lumber could conceivably be cut and still stay within grade size by the end of the process. The concept of critical size assumes no sawing variation in thickness or width—which is impossible, of course, in the real sawmill. Critical size is represented graphically by the three smallest "steps" in Figure 1 (page 3). Only when sawing variation is added to critical size do we get the rough green target size.

For surfaced-green 2-inch (nominal dimension) lumber such as Douglas-fir, the critical size is the final size, 1.560 inches, plus the planing allowance of, say, 0.030 inch bottom head and 0.030 inch top head. Thus, the critical size is 1.560 + 0.060, or 1.620 inches. In other words, even if there were no sawing variation, the lumber would need to be cut to at least 1.620 inches. Notice that in this example there is no shrinkage allowance factored into the critical size because Douglas-fir dimension lumber often is sold surfaced-green to a final size of 1.560 inches.

Under some circumstances, the critical size might not be 1.620 inches. For lumber to be cleanly surfaced, the top head planing allowance does not have to be a full 0.030 inch if the lumber is straight, flat, and not overly rough. Recall that in this example, the bottom head allowance is 0.030 inch, and so the planer will take off that much. The top head takes off what is left in excess of the desired final size. Thus, a person might argue that the true critical size is 1.560 + 0.030 + "some very small amount" to allow for the top head to plane the top surface.

The problem is that "some very small amount" could end up being an amount as large as the bottom head allowance depending on warp, roughness, and other features of the lumber being planed. As a result, I always define critical size as containing just as much top head allowance as bottom head allowance—perhaps not strictly necessary but warranted from a practical standpoint. If the allowance for top head removal exceeds "some very small amount," this safety margin helps compensate for variations in shrinkage and planing.

The critical size for surfaced-green lumber, then, is defined as:

$$CS = F + P$$

Where CS = Critical size
F = Final size
P = Total planer allowance (both top and bottom heads)

Using values from the example above, the critical size is:

$$CS = 1.560 + 0.060 = 1.620 \text{ inches}$$

When setting critical size for surfaced-dry lumber such as southern pine or SPF, shrinkage must be considered. The critical size for surfaced-dry lumber is:

$$CS = (F + P) \times (1 + \%Sh/100)$$

Where %Sh = Percent shrinkage

Given a final size of 1.500 inches, a total planer allowance of 0.080 inch, and shrinkage of 3 percent, the total calculation for surfaced-dry lumber critical size is:

$$CS = (1.500 + 0.080) \times (1 + 3/100)$$
$$CS = 1.580 \times 1.03 = 1.627 \text{ inches}$$

## Rough green target size

Rough green target size should be determined for each sawing machine center so that the amount of undersize lumber coming from that machine center is minimal. As seen in Figure 1 (page 3), rough green target size includes critical size (final size + planing allowance + shrinkage allowance, if the lumber is dried) and an added amount of sawing variation. We assume that the target size in all the figures showing a size distribution is the same as the average size of the distribution. In fact, this is not normally the case in the mill. Target size is a desired result, sometimes a planned-for result. Average size, however, is an actual result and may or may not be the target size. Actually, many times a machine center may be set to a target size of, let's say, 1.680 inches, but the average size of the lumber cut is 1.700 inches. In that case, 1.700 inches is the center of the size distribution.

The key point in establishing rough green target size is to minimize undersizing. Let's look at this point, using the critical size of 1.620 inches which we calculated for surfaced-green Douglas-fir and the two size distributions in Figure 6 (page 9). Remember, we cannot tell whether either distribution in Figure 6 predicts the lumber will be undersize because we don't yet know the critical size in either distribution.

## A balanced distribution

In this example, the target size is 1.680 inches, total standard deviation ($S_T$) is 0.030 inch, and we assume that 95 percent of the lumber is between 1.740 and 1.620 inches thick. We calculated critical size to be 1.620 inches. Because the size of the thinnest board, 1.620 inches, is the same as the critical size, we say that this distribution is *balanced* (Figure 9, page 14).

