

IE 361 Module 14

Patterns on Control Charts and "Special Checks" / Extra Alarm Rules

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Reading: Section 3.4, *Statistical Quality Assurance Methods for Engineers*

Patterns on Control Charts (and other Plots Against Time)

To this point, we've spoken as if the only use one makes of a Shewhart chart is to compare the value of Q to control limits. If that were true, there would be little point in making the plot ... the calculations alone would suffice. But, in fact, people make and examine the plots, looking for interpretable patterns.

Under stable process conditions, one expects to see a sequence of plotted values Q that

- are without obvious pattern or trend,

- only on rare occasions fall outside control limits,
- tend to cluster about the center line, about equally often above and below it, but
- on occasion approach the control limits.

When something other than this kind of "random scatter" picture shows up on a control chart, it can be possible to get clues as to what kinds of physical causes are acting on the process, that can in turn be used in process improvement efforts.

Systematic variation/cycles, regular "up then back down again" patterns sometimes appear. Figure 1 is an example of this kind of plot.

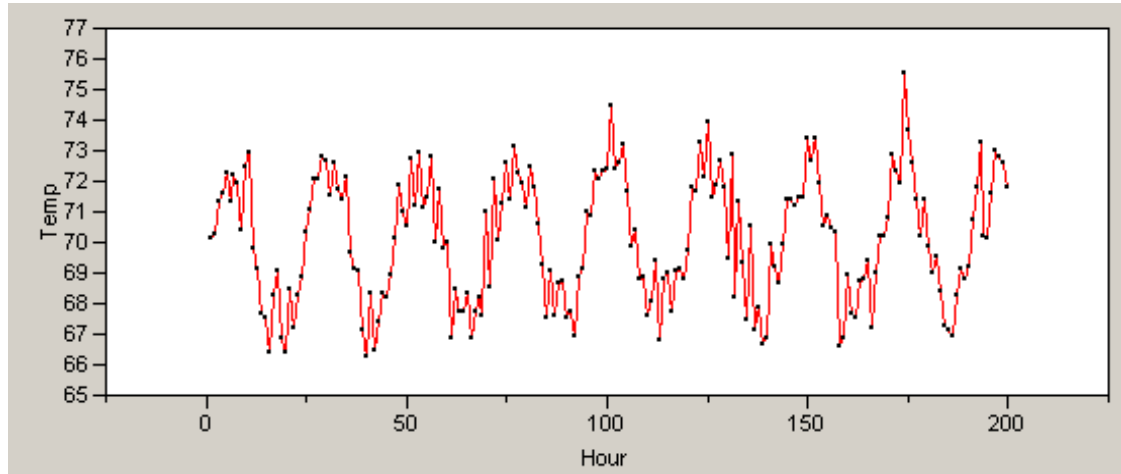


Figure 1: A Plot of Factory Ambient Temperature vs. Time Exhibiting Systematic Variation or Cycles

Identification of the period of variation can give hints where to start looking for physical causes. Examples of the kind of factors that can produce cycles are seasonal and diurnal variables like ambient temperature. And sometimes regular rotation of fixtures or gages or shift changes in operators running equipment or making measurements can stand behind systematic variation.

While systematic variation is variation of the "second kind," it may not always be economically feasible to eliminate it. For example, it may be preferable to live with effects of ambient temperature rather than try to control the environment in which a process operates. But recognition of its presence at least allows one to intelligently consider options regarding remedial measures, and to mentally remove that kind of variation from the baseline against which one looks for the effects of other special causes.

Instability is a word traditionally applied to patterns on control charts where many points plot near or beyond control limits. Figure 2 shows two Shewhart \bar{x} charts. The first is "properly behaved" while the second shows instability.

