How to plan a control chart program

Alfred H. Jaehn

The awareness of the power of control charts as a tool for heading off problems is becoming increasingly prevalent in our industry. As a leading quality indicator, control charts provide the signal to get into action when the process shows signs of going out-of-control. They can serve as an essential tool for people at all levels in the organization who recognize the need for making intelligent decisions in response to changes in the level of process performance or increases in variation.

Control charts not only have applicability in manufacturing but also can be advantageously employed in service and administrative functions. However, it would be impractical to think about maintaining a control chart on every measurement made in the mill. To maximize return on effort, planning when, where, and how control charts are to be used is essential.

Getting started

Concise documentation is required in developing a control chart program. It is vital that all those involved understand and agree upon the objective of the chart, the source of the data, sampling frequency, and measurement method. All of this information can be recorded on a planning sheet as shown in **Table I**.

An important and often overlooked factor in control chart planning and analysis is the magnitude of variation associated specifically with sampling and measurement. If this is not known, plans need to be developed to obtain this information prior to initiating the control chart. In the chemical process and paper industries, it is common for sampling and testing to account for one third of the variation experienced in the reported measurement. When measurement variation is judged to be excessive, it is advisable to make replicate measurements and plot average values.

Selecting the proper chart

There are basically two categories of control charts: control charts for variables data and control charts for attribute data. Variables data deal with quantitative data or measurements. Attribute data are concerned with qualitative data or counts. **Table II** lists the most commonly used types of control charts and the parameters plotted.

The application of these various control chart procedures is described in most textbooks on statistical quality control. The *ASTM Manual on Presentation of Data and Control Chart Analysis* (*1*) is one of the better texts available. It contains numerous examples covering the construction and use of control charts for both variables and attribute data.

If confronted with the problem of excessive sample and test variation and the inability to perform replicate measurements, a control chart employing moving averages should be considered (*2*). The effect of measurement variation is minimized by the moving average smoothing technique. Control charts of moving averages are particularly useful for continuous or semicontinuous processes. The smoothing effect is similar to that of the blending and mixing occurring throughout various phases of the operation.

Construction and interpretation

A prerequisite to construction of a control chart is a knowledge of the current average performance of the process and its expected variation. This is best accomplished by carrying out a process study. Generally 20 points should be obtained and plotted, although 30-40 data points may occasionally be warranted. It is important that the data be obtained over a sufficient time frame to allow the natural dispersion of the process to become evident. Once these data are generated, the conventional textbook techniques are used to establish the centerline and control limits.

The variability occurring within the control limits can most often be attributed to normal variation, i.e., due to chance alone. However, certain patterns may occur between the control limits that need to be recognized. The identification of these patterns is referred to in the world of statistical process control as "tests for instability." The *Western Electric SQC Handbook* tests (*3*) have been found to be very efficient for detecting assignable causes when all points are still within the control limits. These tests involve dividing the control chart into zones that are equivalent to one standard deviation. Rules are provided concerning the number of successive points required to be in one or more of the zones to indicate a change in process level. The zone control chart procedure (*4*) now being used by several mills is based on this concept.

Assignable causes and corrective action

Control charts need to be a working document similar to

Jaehn is a private consultant in quality management for the process industries, 1430 Clyde Ave., Wisconsin Rapids, Wis. 54494. He is an ASQC-certified quality engineer, TAPPI Fellow, and an examiner for the Malcolm Baldrige National Quality Award.

