

# Quality Control Troubleshooting Tools for the Mill Floor

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## Introduction

Statistical Process Control (SPC) provides effective tools for improving process quality in the forest products industry resulting in reduced costs and improved productivity. Implementing SPC helps identify and locate problems that occur in wood products manufacturing. SPC tools achieve their real value when applied on the mill floor for monitoring and troubleshooting processing problems.

This paper looks at SPC tools called control charts and describes the interpretation of statistical process control information as it relates to troubleshooting processing problems and improved mill efficiency. The presentation is designed to bridge the gap between quality control and process performance problems encountered on the mill floor. Example control charts with step-by-step procedures show how control charts help identify processing and quality problems. A case study is presented to illustrate the benefits of such things as lumber size control, tightening up, and improved mill efficiency.

## Control Charts

Control charts are valuable diagnostic (troubleshooting) tools that identify when process trouble occurs. They objectively evaluate process performance. The power of the control chart comes from its ability to determine when a process is in chaos and when it is in statistical control. Control charts do this by separating special causes of variation from common causes of variation. “In essence, control charts are your process talking to you” (Deming 1986).

## Nature of Process Variation

Process variation is inevitable and can be classified as either special causes of variation or common causes of variation. Special causes are unnatural intermittent interruptions to a process that affect some of the output some of the time. Common causes of variation occur naturally and are part of the system, affecting all output all of the time. It is important to know what type of variation is causing trouble, as the actions needed to correct them are totally different.

**Special Causes of Variation**—Special causes of variation result from either process instability (i.e., chaos) or a shift in process centering (i.e., process average). Process performance will be unpredictable and unmanageable until special causes of variation are removed from the process. While special causes occur relatively infrequently, they represent excessive process variation. Fortunately, special causes can be discovered, corrected, and controlled, usually by employees on the mill floor. This is done by monitoring the process with control charts, searching for special causes, and taking corrective action. Corrective action may be as simple as making a minor adjustment to the process or changing out a dull saw. Special causes are generally less expensive to track down and correct than common causes.

Common Causes of Variation — are characterized by a stable system of trouble (Deming 1986). Common causes are due to the design and operation of the process itself and affect all output. No amount of adjustment can correct the common faults of a process. The process can only be improved by removing common causes of variation (Gitlow and others 1989) through such efforts as rebuilding or replacing worn equipment, training employees, and employing preventative maintenance (PM). Improving the process can be expensive but worth the benefits received.

### What is a Control Chart?

A control chart is a simple graph with a centerline, an upper control limit (UCL), and a lower control limit (LCL) on which fraction defective (attributes) statistics or sample average and variation (variables) statistics are plotted over time. Figure 1 is an example of a control chart. The control chart centerline represents an average of initial sampling observations, such as the average fraction defective, overall process average, or average process variation. Control limits are statistically calculated boundaries on the control chart used to determine if the process is in statistical control or in a state of chaos.

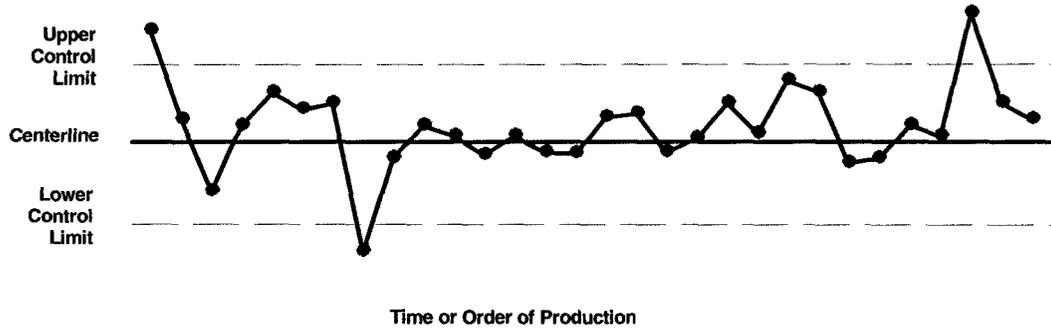


Figure 1—Example of a control chart with three out-of-control points.