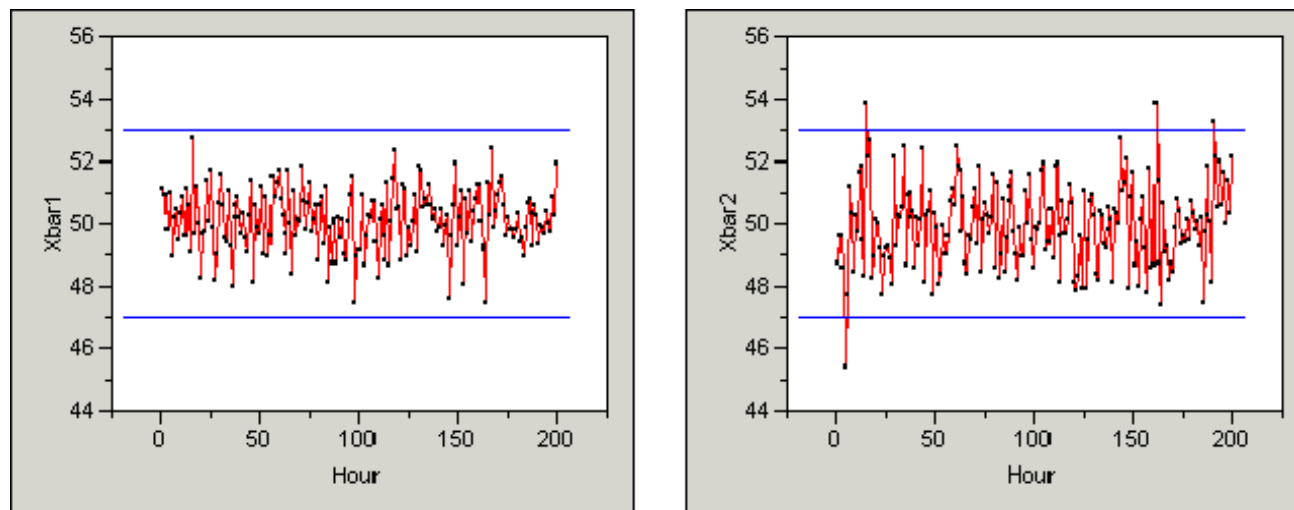


Figure 2: Two \bar{x} Charts, the Second of Which Shows "Instability"

Standing behind a pattern of instability can be more or less erratic and unexpected causes, like different lots of raw material with different physical properties mixed as process input. Another important possible cause is that of unwise operator overadjustment of equipment. Control charting is useful both because it signals the existence of conditions that deserve physical intervention, and because it tells one to leave equipment untouched when it seems to be operating as consistently as possible.

Changes in level sometimes appear; the average plotted value seems to move decisively up or down. The change can be sudden (as in Figure 3) and traceable to some basic change at the time of the shift. (The introduction of new equipment or a clear change in the quality of a raw material can produce such a sudden change in level.) Or the change can be more gradual (as in Figure 4) and attributable to an important cause starting to act at the beginning of the change in level, but "gathering steam" as time goes on until its full effect is felt. (For example, effective worker training in machine operation and measuring techniques could begin a gradual decrease in level on an R chart.)