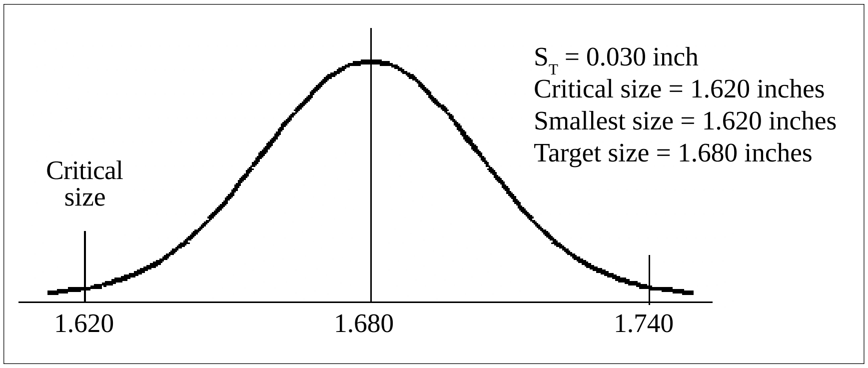


*Figure 9.—Balanced size distribution.*

All lumber thinner than 1.620 inches (critical size) will be undersize after final cut. So, given the distribution in Figure 9, how much lumber is undersize? Recall the rule of thumb: thicknesses of 95 percent of the lumber will be within in a range equal to two standard deviations on either side of the average size. Therefore, of the lumber remaining, 2.5 percent will be thicker than 1.740 inches and 2.5 percent will be thinner than 1.620 inches—that is, undersize. In the example illustrated in Figure 9, our target size could be the same as the average size, 1.680 inches. Because the thin end of the range (the lower thickness value) and the critical size are the same, we are undersizing only about 2.5 percent of the lumber being cut.

This situation would be considered ideal and balanced for a final size of 1.560 inches, a planer allowance of 0.060 inch, a total standard deviation of 0.030 inch, and a target size of 1.680 inches. Unfortunately, this is not always the case in lumber manufacturing.

## Neglecting a size control program results in a too-small target

Let's first look at the case of a mill that once had an effective lumber size control program and a target size of 1.680 inches. Now, because they have not done a good job of either monitoring or maintaining the machine center, their total standard deviation, $S_T$, has grown to 0.040 inch. Figure 10 shows this distribution as the bell-shaped curve on the left. Because the $S_T$ is 0.040, the thickest and thinnest sizes are 1.760 and 1.600 inches respectively. Note that critical size is 1.620 inches. An unacceptable amount of lumber is being produced below 1.620 inches—far more than 2.5 percent. This will result in excessive skip.

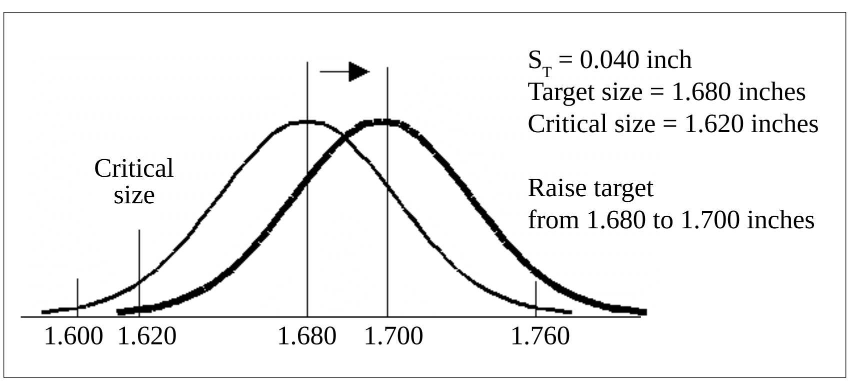


*Figure 10.—Target too small.*

The only way the mill can prevent undersizing is to raise target size. But by how much? By 0.020 inch, to 1.700 inches. This shifts the distribution to the right, as represented by the heavier-line bell curve. The lower end point rises from 1.600 to 1.620 inches, which coincides with critical size and an undersize rate of 2.5 percent. Figure 10 illustrates what most lumber manufacturers know intuitively: if your sawing variation (thick and thin) increases, you have to raise the target size to keep from undersizing lumber.