Control charts are used as a troubleshooting tool to help tighten up process performance. Control charts help identify trouble (i.e., chaos and shifts in process average) as it develops within a process. They help you decide when to take corrective action and when to leave the process alone, avoiding unnecessary expense. When trouble occurs, it can be identified and corrected in a timely manner.

The construction of control charts is based upon statistics calculated from samples called subgroups drawn from a process. Both the control limits and centerline are calculated using subgroup sample statistics. Because the control chart is based on actual process statistics, most points (99.73 out of 100) plotted on the control chart are expected to fall somewhere between the upper and lower control limits. In fact, most points will lie on or around the centerline with few individual points much larger or smaller than the average. Points falling outside the control limits indicate lack of statistical control.

## Interpreting Control Charts

Process performance is monitored with control charts by taking periodic subgroup samples from a process and plotting the sample points on a control chart. Sample points are compared against the control limits and evaluated for trends. The process is deemed to be in statistical control when all points fall within the control limits and there are no unnatural patterns (i.e., trends) in the plotted data. Out-of-control is indicated by one or more points falling outside the control limits or when unnatural patterns or trends occur in the data.

**In-Control**—Points falling within the control limits and natural (i.e., random) patterns of the plotted sample points indicate a process in good statistical control. In-control is the state of a process that is operating in a stable and predictable manner. In theory, in-control processes operate with only common causes of variation. Control charts can identify good process performance (i.e., in statistical control) and thus indicate when to leave the process alone, preventing unnecessary and frequent adjustments to the process. Over-adjustment only serves to increase process variability (i.e., introduce artificial special causes) rather than decrease it, resulting in lower quality and unnecessary expense.

**Out-of-Control**—Points falling outside the control limits or unnatural (i.e., nonrandom) patterns in the data indicate lack of statistical control. Out-of-control points indicate that special causes of variation are probably (99.73% chance) at work within the process. When special causes of variation arise, they can be identified and corrected in a timely manner. Out-of-control calls for an investigation of the causes of trouble. Upon discovery of a special cause, corrective action is taken to bring the process back into statistical control.

**Trends**—Trend patterns in the data also indicate out-of-control. Trends are identified with a technique that evaluates “runs of data.” A run is a succession of items in consecutive order with similar characteristics (Duncan 1974). Evaluation of trends in control chart data may indicate potential problems, calling for close observation. Be on the lookout for possible shifts in the process average or variation before the process goes out of control. When the process does go out of control, investigation of special causes and corrective action upon their discovery can be quickly taken.

## Types of Control Charts

The two basic types of control charts are attributes and variables charts. There are several specific control charts of each type depending on the application. An attributes control chart is based on count (i.e., number of defects or defective items) or percentage of count (i.e., fraction defective). Attribute control charts are the first step beyond quality assurance inspection and are used to track product quality. Variables control charts monitor measurable characteristics such as dimensional size (thickness, width, length), moisture content, weight, or temperature. Variables control charts use two charts together: one chart tracks the process average and the other monitors process variation.

### Constructing Control Charts for the Mill Floor

The following section focuses on a set of typical variables control charts; namely,  $\bar{X}$  (average) and R (range) Control Charts. Control charts are developed from data sampled from the process under study. The data are used to construct control charts for the mill floor for monitoring and troubleshooting. To set up control charts, the quality control supervisor must decide what specific process will be studied; how samples should be selected; how often samples should be taken; and where the samples should be taken, measured, and analyzed. A good reference for using control charts and other quality improvement techniques is *The Memory Jogger II: A Pocket Guide of Tools for Continuous Improvement and Effective Planning* (Brassard and Ritter 1994).

## Selecting a Process to Study

The first step is to decide where to use control charts. It is not necessary, nor recommended, to use control charts on every process. In general, use control charts when trouble is suspected or when processes are critical. Many problem-solving tools are available for identifying and analyzing processing trouble (i.e., out of control). A number of these tools were discussed at the 1997 Wood Technology Clinic (Dramm 1997). Some specific techniques include: (1) Brainstorming, (2) Nominal Group Technique, (3) Check Sheets, and (3) Pareto Charts (Brassard and Ritter 1994).

**Brainstorming**—can generate many ideas quickly and is useful in identifying problems as well as possible solutions. Brainstorming can be structured or informal. The concept is to generate as many ideas, no matter how farfetched, without discussing the merits of the ideas, in as short a time as possible. A group should be able to generate 30 to 40 ideas in less than 10 minutes.

