



PERFORMANCE EXCELLENCE  
IN THE WOOD PRODUCTS INDUSTRY

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# STATISTICAL PROCESS CONTROL

## Part 1: An Introduction

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The objective of this series is to help improve the competitiveness of Oregon's wood products manufacturers. This can be achieved by fostering a companywide focus on and dedication to continuous quality improvement. W. Edwards Deming (1982) described the "chain reaction of quality."

1. Quality is improved.
2. Costs decrease due to more efficient use of machines and materials and less scrap, rework, errors, and downtime.
3. Productivity increases as a result of cost decreases.
4. The company can capture the market with better quality and a lower price.
5. Competitive position improves, and the company stays in business.
6. Jobs are retained, and jobs are added as the company grows.

Given our objective, you may be wondering why we have chosen to focus solely on Statistical Process Control (SPC) and not on all quality improvement tools. As you will discover in future publications in this series, we do not, in fact, limit our focus solely to SPC. We also discuss other tools such as Pareto analysis, flow charts, cause-and-effect diagrams, and *histograms*. The focus, however, is on SPC because we believe that, in the continuous-quality-improvement tool kit, SPC is the primary tool for monitoring, control, and diagnostics. For this reason, we have chosen to discuss other quality-improvement tools in the context of how they support implementation and use of SPC.

The target audience for this series includes readers new to SPC, people wishing to improve their current understanding of SPC, and those who have used SPC in the past and, for whatever reason, believe it did not work. For the latter group, we hope this series will help you take a new look at SPC and continuous process improvement. Personnel in all departments—including management, sales and purchasing, production, engineering, maintenance, and design—will find the information valuable.



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## Statistical Process Control: Is it for your company?

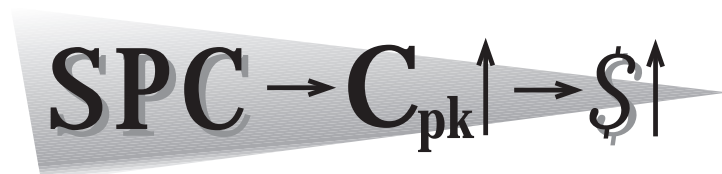
- Do you currently scrap, downgrade, and/or rework product?
- Do your customers demand consistently high-quality products?
- Are you interested in increasing productivity?
- Have customers requested quality-control documentation such as your “process capability index” (commonly referred to using the symbols  $C_{pk}$ ,  $C_p$ , or PCR)?

If you answered yes to any of these questions, SPC is for you!

Companies throughout the world have used SPC for almost 70 years. There is ample documentation (see “For more information,” page 13) that SPC reduces costs, increases productivity, builds customer loyalty, attracts new customers, and improves employee morale. Using SPC is a critical step to attaining international quality standard certification such as ISO 9000 and toward winning quality awards such as the annual Malcolm Baldrige National Quality Award.

What is SPC? Will it work for your company? How do you begin to implement an SPC program? What approaches have other companies taken that worked well, and what are the pitfalls you should avoid? This publication is the first in a series to help answer these questions. Part 1 sketches the history and philosophy of SPC, suggests ways to successfully implement it, provides evidence of SPC’s benefits, and attempts to alleviate fears of the math associated with SPC.

Part 2 provides a management overview of SPC. It gives management personnel sufficient background to support and lead those responsible for the hands-on implementation and day-to-day use of SPC. Future publications in the series will provide step-by-step approaches to build the skills required to implement SPC. Case histories of wood products firms using SPC will provide real-world evidence of the benefits. Pitfalls and successful approaches will be examined.



## The roots and development of SPC<sup>1</sup>

During the 1920s, Walter Shewhart of Bell Telephone Laboratories pioneered the use of statistical techniques for monitoring and controlling quality. Bell Labs wanted to **economically** monitor and control the variation in quality of components and finished products. Shewhart recognized that inspecting and rejecting or reworking product was not the most economical way to produce a high-quality product. He demonstrated that monitoring and controlling variation throughout production was the more efficient and economical way. Shewhart invented a visual tool for monitoring process variation which came to be known as the *control chart*, or the Shewhart control chart in honor of its inventor.

By the 1930s, the U.S. telecommunications industry operated by Bell Labs was recognized as the international standard for quality, due in large part to the use of Shewhart's techniques. During this decade, a great deal of groundbreaking research was conducted in statistical methods for controlling and improving product quality. During the 1930s, SPC began to spread to other industries and large enterprises, including the U.S. Bureau of the Census.