## An excellent size control program enables a target-size reduction

A company that dedicates itself to creating an excellent size control program can reduce target sizes without increasing the percentage of undersize lumber. For example, a particular machine center in this mill once produced lumber with an average size of 1.680 inches, a critical size of 1.620 inches, and a total standard deviation, $S_T$, of 0.030 inch. The "before" data in Figure 11 create a distribution in balance; that is, the lower limit of thickness and the critical size are the same.

Now, after many months of diligent effort, this mill has reduced total standard deviation to 0.015 inch. The "after" data result in the more compressed bell curve in Figure 11. After reducing $S_T$ to 0.015 inch, the smallest size has been raised to 1.650 inches. The critical size is 1.620 inches, so it is clear that there is no undersizing at all. As a result, the mill can reduce its target size. Figure 12 shows that the original target size can be reduced from 1.680 to 1.650 inches with no increase in undersizing.

What is this worth to the mill? That depends on the amount of lumber this machine produces and on lumber prices. For a rotary gang in a small-log

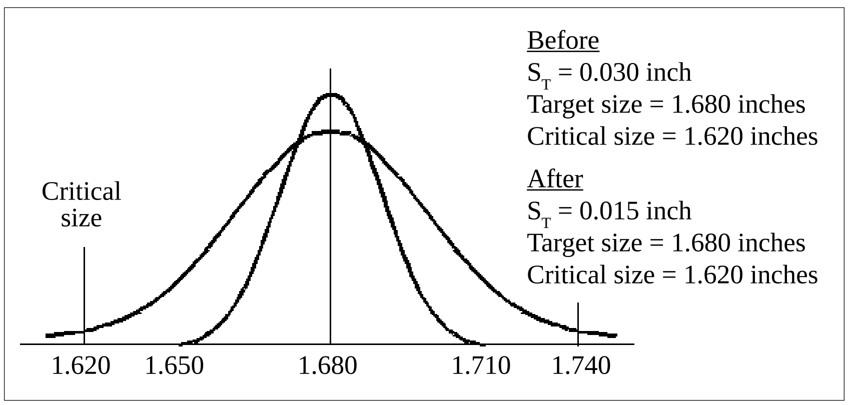


*Figure 11.—Reduction in $S_T$.*

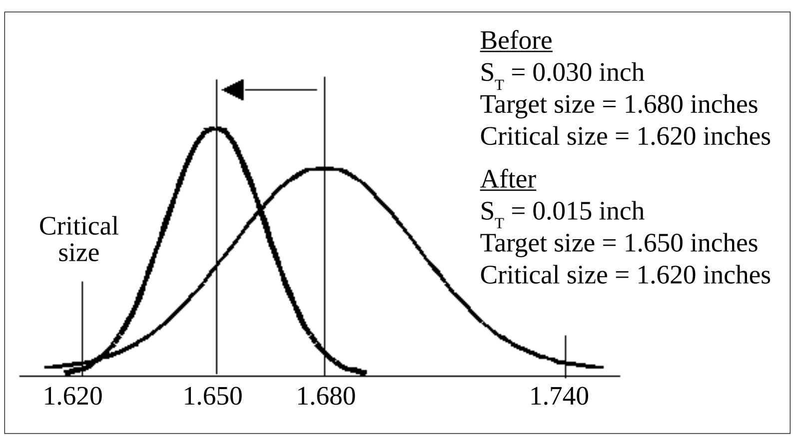


*Figure 12.—Reduction in $S_T$ enables a reduction in target size.*

*Table 2. Z values.*

| Undersize boards (%) | Z |
|---|---|
| 0 | 3.09 |
| 1 | 2.34 |
| 2 | 2.05 |
| 2.5 | 1.97* |
| 3 | 1.88 |
| 4 | 1.75 |
| 5 | 1.65 |
| 10 | 1.28 |
| 15 | 1.04 |

*2 approximates this value in examples

sawmill cutting 80 MMBF per year, it could amount to $300,000 or more in increased revenues.