**Nominal Group Technique (NGT)**—is a method to bring group consensus to the most important problems such as generated by brainstorming. Each group member individually ranks the ideas in order of importance, and results are compiled for the group. Ideas with the highest scores represent the group's consensus of the most important problems.

**Check Sheets**—are used to gather information about processing problems and help determine what problems are occurring most frequently. They are simple forms that help answer the question “How often are certain problems happening?” Check sheets help turn opinions into facts.

**Pareto Charts**—show the relative importance of all problems or causes to one another on a bar graph. These charts help mills decide where to start solving problems or identifying basic causes of a problem. Pareto analysis summarizes information from a check sheet or other forms of data collection (e.g., maintenance log). This helps focus attention and efforts on solving the most important problems. Pareto charts are also useful in communicating problems and causes and their relative importance to employees and upper management.

## Equipment Checklist

The equipment and supplies needed to construct and use control charts include

- Calculator
- Clipboard
- Graphpaper
- Pencils (red and black)
- Broken ruler or straight edge

## General Sampling and Recording Procedures

Specific procedures must be followed when constructing and using control charts. It is important that sampling, measuring, recording, calculating, plotting, and interpreting procedures be done properly. Integrity of the sampling procedure is the most critical consideration in statistical process control work (Duncan 1974, AT&T 1985). The following rules are based on research and practical experience. It is essential that these be followed to ensure the reliability of results. Since all the information on control charts will come from samples, samples must be selected properly. To do otherwise may violate statistical sampling rules and can result in making wrong conclusions about process performance. Sampling requires careful planning before any measurements can be taken.

**Rational-Ordered Subgroups**—A rational-ordered subgroup is an unbiased sample drawn from the process. Select subgroups in a manner that minimizes special causes of variation. To do this, draw consecutively produced items from production. Sample each process separately to ensure rational

subgrouping. Measure and record subgroups in the order they are produced. This is necessary for evaluating trends and unnatural patterns of variation. For  $\bar{X}$ -R Control Charts, draw subgroups of four or five consecutively produced items, one at a time, in an unbiased manner at regular intervals, and measure and record their quality characteristics.

Subgroup Sampling Procedures—Samples should give an unbiased picture of the process and must be selected in an unbiased manner. Do not deliberately select items (e.g., lumber, logs) that you have reason to believe may be different from the others. Do not take part of the sample from one breakdown system and part from another. Always use the sample originally selected; do not resample (AT&T 1985).

Take subgroup samples at regular intervals and plot sample points on the control charts. Obtaining a proper sample is extremely critical and requires careful planning. Take a minimum sample of 30 rational-ordered subgroups for initial construction of control charts.

Sample measurements from each subgroup are used in calculating subgroup average ( $\bar{X}$ ) and range ( $R$ ). Control chart centerlines and control limits are then calculated and used to construct the control charts. Each calculation and procedure for constructing the control charts is described in the following text.

Sampling Period—Initial control charts should be based on subgroup samples that reflect the full range of variation characteristics of the process under study. As a rule of thumb, sampling should be done over at least an entire week's production.

Sampling Frequency—Subgroups are to be selected at regular time intervals throughout the sampling period. The first subgroup should be selected randomly and subsequent subgroups should be pulled at relatively uniform intervals for the entire sampling period. Use a time interval of about 1 or 2 hours between subgroup sampling. This recommended sampling interval should be sufficient for normal operating conditions when the process is not in unusual trouble. Do not always take the sample exactly at the same time each day. Avoid sampling on the hour, half hour, quarter past or quarter to the hour. Vary the sampling time between intervals.

Recording Procedures—Record subgroup sample data, date, time, and employee responsibility for taking the subgroup sample on the data sheet. Also maintain the order in which the subgroups are taken and recorded. Note system problems or adjustments made during the sampling period, as well as saw, machine operator, and shift changes. Also note anything unusual about the process or operation on the data sheet. Each subgroup sample must be identified with what the process is doing at the time of sampling (AT&T 1985). Such information is essential for tracking down special causes of variation. Relate each subgroup with unusual occurrences at the time the subgroup was taken (i.e., log size, species, operator, saw blade heating). The more ways data are identified, the greater the possibility to learn about the process (AT&T 1985). This is one of the first principles of control chart analysis and is the source of much of its power.