The onset of World War II created the need for high-volume and consistently high-quality armament production. To assist the war effort, Bell Labs personnel trained thousands of workers in quality control. Ten-day courses in SPC were offered at Stanford and Columbia universities. The first quality control (QC) journal, *Industrial Quality Control*, was published in 1944, and the first QC professional society, the American Society for Quality Control (ASQC, now known as ASQ, the American Society for Quality), was formed in 1946.

After the war, it is said that SPC was "laid off" in U.S. industry. With our economy intact and a huge demand for consumer goods, many manufacturers felt little need to invest in SPC. In the United States, the growth of SPC outside the defense industry was, at best, sluggish for decades.

The situation in postwar Japan, however, was quite different. The Japanese economy was devastated, and industry required rebuilding from the ground up. In the late 1940s, Joseph M. Juran and W. Edwards Deming, both understudies of Shewhart and by

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<sup>1</sup>Information in this section is adapted from Lewis, D.K. 1994. History, trends, and state of the art of SPC. *In*: Proceedings No. 7307, Statistical Process Control Technologies: State of the Art for the Forest Products Industry (Madison, WI: Forest Products Society).

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then widely recognized as the world's foremost experts on quality, traveled to Japan.

Juran's mission was to teach the Japanese about quality management; Deming's mission was to help the Japanese with the census. Deming, however, soon became more interested in helping the Japanese rebuild their industry. The two had found little interest among U.S. companies in their quality-management philosophies, but the Japanese heartily welcomed them.

During the 1960s and 1970s, quality methods and their practice grew rapidly in Japan. By 1980, American industry was feeling the competitive pressure from consistently high-quality Japanese imports. Manufacturers, beginning with the automotive and electronics industries, reawakened to the benefits of SPC.

The wood products industry's first large-scale quality efforts were in primary sawmills during the late 1970s and early 1980s. Terry Brown of Oregon State University's Forest Products Department helped sawmills implement quality programs, primarily for lumber size control.

Several larger secondary wood products firms now have SPC programs. However, in a study of cabinet and furniture companies, Patterson and Anderson (1996) found that only a small portion were using SPC, which is consistent with our experiences with small to medium-size secondary wood products firms in Oregon.

The 1990s have seen increasing interest in SPC and other tools of Total Quality Management (TQM) and Continuous Process Improvement (CPI). Many firms have invested a great deal of time and resources in quality-improvement programs only to realize very little if any impact on the bottom line. In *Harvard Business Review*, Schaffer and Thomson (1992) state that the problem has been the focus on activities rather than on results. We will discuss this issue below, in "Suggestions for implementing an SPC program," and in Part 3 of this series, *Starting an SPC Program*.

**A product-oriented quality control system,** according to QC pioneer W. Edwards Deming, pays workers to make defects and then to correct them.

### The philosophy of SPC

For many companies, adopting SPC requires substantial changes in the existing quality program. Traditional QC programs emphasize **product** quality control whereas SPC is **process** oriented.

Traditional product-oriented QC systems emphasize **defect detection**. The company depends on inspection, scrap, and rework to prevent substandard product from being shipped to the customer.

This is an ineffective and inefficient system. As Deming puts it, under a product QC system, a company pays workers to make defects and then to correct them.

Process QC systems, by using SPC, emphasize **defect prevention** through improving the production system. When a company first uses SPC, the objective often is to ensure that the production process is stable and capable of producing product to the specifications. Production personnel monitor variation at critical stages in the process and, when necessary, act to prevent defects before more value is added. Scrap, rework, and therefore work-in-process inventory are reduced considerably. As these initial objectives are met, the objective of an SPC program should shift to **improving the system** by continuously striving to reduce variation.

Given the distinction between traditional product QC systems and process QC systems, the philosophy of SPC can be summarized as:

- Defects are prevented by monitoring and controlling variation
- Real quality improvement comes from improving the system and reducing variation

An understanding of variation is crucial to understanding SPC. Shewhart, whose work led to the invention of SPC, recognized that variation is unavoidable in manufactured products. Further, he recognized that every system has inherent variation due to *common* (also called *random* or *chance*) *causes*. Shewhart also recognized another type of variation—variation due to *special* (also called *assignable*) *causes*.

Common-cause variation is evidenced by a stable, repeating pattern of variation. Special-cause variation is evidenced by a break in the stable, repeating pattern of variation and is an indication that something has changed in the process. Product consistency is ensured by detecting and eliminating special-cause variation. Long-term quality improvement results from reducing common-cause variation.