### About undersizing

Undersize has been defined many ways. I define undersize lumber as any lumber that, after planing, has some part of its wide or narrow faces that are not smoothly surfaced, that show skip. Lumber sold in the rough green state is undersize if any part of it is smaller than the final graded size.

It is important to note that some products, such as lam-stock and shop, cannot be at all undersize. On the other hand, dimension or structural lumber graded “2 & better” can be up to 1⁄16-inch (0.063 inch) scant, as spelled out in grade rules, and still make grade. Therefore, lam-stock usually is produced to a thicker target size than dimension lumber.

Even though undersize is a relative term depending on the products, it is possible to establish a target size based on a certain amount of allowable undersize. In each of the previous examples, the amount of undersize allowed was approximately 2.5 percent. Because a normal, or bell-shaped, curve is symmetrical on both sides of the average-size point, a corresponding 2.5 percent of the lumber is oversize. This leaves 95 percent of the lumber between these two points because, as previously stated, statistical theory is that 95 percent of all lumber will fall between + 2 $S_T$ and – 2 $S_T$ of the average. That is how we determined the thickest and thinnest sizes in Figure 8 (page 11).

What if we wanted to establish a target size based on some undersize rate besides 2.5 percent? We would multiply $S_T$ by a value called the *standard normal deviation,* which is referred to as Z. Table 2 lists several values of Z for various rates of undersize. These values are statistically determined and are based on the characteristics of a normal distribution.

Figure 13 illustrates that the target size is Z x $S_T$ above the lower thickness value (thinnest size), 1.620 inches. In this example, Z = 2. (The lower thickness value and critical size are the same in this example.)

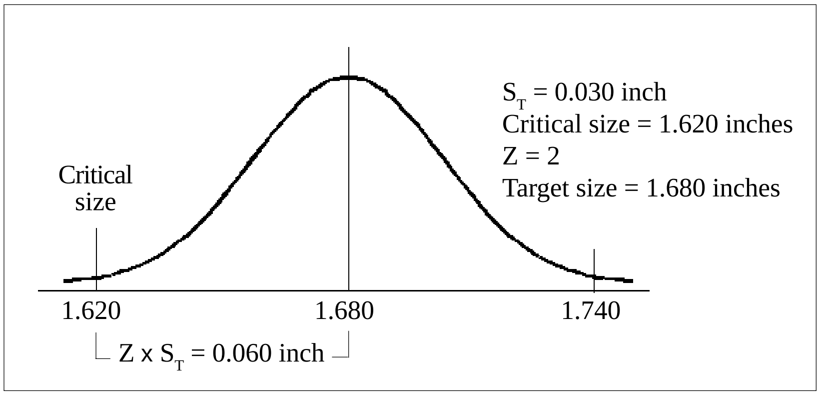


*Figure 13.—Relationship of Z x $S_T$ to target size.*

## Estimating target size

All components of the target-size equation have been described. Now they can be put together to estimate target size for surfaced-green lumber:

$$T = [(F + P) \times (1 + \%Sh/100)] + (Z \times S_T)$$

Where T = Target size
F = Final size
P = Total planer allowance
%Sh = Percent of shrinkage (zero, in this case)
Z = Standard normal variation
$S_T$ = Total sawing deviation

Thus:

$$T = [(1.560 + 0.060) \times (1 + 0)] + (2 \times 0.030)$$
$$= (1.620 \times 1) + 0.060$$
$$= 1.620 + 0.060$$
$$T = 1.680 \text{ inches}$$

Notice in Figure 12 (page 15) that in both “before” and “after” cases critical size is 1.620 inches and target size is calculated by adding ($Z \times S_T$) to critical size. In both instances, Z = 2.