#### Constructing Control Charts

Calculating Subgroup Average—Subgroup average ( $\bar{X}$ ) is the sum of the individual values ( $X$ ) for any given subgroup divided by the number of values ( $n$ ) in a subgroup sample:

$$\bar{X} = \frac{\sum X}{n} \quad (1)$$

**Calculating Subgroup Range**—Subgroup range ( $R$ ) is the difference between the largest ( $X_{\max}$ ) and smallest ( $X_{\min}$ ) observations in any given subgroup:

$$R = X_{\max} - X_{\min} \quad (2)$$

**Construction of the R (Range) Control Chart**—Control limits of the  $\bar{X}$  Control Chart are dependent on the process variation, therefore, the R Control Chart should be constructed first. The R Control Chart compares variability of each subgroup range ( $R$ ) to the average subgroup range ( $\bar{R}$ ).

The centerline of the R Control Chart is the average range ( $\bar{R}$ ) of the subgroups.  $\bar{R}$  is the sum of each of the subgroup range values calculated using Equation (2) divided by the number of subgroups ( $k$ ). Average subgroup range is calculated as shown by the following equation:

$$\bar{R} = \frac{\sum R}{k} \quad (3)$$

Next, compute the upper ( $UCL_R$ ) and lower ( $LCL_R$ ) control limits as follows:

$$UCL_R = D_4 \bar{R} \quad (4)$$

$$LCL_R = D_3 \bar{R} \quad (5)$$

where  $\bar{R}$  is calculated using Equation (3). Values for  $D_3$  and  $D_4$  are found in Appendix A for the number of observations per subgroup ( $n$ ).

The R Control Chart should be drawn on graph paper. Points are then plotted on the chart and evaluated. The process is deemed to be in statistical control when all points fall within the control limits and there are no unnatural patterns (i.e., trends) in the plotted data. Out-of-control is indicated by one or more points falling above the upper control limit or below the lower control limit or when unnatural patterns occur in the data.

Out-of-control points on the range chart should be investigated to determine what (if any) special causes exist. When a special cause is discovered through the investigation of one or more out-of-control points, corrective action should be taken to remove the special cause from the process. This is the first opportunity to remove trouble from the process.

### Construction of the $\bar{X}$

**Control Chart**—Variations in subgroup averages ( $\bar{X}$ ) are shown on the  $\bar{X}$

Control Chart. The centerline of the chart is established similarly as the centerline for the R Control Chart.

The centerline ( $\bar{\bar{X}}$ )

is the average measured size. Sum the  $\bar{X}$

values using Equation (1) and divide by the number of subgroups ( $k$ ) as shown in the following equation:

$$\bar{\bar{X}} = \frac{\sum \bar{X}}{k} \quad (6)$$

Control limits for  $\bar{X}$

Control Chart are established differently than R Control Charts. The following equations are used to calculate upper ( $UCL_{\bar{X}}$ )

and lower ( $LCL_{\bar{X}}$ )

control limits:

$$UCL_{\bar{X}} = \bar{\bar{X}} + A_2 \bar{R} \quad (7)$$

$$LCL_{\bar{X}} = \bar{\bar{X}} - A_2 \bar{R} \quad (8)$$

where  $\bar{\bar{X}}$

is calculated using Equation (6) and  $\bar{R}$

is calculated using Equation (3). Values of  $A_2$

are found in Appendix A for the number of observations per subgroup ( $n$ ).