**A *process*-oriented  
quality control system**

uses SPC to prevent defects by improving the production system.

## What will SPC do for your company?

The benefits of SPC have been well documented. Some are:

- Increased productivity
- Improved employee morale which may lead to reduced turnover
- Improved customer loyalty
- Better understanding of the process
- Reliable data for documenting improvement

In addition, SPC is one step toward attaining ISO 9000 certification, the international quality standard.

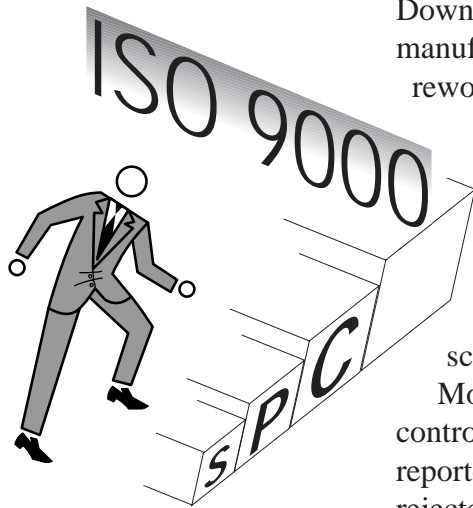
Profits can be increased by reducing scrap, downgrade, and rework and by increasing productivity. Management often doesn't know the costs associated with scrap, downgrade, and rework. Downgrade, in particular, is a significant issue for wood products manufacturers because it commonly is used as an alternative to rework. SPC helps to reduce scrap, downgrade, and rework by

detecting and correcting problems throughout the process rather than at final inspection after significant value has been added. Also, by tracking trends in the process, adjustments can be made before problems occur. Productivity increases as production time focuses on producing saleable product versus product that is reworked, downgraded, or scrapped.

Morale improves as employees gain a sense of ownership and control over the process. Workers who have had their mistakes reported to management by the "QC cops" or have had work rejected by inspectors know the effects of these types of QC programs on morale. Most employees want a sense of ownership of their jobs and appreciate being given the authority to monitor and make adjustments as necessary. Employee ownership leads to improved morale and overall job satisfaction and can translate to reduced turnover.

Customer loyalty can improve as customers learn of the vendor's efforts to improve quality and consistency. Many companies now ask their vendors to document their use of SPC with, for example, control charts and process capability indices such as  $C_{pk}$ . So, for some companies, using SPC is becoming a requirement just to stay in business. Likewise, documenting use of SPC has helped some companies attract new customers.

SPC gives companies a better understanding of their manufacturing processes. Implementing SPC often requires companies to





create process flow charts and Pareto charts (the Pareto principle also is known as the 80:20 rule). A Pareto chart might show, for example, customer claims by defect category. Pareto charts clearly show the most significant causes of quality problems and therefore provide direction and focus for quality improvement programs. For many companies, this is their first in-depth examination of the process. Data collected for SPC also help a company to know fully the capabilities of the various stages of the process. For instance, SPC data may show that a particular piece of machinery can operate only within specifications of plus or minus 0.05 inch. This sort of data is invaluable to all departments of the company—engineering, production, and sales.

SPC provides reliable data to document improvements. Have you ever been involved in a quality-improvement project only to discover that, at the end of it, no one could document the benefits clearly? SPC data and charts enable a company to compare current data to past data easily and to verify any improvements.

## Suggestions for implementing an SPC program

The success of any quality improvement program depends very heavily on management commitment. In SPC, attaining this commitment requires, first, that management understands SPC and the changes necessary for implementation; and, second, that management has in-house evidence that SPC has positive impacts on the bottom line.

We present two common scenarios (Options A and B) that are **not** likely to have positive bottom-line impacts. A third approach, Option C, is our recommendation for implementing SPC.

### Option A, the traditional approach: “Quality is the responsibility of the quality department”

In this approach, one person—let’s say the quality control director—is sent to an SPC training program. When the QC director returns to work and begins to use SPC, substantial changes in the way the company manages its quality program often are recommended. Lacking an understanding of SPC and any hard evidence that it can work in their company, management and production personnel often resist making the suggested changes.

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Using this approach, implementing SPC often becomes a frustrating, uphill battle for the QC director. A return to the old way of doing things often results.