The target-size equation above gives only an *estimate* of what target size actually should be. I cannot state this strongly enough: it is only an estimate, but probably a reasonable start. Recall that the definition of undersize is somewhat a moving target depending on the product being manufactured. Another factor that affects target-size calculation is that we in effect add wood fiber to account for planer allowance, and we add more wood fiber to account for sawing variation. One of the components of sawing variation is within-board variation ($S_W$). The greater the within-board variation, the larger $S_T$ will be, but the relationship between the two isn’t as simple as adding or subtracting. That’s because part of within-board variation is removed during planing, and there is no way to say just how much will be removed because within-board variation is different from board to board.

Another component of the target-size equation that also varies from board to board—and even within a board—is shrinkage. The target-size equation treats shrinkage as a constant, *Sh*. However, some boards may be cut a little thin in the sawmill and do not shrink as much in drying as another board cut to the correct size. In both cases, these boards could be planed with no undersize.

If we wanted to get very heavily involved in mathematics, we would have to view shrinkage as a bell-shaped distribution just as

***Estimating target size …***

is valuable in establishing whether or not an existing target size is realistic.

sawing variation is, then try to develop a relationship that can account for each possible combination of thickness and shrinkage. To make it more complex, then we would have to recognize that the planer does not surface each board to the exact same thickness or width, and that final size also is a bell-shaped distribution, which would have to be considered in the target-size equation. Finally, we would have to realize that some boards have surfaces that are cut on two different machine centers, and we would need to account for the variation in each machine center as part of the target-size equation. It is just not practical to try to accommodate all this in calculating target size. As a result, we assume that planer allowance and shrinkage are constants. This causes the target-size calculation to be only an estimate of true target size. Some readers might think that, because of these factors, estimating target size has no value. To the contrary, an estimate is valuable in establishing whether or not an existing target size is realistic.

It bears repeating that the true value of size control is not in trying to estimate a target size. It is in using the values of $S_W$ and $S_B$ to troubleshoot machine centers, with the goal of reducing both components of variation over time and thus reducing total sawing variation, $S_T$. Only then can mills begin the process of reducing target sizes.

## When and how to reduce target sizes

Target-size reduction should be started only after quality control personnel are certain they can maintain a reduced total sawing variation on a machine center over a month's time. There have been instances in which a mill's QC supervisor measured the sawing variation on a machine center, and it just happened that, due to a particular combination of saws and feed speed that day, the sawing variation was much lower than usual. Management then decided to reduce target size based on that measurement. A few days later, after additional lumber had been manufactured, dried, and planed, that lumber was found to be undersize.

Once the machine center has been kept under control for a month or so, it is appropriate to consider reducing the rough green target size. Now the question becomes, by how much? Begin calculating by plugging in the old and new values for $S_T$ in the target-size equation. This will tell you the relative magnitude of the change. Next, if the mill is evaluating a machine center that has settable sizes, reduce the target size by half the amount first estimated, and saw several hundred boards at several different times during the day. Track those boards until they are planed, then evaluate the results. If everything is still OK, reduce the target the rest of the way and reevaluate as before.

#### *Reducing target sizes on rotary gangs*

Deciding to reduce a target size on a rotary gang is not easy; usually it involves a major change in the guides and spacers, thus creating a major expense to the mill. It is much better to simulate what that size reduction would look like after planing the lumber. This is easily done by making a test run. Recall that if the mill is not going to reduce the bottom head planer allowance, the change in target size will affect only how much wood the top head removes. Let's say a reduction of 0.030 inch is being considered. For the test run, set the final size out of the planer to 0.030 inch thicker by raising the top head 0.030 inch. This simulates what would be removed by the top head if the target were reduced by 0.030 inch and if final size were the same as before. This approach is much less costly than a rotary gang retrofit and yet accomplishes the same thing.

***Look at a large number of logs…***

with a complete log-diameter distribution for your mill to see how small changes in target size can increase recovery.

### Small target reductions and their impact on recovery

Some people mistakenly believe that a reduction in target size of 0.030 inch, for example, cannot translate into added recovery because they believe it is not possible to get another board from so small a change. Granted, it is not very often that another board is gained by a change this small. The added recovery comes from longer boards and wider boards being created in either cants or side boards. The easiest way to see the effect of target-size changes—and, for that matter, kerf changes—on recovery is to run data on a series of logs through the mill's headrig computer program, if one is installed, using current mill settings and the new (reduced) kerf or target-size settings. It should be possible to see, log by log, the board-foot recovery before and after. If such a software program is not installed, commercial programs exist that allow QC personnel to simulate sawing various log mixes according to different mill parameters.