Plot points on the  $\bar{X}$

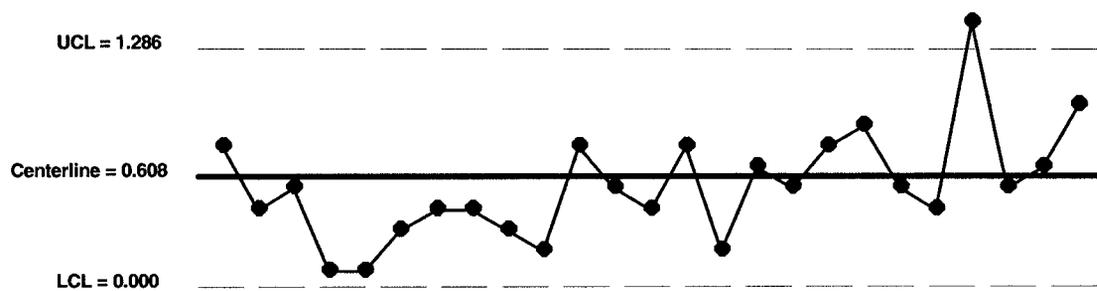
Control Chart and evaluate for out-of-control conditions in the same manner as the R control chart. A subgroup containing an out-of-control point should be investigated by searching for special causes. If a special cause is found, take corrective action to bring the process back into statistical control.

The example in Figure 2 illustrates  $\bar{X}$

- R control charts for monitoring log lengths. This example illustrates trouble with under- and overlength logs purchased from a number of contract loggers. Appendix B shows the necessary calculations and construction of these log length control charts.

$\bar{X}$

Control Chart



R Control Chart

**Figure 2—Log length control charts example.**

**Using Control Charts for Troubleshooting on the Mill Floor**

Control charts monitor mill performance. Subgroup samples are taken on a relatively frequent basis, plotted on the appropriate control chart, and evaluated for statistical control. Corrective action is taken upon investigation of out-of-control conditions and discovery of special causes of variation.

Specific procedures must be followed when using control charts for either monitoring mill performance or troubleshooting. After a subgroup has been taken and the data calculated, data points should be plotted immediately on the control chart on the mill floor. The data points are then evaluated for being either in control, out of control, or part of a trend. Out-of-control conditions call for the investigation of possible special causes of variation and appropriate corrective action.

**Employees Should Plot Their Own Control Charts**

Control charts are essential tools for doing the job right. Operating personnel should do their own plotting because they are most sure of what action to take, able to take action with the least delay, and responsible for running their operation (AT&T 1985).

**Sampling, Measuring, and Recording Procedures**

It is important that sampling, measuring, and recording procedures be done properly. A proper sample is an ordered-rational subgroup. Subgroups are drawn one at a time in an unbiased manner at regular intervals from production. Each subgroup sample must be identified with what the process is doing at the time of sampling (AT&T 1985). Such information is used for tracking down special causes of variation. It is critical to record this information every time a subgroup is taken.

The frequency of sampling determines the time in which special causes are discovered (Duncan 1974). Each process under study should be sampled about six or eight times per shift (that is, about once per hour) until the process is brought into statistical control. When using control charts for troubleshooting, sampling should be more frequent, perhaps once every 10 to 20 min. When statistical control is achieved, it may be possible to sample production less frequently, perhaps three or four times per shift.

**Calculating, Plotting, and Interpreting Control Chart Data**

Plot the control chart points on the mill's set of control charts. Interpret the charts for out-of-control points or trends as soon as possible after taking the subgroup measurements. All notes identifying the subgroup should be written on the control chart itself.

If the control chart is out of control or looks unusual after it is plotted, check your math before proceeding. Do the answers look reasonable? If not, take another sample and plot it on the charts.

If all the data plotted on the control chart fall within the control limits and they do not display any unnatural patterns (i.e., trends), the process is deemed to be in-control. When points fall in-control, no action is called for; in fact, the system should not be tampered with! Making adjustments to a process that is in statistical control will only increase process variation rather than decrease it.

If data points fall outside the control limits or the data display unnatural patterns, the process is deemed to be out-of-control. It indicates instability or shifts in the process and calls for the investigation of special causes. If special causes are found upon investigation, take corrective action to remove the trouble. Corrective action should be taken at the appropriate time, ideally as soon as possible, to bring the process back into statistical control (AT&T 1985).

## Search for Special Causes of Variation

When a process is out of control, a search for special causes should be undertaken. The six types of special causes of variation to be concerned with are

- change in process average,
- change in process variability,
- change in the shape of the sample distribution as shown on a histogram,
- steady shifts upward or downward (trends) of either process average or variation,
- cyclic or erratic shifts in process average or variation, and
- mistakes made in measuring, recording, and computing data.