### **Option B, a newer approach:**

#### **Large-scale, activity-centered programs**

Option A demonstrates the traditional approach with only minimal management commitment to quality improvement. At the other end of the spectrum are companies that commit wholeheartedly and jump headfirst into large-scale SPC, TQM, and other quality-improvement training programs. As Schaffer and Thomson (1992) point out, all too often these programs are activity centered rather than results centered. Activity-centered programs measure success in terms such as number of employees trained or number of teams formed. As with Option A, programs following this approach often flounder and die due to lack of results.

Companies that follow Option B often become very cynical of all “quality improvement” techniques because they invest significant time, energy, and resources but receive little or no payoff.

#### ***We recommend . .***

starting small and using successes as leverage to build the SPC program.

#### **Option C: Small-scale, results-centered approach**

The approach we recommend is based, in part, on reports by Schaffer and Thomson (1992). This approach is to start small and use successes as leverage to build the program incrementally. The focus is on achieving measurable results. As opposed to the activity-centered programs of Option B, results-centered programs focus on the short term (a few months versus a few years) and on specific, measurable goals such as reduction in a specific defect category, increased yield, reduced delivery time, and increased inventory turn. Results-centered programs work because:

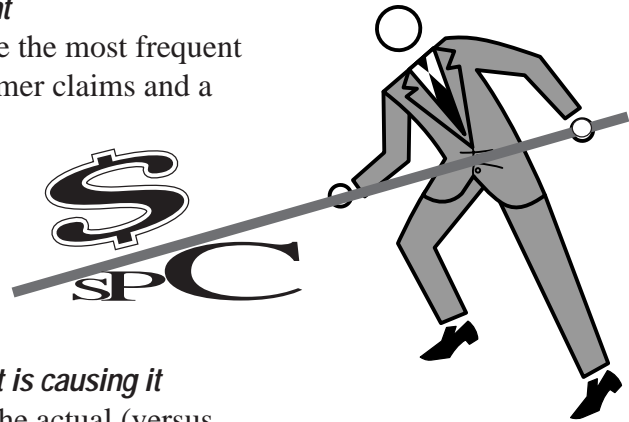
- Quality improvement tools such as SPC are introduced only when needed—namely, when they help
- Trial and error reveals what works and what does not work; future projects benefit by using only methods that work
- Incremental successes at each stage of a project give positive reinforcement and energize the improvement process
- Continuous process improvement is fueled by experience and past successes

The specific steps should be adapted to suit each organization and problem. However, the general outline is as follows.



***Step 1. Target one project for quality improvement***

To get the “biggest bang for the buck,” choose the most frequent or costly quality problem. For example, if customer claims and a Pareto analysis (discussed in detail in Part 3 of this series) reveal that most defects are due to out-of-specification product size, then the initial goal of the quality improvement effort would be to reduce defects due to out-of-specification size.

***Step 2. Determine where the problem is and what is causing it***

Be certain that all parties involved agree on the actual (versus ideal) steps involved in the process by drawing a flow chart (discussed in Part 4 of this series) for the manufacturing process. Develop a list of possible causes of the problem and determine the root cause using cause-and-effect analysis (discussed in Part 5).

***Step 3. Determine the current status of the process***

Where is the process *centered*? What is the *spread* around the center? Is the process stable and predictable? What is the defect rate? The tools to answer these questions—histograms, control charts, and process capability analysis—will be discussed in future publications in this series.

***Step 4. Act to solve the problem***

The answers to the questions in Step 3, combined with an understanding of SPC, will help determine the specific steps to solve the problem. Steps might include adjusting the process to recenter it on the target; searching for sporadic problems; minimizing operator overcontrol (i.e., instructing personnel to make adjustments only when a control chart—a tool of SPC—indicates that adjustments are needed); and looking for ways to improve the system by reducing the natural variability (different suppliers, machines, raw materials, process flow, etc.).

At the end of the project, write a brief final report. In it, state the problem and its root cause, status (defect rate associated with the problem and production efficiency) of the process before the project, the steps taken to solve the problem, the status of the process at the end of the project, and an **estimate of economic impact to the company**. To assist with future projects, also say what did and did not work. This documentation will help to fuel continuous process improvement and will help convince management to commit to future projects.

## If SPC is the answer, what was the question?

Hopefully by this point you are at least considering exploring SPC a little further. However, maybe you want to know what **specific** questions SPC will help answer. Here are some of them.

• How well is your current process meeting internal and external customer expectations (i.e., specifications)? And, are your suppliers' products meeting specifications? For example, if you are buying lumber with a moisture-content specification of 6 to 10 percent, how do you know this specification is being met? If you have an incoming inspection program, is it effective? Without using statistical methods, as in SPC, many incoming inspection programs are costly and ineffective.