Not every log is affected by a small target-size change. Certain increases in log diameters will yield significant increases in board lengths and widths; others will not. Look at a large number of logs with a complete log-diameter distribution for your mill to see a true picture of the potential that small changes in target size have for increased recovery. In addition, these programs can be used to determine the impact of wane allowance changes as compared to a resulting change in market price for the lumber.

## Calculating $S_W$, $S_B$, and $S_T$

Calculating within-board, between-board, and total sawing standard deviation is a necessary part of any size control program. Originally size control methods were developed so that people could use calculators to determine these values (Brown 1982, 1986). Today, dedicated lumber-size-control programs and computer spreadsheets are widespread. Calculator methods are no longer time-efficient.

Readers not interested in the background mathematics of size control should skip this next section; those interested in the derivation of within-board, between-board, and total sawing standard deviation should read on.

### *New statistical methodology*

The methodology used previously (Brown 1982, 1986) is based on original work by Warren (1973). This Analysis of Variance Approach (ANOVA) is slightly more accurate than the new methodology presented here. However, there was a problem with the older methodology. If within-board standard deviation was large, the value for between-board standard deviation would compute as zero. Statistically, this was like saying that all the variation in size was due to within-board standard deviation. From an ANOVA standpoint, between-board standard deviation encompasses a within-board standard deviation component. The within-board deviation component divided by the number of measurements per board was subtracted from the between-board component in the older method; the remainder was pure between-board deviation when $S_B$ was calculated (Brown 1982, page 133). If that within-board component ($S_W$ ÷ the number of measurements) was larger than the between-board component, $S_B$ was assumed to be zero.

This outcome, though uncommon, did not lend itself well to the practical matter of using within- and between-board standard deviation to troubleshoot machine centers. As a result, the new method of calculating $S_B$ does not subtract the within-board deviation divided by the number of measurements per board, eliminating the $S_B = 0$ result. Obviously, values calculated for $S_B$ by this new method will be slightly larger than by the old method. However, if four to six measurements per board are taken, the difference in $S_B$ values is minimal, only a few thousandths of an inch.

Included here are the statistical formulas for the new methodology as well as tables from a Microsoft Excel spreadsheet that show the calculations and underlying spreadsheet formulas to calculate the various standard deviations.

Table 3 is based on a sample of eight boards with four measurements per board, which will be used to calculate the standard deviation.

*Table 3. Lumber measurements and calculated values for lumber size control.*

| Board number | Board measurements 1 | 2 | 3 | 4 | Board average | Mean square | Standard deviation |
|---|---|---|---|---|---|---|---|
| 1 | 1.700 | 1.730 | 1.710 | 1.720 | 1.7150 | 0.0001667 | 0.013 |
| 2 | 1.670 | 1.720 | 1.700 | 1.710 | 1.7000 | 0.0004667 | 0.022 |
| 3 | 1.690 | 1.720 | 1.700 | 1.680 | 1.6975 | 0.0002917 | 0.017 |
| 4 | 1.740 | 1.730 | 1.750 | 1.720 | 1.7350 | 0.0001667 | 0.013 |
| 5 | 1.700 | 1.680 | 1.660 | 1.670 | 1.6775 | 0.0002917 | 0.017 |
| 6 | 1.710 | 1.720 | 1.720 | 1.740 | 1.7225 | 0.0001583 | 0.013 |
| 7 | 1.660 | 1.690 | 1.680 | 1.680 | 1.6775 | 0.0001583 | 0.013 |
| 8 | 1.710 | 1.750 | 1.740 | 1.720 | 1.7300 | 0.0003333 | 0.018 |
| | | | | Totals | 13.6550 | 0.0020333 | |