I. Control chart planning sheet

Describe	*Pertinent comments*
1. Data to be plotted	Process measurement, complaint frequency, sales figures, etc.
2. Purpose	Why is control chart being established? Monitor process, signal for process adjustment, etc.
3. Source of data	Test station log sheets, daily production records, sales reports, special study, etc.
4. Sampling and measurement methods and frequency	Sampling point. Sampling frequency. If process samples, are they to be composited or tested individually? Measurement method. How many measurements will represent a data point?
5. Normal variation due to sampling and measurement	Expected variation in data to be plotted if nothing has changed (i.e., if the entire procedure used to obtain the data were repeated).
6. Type of control chart	Variables or attribute data? See Table II for types of control charts and parameter to be plotted.
7. Centerline and limits	Will centerline be the process average or standard? How will limits be calculated? Two sigma or three sigma? RMS standard deviation or standard deviation estimated from range?
8. Out-of-control criteria	Will reaction be to points outside of control limits only, or also trends within limits? What control chart rules will be employed?
9. Special notes required	Change in process (equipment, speed, etc.), change in raw materials, change in testers, etc.
10. Action plan for out-of-control	Who will be notified? What are they expected to do? What is long-term program?
11. Administrative responsibilities	Who will calculate control limits? Who plots the data? Who will review the chart? At what frequency? Who will file the chart? For how long?
12. Control chart analysis	Schedule for formal review to determine: What new information has been gleaned. If limits still appropriate. If the chart is meeting purpose originally described.

a log sheet in the laboratory or operator report on the production floor. As such, it is necessary to incorporate special notes on the chart that will aid in better understanding the causes of the variation occurring. These notes would include information on process changes, formulation changes, raw material changes, as well as any changes in the measurement system. Providing a list of exactly what type of notes are wanted prior to initiating a control chart can add to the success of the program. Preparing a cause-and-effect diagram should be helpful in arriving at such a list.

Developing an action plan when assignable causes are identified via control chart analysis also should be a part of the planning process. This includes what needs to be done both short- and long-term. A single out-of-control condition can most often be successfully rectified by the action of the employee or immediate supervisor. These actions, however, must be spelled out. On the other hand, a high rate of out-of-control situations due to a specific cause requires management attention. A Pareto analysis of associated special causes will aid in pointing out which areas require immediate study.

II. Kinds of control charts

Type of chart	*Parameter plotted*
	For variables data
$\bar{x}$-R	Average and range of subgroups of two or more measurements
$\bar{x}$-σ	Average and standard deviation of subgroups having 10 or more measurements
x	Individual measurements
$\overline{Mx}$	Moving average of two or more measurements
	For attribute data
np	Number of defective items (use when sample size is constant)
p	Fraction defective (use when sample size varies)
c	Number of defects (use when sample size is constant)
u	Defects/unit (use when sample size varies)

Defining responsibilities

An effective control chart program demands that all administrative duties be clearly defined. This includes documenting who is responsible for calculating limits, plotting the data, and reviewing the charts. In addition, the frequency of this activity should be understood by all involved. A system for filing charts must be established to allow for comparing performance with previous periods. Whoever has the responsibility for all of this activity needs to be included on the control chart planning sheet.

Finally, but key to the success of the total effort, conduct a periodic formal review of the control chart being plotted. This involves going back to the statement of purpose that was prepared when initiating the chart to determine if, in fact, it is being met. If not, ask why. The review should include examination of the original planning document to determine if any changes are warranted. The timing for scheduling such a review is, of course, dependent on the importance being placed to the particular chart being plotted. However, a complete analysis of a control charting program should be conducted at least every three months.

Some final remarks

When first introducing a control chart in the mill, it is advisable to select an application where there is a high probability of success. Once management becomes convinced of its value, the necessary support for continued use is assured.

Control charts should be used only where trouble is occurring or where it is likely to occur. There is no need to establish control charts at points in the process where it is highly improbable that the process would go out-of-control.

Benefits of control charting are numerous. They are invaluable as an aid to identifying special causes of variation, which most often can only be removed through management action. An important by-product of a well-run control chart program is disciplined record keeping and analysis. Control charts are an essential tool for achieving continuous quality improvement. Their ultimate success, however, is highly dependent on the planning effort put forth.□

Literature cited

1. ASTM Manual on Presentation of Data and Control Chart Analysis, ASTM Special Technical Publication 15 D, American Society for Testing and Materials, Philadelphia, 1975.
2. Jaehn, A. H., Tappi J. 71(4): 215(1988).
3. Western Electric Statistical Quality Control Handbook, Mack Printing Co., Easton, Pa., 1977.
4. Jaehn, A. H., Tappi J. 70(2): 159(1987).

Received for review April 3, 1991.

Accepted April 18, 1991.