• Where is the process centered, and how much does it vary from the center? In other words, what is the chance of producing (or purchasing) defective items? For example, you buy lumber with a moisture-content specification of 6 to 10 percent. You sample the material and find the average is 8 percent and the *standard deviation* (a measure of variation) is 2 percent. What are the chances of getting a board with a moisture content of 12 percent or higher? One in a hundred? One in a thousand? The answer depends on several factors, which will be discussed in detail in Part 2.

• What is causing the variation in the process? How do you decide when to retrain, reassign, or terminate employees? The risk, of course, is that if the variation is *not* caused by operator errors, the wrong decision will frustrate employees and possibly worsen, rather than improve, quality. When excessive variation and problems arise, production personnel often are “encouraged” to do a better job and to focus on quality. To counter this attitude, Deming (1993) states that in his experience 94 percent of troubles—and therefore the most possibilities for improvement—belong to the system, which is the responsibility of management. The remaining 6 percent are attributable to special causes (see “Philosophy of SPC,” above), of which production personnel control only a small percentage.

? Can you afford to minimize the variation? This depends, in part, on answers to the questions above. If control charts reveal that the variation has a special cause, a little detective work may reveal the cause to be something as simple as a worn bearing or belt, dull knives, improper target setting, or a plugged blowpipe. These may offer a “cheap fix.” On the other hand, control charts may indicate no special causes of variation but, instead, excessive common-cause variation. This is sometimes the case with machinery that uses older technology; even running at its best, it is incapable of meeting the specifications. The question then becomes, do you have to buy a new machine in order to meet specifications?

? Over time, how can you be sure the process hasn’t changed? Companies often invest significant time and labor in setting up equipment, after which a few test runs are made to ensure the machine is “on target.” How can you be sure, at a later time, that the process has stayed on target and that variation has not changed? Do changes in raw material (species, supplier, moisture content, etc.) significantly affect the process? How much? How do you know? Does tool wear cause a drift from the target setting? If so, what is the rate of drift? When is it time to change knives or saws? Every 4 hours, for example, may be too long an interval, thereby producing poorly machined product. Or, every 4 hours may be too often, thus incurring unneeded expense.

? When should you tinker with the process, and when should you leave it alone? Many well-meaning equipment operators cannot resist adjusting a machine continually; after all, their job is to “control” the machines. If the operator detects (by whatever means) a change, he or she makes an adjustment. However, without proper data collection and analysis, operator adjustments often **increase** variation rather than improve the process (see Deming’s “funnel experiment” in *Out of the Crisis*, page 327). Even when a process runs at its best, it naturally fluctuates around the target. Without SPC, it is very difficult to know the limits of these fluctuations, when to act to control variation, and—equally important—when to leave the process alone.



## But why statistics and the math that comes with it?

Many managers lose interest in SPC due to an aversion to the mathematics inherent in its use. Statistics is founded in mathematics, so many managers fear that production personnel without a solid mathematical background will not be able to understand and use SPC. This is a legitimate concern. To address it, let's first discuss why we need to use statistics.

As discussed in "The philosophy of SPC," above, SPC emphasizes defect prevention through monitoring and controlling variation. Statistics is the science of variation and therefore is the best tool to monitor variation.

Statistics requires collecting data. As Deming said, "In God we trust; all others must use data." To really understand a process—its ability to meet specifications, and the effect of changes in process variables—and to design effective maintenance schedules or to establish optimal target sizes and specifications, one must collect and analyze data. Rules of thumb or hunches of experienced people are valuable; however, important decisions should be based on properly collected and analyzed data.

How difficult is the math used in SPC? Day-to-day use of SPC requires only simple mathematics—addition, subtraction, multiplication, and division—and can be done easily with any inexpensive calculator on the market. Analyzing data samples for SPC charts for measurement data (as opposed to count data such as number of defects) is as simple as calculating the *average* (i.e., the sum of the sample values divided by the sample size) and the *range* (i.e., the largest sample value minus the smallest value) of a *sample*. Calculating *limits* for SPC control charts is as simple as looking up a value in a table and either multiplying that value by the sample range or multiplying the value by the sample range and adding the result to the sample average. The entire process of data analysis and plotting on charts can be done with a spreadsheet program such as Quattro Pro or Microsoft Excel.