There is a systematic approach for investigating out-of-control conditions. Out-of-control conditions should be investigated as soon as possible for special causes of variation. The first step is to check your calculations and measurements.

It is important to investigate all out-of-control points by searching for special causes (Duncan 1974). Discovery of special causes calls for corrective action. Any delay in plotting and interpreting out-of-control points will make special causes harder to identify. It is important to identify special causes while they are at work in the process. Any delay in corrective action may also lead to unnecessary amounts of mismanufactured product. Investigate favorable shifts in a process as well as unfavorable shifts. Errors made in measuring, recording, and computing data can cause significant artificial shifts (i.e., out of control) on the control chart; these should also be identified and corrected (Duncan 1974).

The following steps should be taken when searching for special causes (AT&T 1985):

1. Make certain that data points are calculated and plotted correctly on the control chart(s).
2. Relate the control chart patterns to things you know about the process. The longer you use control charts, the easier this will become.
3. Trace the special cause back to the specific root cause of the problem, not just the symptom of the problem.

Beware of assuming that “nothing has changed” or that “we are doing everything the same way.” When a control chart indicates out-of-control, chances (better than 99 out of 100) are that there is instability or change occurring within the process. Discuss the situation with others who have expert knowledge of the process. This should include millwrights, saw filers, and lumber graders, as well as the operators themselves who work with the process daily. Remember that only a small part of the information necessary to solve a problem will come from the control charts themselves (AT&T 1985). Most information must come from knowledge of the process.

## Possible Causes of Out-of-Control on Variables Control Charts

Special causes that affect the  $\bar{X}$

Control Chart are generally different from those that affect the R Control Chart. Because of this, it is possible to separate out the special causes of variation — factors that disturb a process.

The  $\bar{X}$

Control Chart shows where the process is centered and indicates when significant shifts occur in the process average. Out-of-control is influenced by special causes of variation that indicate shifts in the process average. The chart indicates when the process is in need of adjustment. If the chart shows a trend, the center of the process is gradually moving up or down. If the chart is unstable, erratic, and out of control, something is changing the center process rapidly and inconsistently.

The R Control Chart shows uniformity or consistency of a process. A narrow chart indicates uniform

product and a wide chart, a nonuniform product. A process in good repair (well maintained) and well-trained operators tend to make the product more uniform. In searching for special causes when the R Control Chart is out of control, look for poor repair, poor maintenance, inadequate training, or improper operation.

### **Taking Corrective Action**

Procedures for using control charts specifically indicate when to take or not take corrective action. Indicators of out-of-control call for the investigation of special causes. Only when special causes are found should corrective action be taken. It is just as important that when the system is in control, it should be left alone. Do not adjust a process that is in statistical control! Unnecessary and frequent adjustments only serve to increase process variation rather than decrease it. Such increased variation will cause the process to go out of control, resulting in unnecessary expense and loss.

Upon discovery of a special cause, first determine a course of action. Is this an emergency repair that needs immediate attention or can the problem wait until the end of the shift? Is this a scheduled maintenance job? If not, what action is required? Next, be sure to follow up. Was corrective action taken and did the corrective action solve the problem? Finally, document on the control chart what the special cause was and the corrective action taken.

To be effective, management should give employees responsibility for taking corrective action immediately themselves (AT&T 1985). The cases that require a supervisor's attention will be one of two types: (1) where the necessary corrective action is known but cannot be taken immediately or (2) where the necessary corrective action is not known.

Once corrective action has been taken, take another sample from production to verify that the corrective action removed the special cause. Also document what action was taken on the control chart. If a special cause is not found during the search, sampling should be done more frequently until the special cause is found. Always document on the control chart when a special cause is not found.

### **Summary of Action to Deal with Special Causes**

As soon as special causes are discovered, do what is necessary to bring the process back into statistical control. Immediate and appropriate action should be taken as soon as a control chart shows the process to be out-of-control. A search for special causes should be undertaken and, if any are found, corrective action promptly taken. This should be done as quickly as possible in order to restore efficiency and economy. If it is not possible to take immediate corrective action or the course of action not easily determined, management should be informed so special help can be obtained. Delays should be noted on the control chart.