Within-board standard deviation ($S_W$) = 0.016
Between-board standard deviation ($S_B$) = 0.022
Total standard deviation ($S_T$) = 0.025

***Formulas for calculating $S_W$, $S_B$, and $S_T$***

$x_i$ = Individual board measurement
$n_j$ = Number of measurements in board *j*
k = Number of boards
N = Total number of measurements
$Avg_j$ = Average of measurements for board *j*. These values are used to calculate the between-board standard deviation.
$MS_j$ = Mean square (variance) for board *j*. These values are used to calculate the within-board standard deviation.
$S_j$ = Standard deviation of board *j*
$S_B$ = Between-board standard deviation. The value calculated is the standard deviation of the board averages.
$S_W$ = Within-board standard deviation. The value calculated is an average of the individual board standard deviations.
$S_T$ = Total standard deviation

Standard deviation and mean square (variance) of measurements in board *j* (values from board 1, Table 3, used in example):

$$S_j = \sqrt{\frac{\sum_{i=o}^{n_j} x_i^2 - \frac{\left(\sum_{i=o}^{n_j} x_i\right)^2}{n_j}}{n_j - 1}} = \sqrt{\frac{11.7654 - \frac{6.860^2}{4}}{4-1}} = 0.01291$$

$MS_j = (S_j)^2 = (0.01291)^2 = 0.0001667$ inch

Within-board standard deviation:

$$S_W = \sqrt{\frac{\sum_{j=o}^{k} MS_j}{k}} = \sqrt{\frac{0.0020333}{8}} = 0.01594$$

Between-board standard deviation:

$$S_B = \sqrt{\frac{\sum_{j=o}^{k} Avg_j^2 - \frac{\left(\sum_{j=o}^{k} Avg_j\right)^2}{k}}{k-1}} = \sqrt{\frac{23.310875 - \frac{13.655^2}{8}}{8-1}} = 0.02235$$

Total standard deviation:

$$S_T = \sqrt{\frac{\sum_{i=o}^{N} x_i^2 - \frac{\left(\sum_{i=o}^{N} x_i\right)^2}{N}}{N-1}} = \sqrt{\frac{93.2496 - \frac{54.620^2}{32}}{32-1}} = 0.02546$$

These are the equations that Microsoft Excel uses to calculate standard deviation. Table 4 shows the same eight-board sample with the underlying Excel equations for the calculations above and in Table 3.

*Table 4. Excel formulas for statistical calculations.*

| Board number | Board measurements 1 | 2 | 3 | 4 | Board average | Mean square | Standard deviation |
|---|---|---|---|---|---|---|---|
| 1 | 1.700 | 1.730 | 1.710 | 1.720 | = AVERAGE (B4:E4) | = Std Dev 2 | = STDEV (B4:E4) |
| 2 | 1.670 | 1.720 | 1.700 | 1.710 | = AVERAGE (B5:E5) | = Std Dev 2 | = STDEV (B5:E5) |
| 3 | 1.690 | 1.720 | 1.700 | 1.680 | = AVERAGE (B6:E6) | = Std Dev 2 | = STDEV (B6:E6) |
| 4 | 1.740 | 1.730 | 1.750 | 1.720 | = AVERAGE (B7:E7) | = Std Dev 2 | = STDEV (B7:E7) |
| 5 | 1.700 | 1.680 | 1.660 | 1.670 | = AVERAGE (B8:E8) | = Std Dev 2 | = STDEV (B8:E8) |
| 6 | 1.710 | 1.720 | 1.720 | 1.740 | = AVERAGE (B9:E9) | = Std Dev 2 | = STDEV (B9:E9) |
| 7 | 1.660 | 1.690 | 1.680 | 1.680 | = AVERAGE (B10:E10) | = Std Dev 2 | = STDEV (B10:E10) |
| 8 | 1.710 | 1.750 | 1.740 | 1.720 | = AVERAGE (B11:E11) | = Std Dev 2 | = STDEV (B11:E11) |
| | | | | Totals | = SUM (Board avg.) | = SUM (Mean sq.) | |

Within-board ($S_W$) = SQRT (Sum_Mean_Sq/8)
Between-board ($S_B$) = STDEV (Board avg.)
Total standard deviation (ST) = STDEV (Board_Measurements)

Typically most mills never calculate the equations in this section manually. Most mills serious about size control buy lumber size control software to run on a personal computer.