As further encouragement, recall that SPC was created in the 1920s, long before the time of personal computers or even affordable hand-held calculators. Had SPC not been simple to use for the hands-on practitioner, it never would have become a standard industry tool for controlling quality and process improvement.

This is not intended to downplay the importance of the mathematics underlying SPC. SPC is a valuable, time-tested quality tool

***If SPC were not  
simple to use...***

...it never would have become a standard industry tool for controlling quality and improving process.

because it is based on sound, scientific principles. Experts in SPC theory must have a solid background in mathematics and statistics. A company considering implementing SPC may want to have a person with this educational background on staff to evaluate the quality program from time to time and to ensure that data are being collected and analyzed properly. Day-to-day use of SPC, however, requires only relatively simple mathematics.

## Conclusions

SPC has been used for many years in a number of industries, is tried and true, and has the potential to save your company money as well as to provide other valuable benefits. For a discussion of how SPC works and an example of applying SPC, please see Part 2 of this series.

## Acknowledgments

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## Glossary

Assignable causes of variation—See *special causes of variation*.

Attributes data—Qualitative data that can be counted for recording and analysis. Results may be recorded as yes/no, go/no go, or defective/not defective. Examples include percent defective in a *sample* and number of blemishes on a surface.

Arithmetic mean—See *average*.

Average—A measure of location or *central tendency* which is the sum of the observed values divided by the number of observations. Also called the *arithmetic mean* or, simply, the *mean*.

Bell curve—Common name for the *normal distribution*, a name derived from the shape of the curve.

Cell—A grouping of values between specified upper and lower boundaries used to create *frequency distributions*.

Center (centered, centering)—A numerical value that is “typical” for a set of data. Values used include the *average*, the *median*, and the *mode*.

Central tendency—See *center*.

Chance causes of variation—See *common causes of variation*.

Common causes of variation—Sources of variation that affect all the individual values of the process output being studied. The sources generally are numerous and individually of small importance but cannot be detected or identified. Also called *chance*, *random*, and *unknown causes* of variation.

Control (statistical)—The condition that exists following a process in which all *special causes* of variation have been eliminated and only *common causes* remain.

Control chart—A graphic representation of a characteristic of a process, showing plotted values of some statistic gathered from the characteristic, a central line, and one or two control limits. Used to determine whether a process is in *statistical control* and to help maintain statistical control.

Control limits—On a *control chart*, the criteria for signaling the need for action, or for judging whether a set of data does or does not indicate a “state of *statistical control*.” Control limits are calculated from process data and are not to be confused with *specification limits*.

Distribution—See *frequency distribution*.

Frequency distribution—A tally of the count, or frequency, of occurrences of data in specific *cells*.

Histogram—A bar chart for displaying a *frequency distribution*.

In control—See *control (statistical)*.

Mean—See *average*.

Median—The value at the midpoint in the ordered range of values: half the values are greater than the median value, and half the values are less than the median value.

Mode—The most frequently observed value.

Normal distribution—A continuous, symmetrical, bell-shaped *frequency distribution* for variables data that underlies *control charts* for variables.

Out of control—The absence of conditions described in *control (statistical)*.

Probability—A scientific discipline whose objective is to study uncertainty. Probability is the likelihood (commonly called the “odds”) that a specific event will occur.

Process limits—See *control limits*.

Random causes of variation—See *common causes of variation*.

Range—A measure of dispersion; the difference between the largest observed value and the smallest observed value in a given *sample*.

Sample—A group of items, observations, test results, or portions of material taken randomly from a larger collection of items, observations, test results or quantities of material, which provide information that may be used as a basis for making a decision about the larger collection. See also *subgroup*.

Special causes of variation—Sources of variation that are intermittent, unpredictable, and unstable and that can be detected and identified.

Specification limits—The engineering requirement for judging acceptability of a particular characteristic. Specifications are not to be confused with *control limits*.

Spread—General term describing the dispersion or variability in a data set. Commonly measured with the *range* or *standard deviation*.

## STATISTICAL PROCESS CONTROL

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Standard deviation (sample)—A measure of dispersion, calculated as the square root of the sum of the squared deviations of observations from their average divided by one less than the number of observations. The *range* often is used to estimate the standard deviation.

Subgroup—In process control applications, generally synonymous with *sample*.

Unknown causes of variation—See *common causes of variation*.

Variables data—Quantitative data, where measurements are used for analysis. Examples include length, width, thickness, viscosity, strength (e.g., pounds per square inch, or psi), and density.



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