### **Case Study: Troubleshooting the Headrig in a Pine Sawmill**

SPC methods developed by the USDA Forest Service, Technology Marketing Unit for the forest products industry were tested under actual industrial processing conditions. Processing problems were frequently discovered while testing the SPC tools during trial mill studies.

The following reports the success in tracking down and correcting trouble at the headrig of a sawmill that saws 5/4 pine boards. A number of thicknesses and widths were sampled in this study. Lumber thicknesses were sampled by individual breakdown system. During the course of one entire shift, 52 subgroups of 2 consecutively produced 5/4 pieces each (a total of 104 pieces) were drawn from production. Three measurements per piece were taken and recorded. The lumber size data collected was analyzed at the Forest Products Laboratory after the mill study.

Average measured size, between-piece variation, within-piece variation, and total variation were calculated

for 5/4 lumber thickness produced on the headrig (Table 1). Lumber size variation is excessive and greater than expected for 5/4 lumber.

**Table 1. Lumber size variation of 5/4 lumber before and after corrective action**

Average measured size	1.502 in. (3.815 mm)	1.501 in. (3.813 mm)
Between-board variation	0.036 in. (0.091 mm)	0.011 in. (0.028 mm)
Within-board variation	0.025 in. (0.064 mm)	0.023 in. (0.058 mm)

In this study, a set of  $\bar{X}$

-R Control Charts were developed to evaluate lumber size control (Figs. 3 and 4). The control charts indicated that the process was out-of-control. The cause of this was not known at the time. The  $\bar{X}$  Control Chart clearly indicated an upward shift in the average measured size over the course of the 9-hour shift (Fig. 3). A shift of about 1/16 in. (1.6 mm) was observed in the plotted points. This was most likely associated with a gradual shift in the networks system. While constant readjustment can cause a sawing process to display out-of-control conditions, such adjustments are unlikely to show up as a constant upward shift in average measured size. One point on the R Control Chart also indicated out-of-control conditions (Fig. 4), which was determined to be the result of a miscut. Overall, the R Control Chart indicated fairly good statistical control.

Not enough information about the headrig process was known at the time of the initial sampling to be able to pinpoint any special causes of variation of the upward shift in process average. Further investigation into possible special causes of this upward shift (i.e., out-of-control condition on the average control chart) was undertaken by the mill employees after the mill trials.

Investigation by the head sawyer, millwrights, sawmill foreman, and QC supervisor confirmed that the linear positioning networks system was suspect. The sawmill was running two shifts per day. At about 5 a.m., the hydraulic pump for the linear positioners was turned on. Through their investigation, the mill employees found that as the hydraulic oil gradually increased in temperature, the networks gradually increased its setting over the course of the day shift. After the second shift, the hydraulic pump was turned off and the hydraulic oil cooled—cause found. The solution was to install a hydraulic reservoir tank with a heater to keep the hydraulic oil at a constant temperature—problem solved.

What was the impact of troubleshooting the headrig? First, the control charts revealed a significant problem. Before control charts were used, mill employees suspected trouble but could not identify it. Second, the process was improved. Between-board variation was reduced from 0.036 to 0.011 in. (0.91 to 0.28 mm) and total variation reduced from 0.044 to 0.026 in. (1.2 to 0.66 mm) (Table 1.) This allowed for a reduction of about 1/32 in. (0.030 in., 0.82 mm) in target size for a lumber recovery improvement of 2.2 percent of jacket boards (i.e., opening cuts) produced on the headrig. The mill realized a savings through reduced log cost per unit output as a result of the improved headrig efficiency.