### *Lumber size control software*

There are two ways to analyze size measurement data. The first and least expensive is to use a spreadsheet to calculate $S_W$, $S_B$, and $S_T$. The big disadvantage is that a mill does not get much additional information, nor can managers archive the information and combine it over time with other measurements.

From a time and information standpoint, the best way to analyze size measurement data is with a dedicated, full-feature computerized size control program. In addition to calculating sawing variations, such programs provide multiple ways to display results and analyze size information. They act as databases in which size data can be stored for later retrieval or combined with measurements taken at later times. In addition, there are data collection systems that connect to digital calipers. These systems greatly increase the speed and efficiency of taking measurements. They have some onboard data analysis capabilities and, most important, can download measurements directly into their PC-based size control programs. Check trade publications and the Internet to learn more about what specific software programs have to offer.

### *Sawing accuracy benchmarks for softwoods*

Table 1 (page 11) lists some sawing-accuracy benchmarks that represent the current abilities of sawing-machine centers to cut *softwoods* accurately. In general, rotary gangs saw lumber most accurately, bandmill carriage systems the least accurately. In a small-log sawmill, all rotary gangs should be cutting with an $S_T$ of 0.015 inch or less, and all resaws at 0.025 inch or less. Shifting edgers tend to be the least accurate.

## The future of size control

As long as sawmills exist, they will need to evaluate individual machine centers. Currently, using manually operated caliper devices is the most common way to collect size information. But in 5 to 10 years, manually collecting size information will be done only in special troubleshooting cases. By then, most lumber size measurements will be made by extremely accurate automated systems.

**_Size control programs…_**

*must* extend beyond the sawmill if they are to be successful.

Currently there are two technological reasons that automated size control methods have not been successful commercially. First is that lasers and other noncontact measuring methods cannot measure lumber to a 0.005- to 0.010-inch precision in the mill—the precision necessary to equal dial caliper measurements. Second, current systems cannot identify which machine center produced which board. Both these limitations will be overcome in the next few years. When that happens, sawmill size control programs will evolve into an even more effective tool. No longer will quality control personnel have to spend so much time measuring lumber. They finally will be free to focus their efforts on analyzing what the numbers are telling them. They also will have more time to conduct recovery and other types of studies that help determine where to focus QC efforts for the greatest benefit. Indeed, lumber size control will become even more meaningful to a mill's overall QC program because the data collected by automated systems will provide a more complete view of a machine center's sawing capability.

### Keeping target sizes small is not just a sawing variation issue

A mill's size control program focus must extend beyond the sawmill if it is to be successful. What good does it do to put a great amount of effort into a size control program but ignore how well the kilns dry the lumber? Overdried lumber shrinks and warps more and can create the illusion that undersize at the planer is due to sawing too thinly in the mill. Likewise, if the planer's bottom head is set to take off too much, the result can be undersize lumber. In either case, the "solution" probably will be to saw thicker and wider lumber in the mill—even though the problem was not at the mill but at the kilns or planer.

The solution is to view quality control as much more than size control, and to view size control as much more than just what happens in the sawmill. It takes everyone's concentrated efforts to maintain excellence in all phases of manufacturing. The definition I like for quality control is “maximizing the value of the log and lumber product through all phases of manufacturing while maintaining or increasing production and meeting the needs of internal and external customers.”

## The attitude of size control

The true value of size control is the management philosophy that accompanies the arithmetic. The philosophy seeks to systematically identify opportunities, then respond to make improvements. The process described here is only the arithmetic to estimate a reasonable target size. The philosophy goes beyond this. The day is approaching when boards will be measured automatically in the process flow and all calculations will be by computer. But the philosophy of size control will continue. Quality-control personnel must continue to identify opportunities systematically and then respond by making improvements.

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