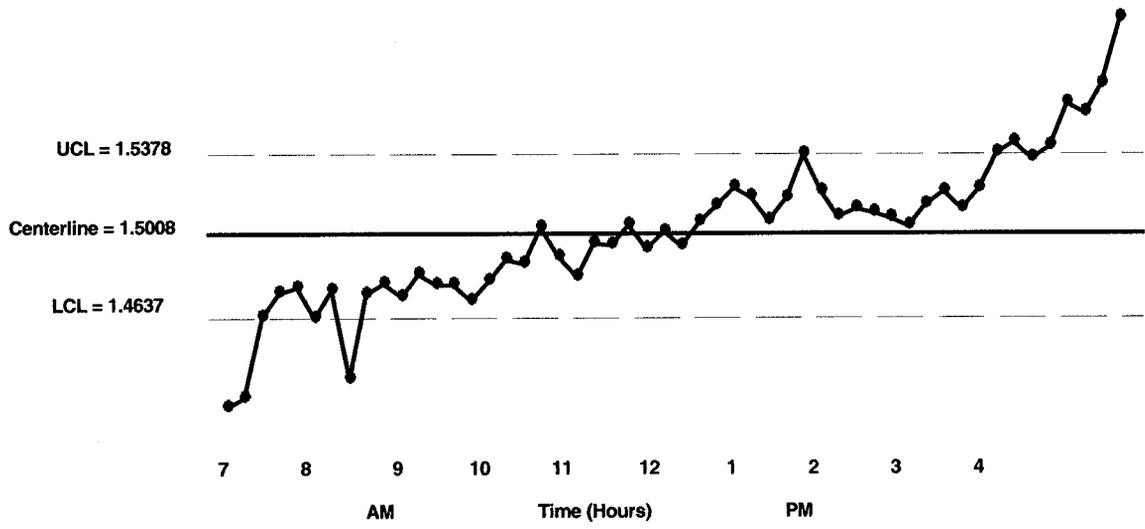
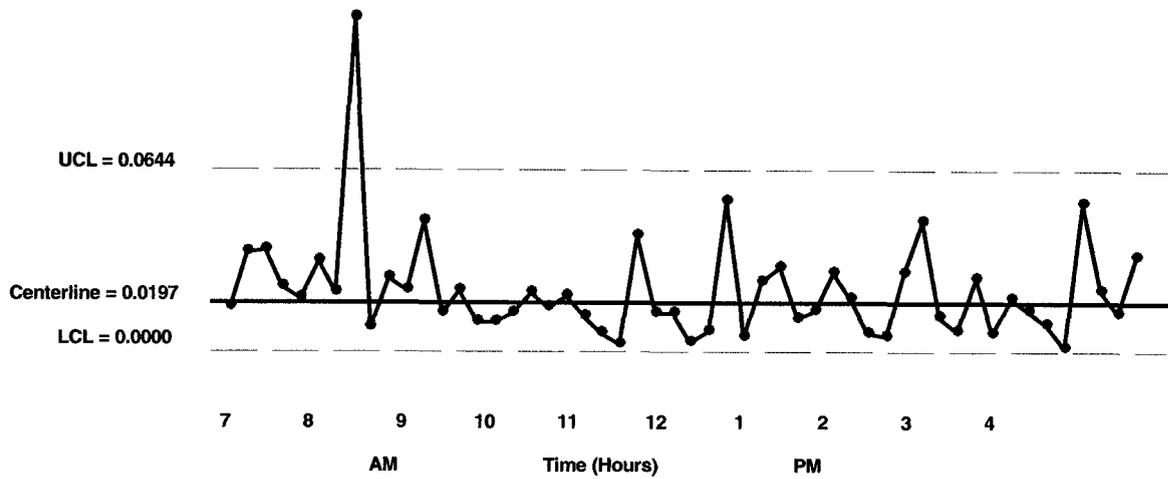


Figure 3—Lumber size average control chart for 5/4 lumber.



**Figure 4—Lumber size range control chart for 5/4 lumber.**

### Concluding Remarks

Control charts provide effective tools for quality and productivity improvement. Implementing such SPC tools helps improve process performance in forest products operations, resulting in reduced costs and improved productivity. Control charts help identify and locate problems that occur in wood products manufacturing process. This paper describes procedures and interpretation of statistical process control information as it relates to troubleshooting processing problems.

The real value in using control charts is where they are applied to monitoring and troubleshooting quality problems on the mill floor. Example control charts with step-by-step procedures show how control charts help identify processing and quality problems and illustrate the benefits of such things as lumber size control, tightening up, and improved mill efficiency.

### **For More Information**

For more information, contact USDA Forest Service, State & Private Forestry, Technology Marketing Unit, Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53705-2398. Phone: (608) 231-9504; Fax: (608) 231-9592; e-mail: [jdramm/fpl@fs.fed.us](mailto:jdramm/fpl@fs.fed.us). Also refer to the references listed below.

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