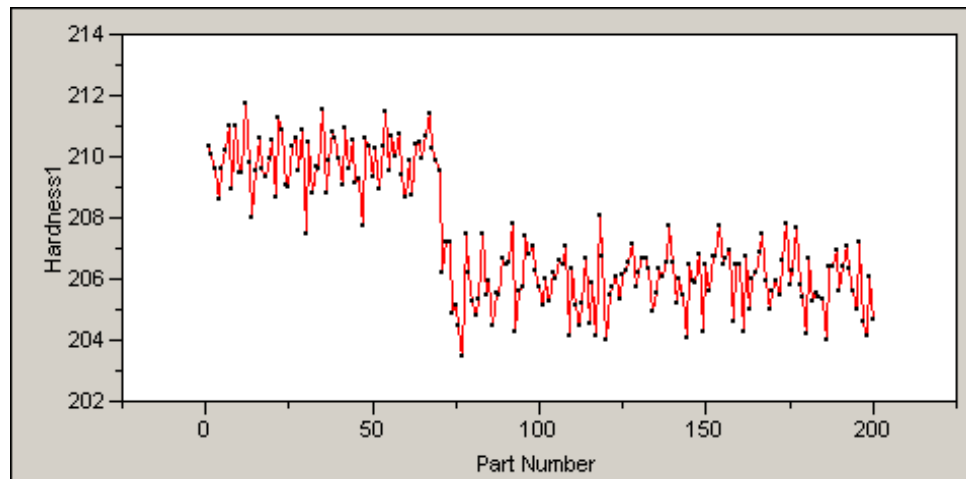


Figure 3: A Sudden Change in Level of Part Hardness

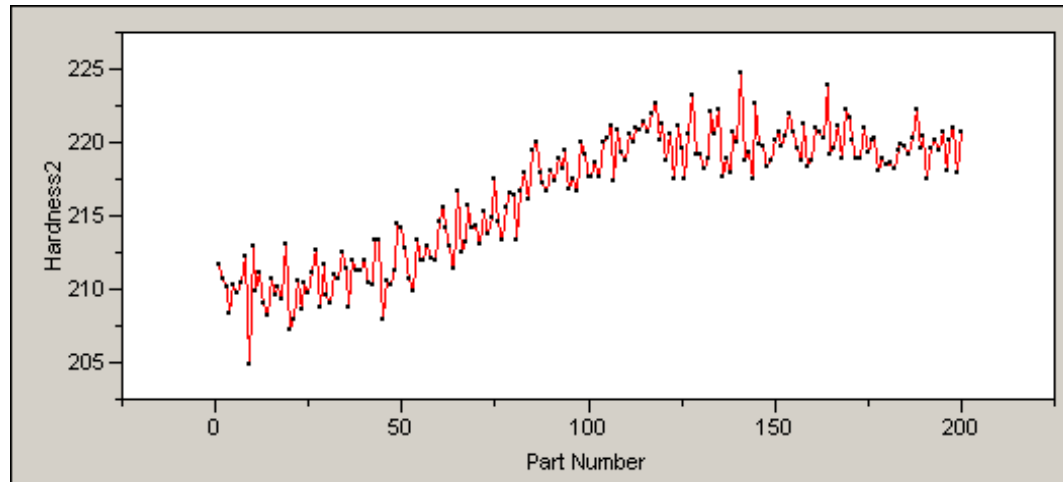


Figure 4: A Gradual Change in Level of Part Hardness

Where a gradual change in level does not end with stabilization around a new mean, it is traditional to say that there is a **trend** on a control chart. Many physical causes acting on manufacturing processes will produce trends if they remain unaddressed. An example is tool wear in machining processes as suggested in the run chart of Figure 5.

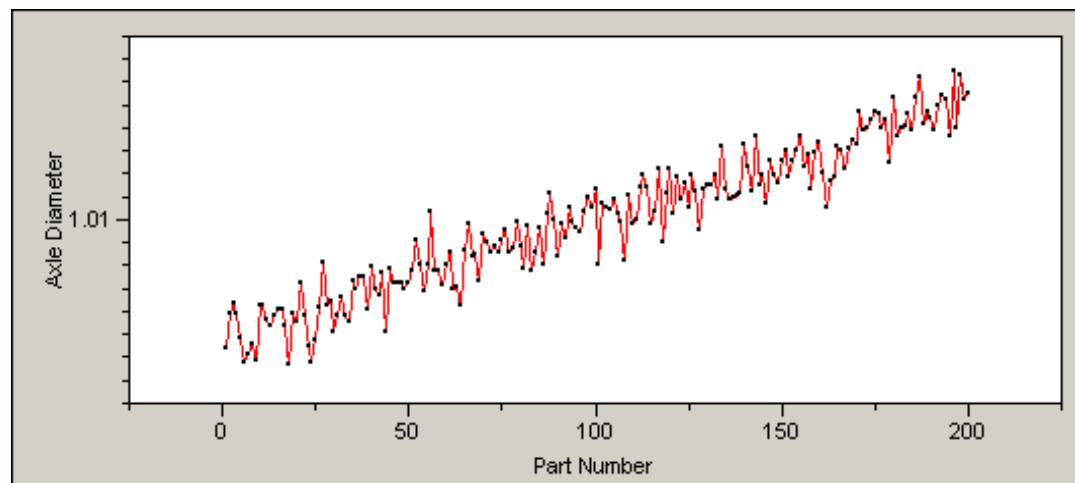


Figure 5: A Run Chart With an Unabated Trend

Another phenomenon that can produce strange-looking patterns on Shewhart control charts is something early users called the occurrence of **mixtures**. These are the combination of two or more distinct patterns of variation (in either a plotted statistic Q , or in an underlying distribution of individual observations leading to Q) that get put together on a single chart. Where an underlying distribution of observations has two or more radically different components, depending upon the circumstances a plotted statistic Q can be *either* unexpectedly variable or surprisingly consistent.

Consider first the possibility of unexpectedly large variation. Where blunders like incomplete or omitted manufacturing operations or equipment malfunctions lead to occasional wild individual observations and correspondingly wild values of Q , the terminology **freaks** is often used to describe the impact of the mixture of normal and aberrant observations. Figure 6 shows both a plot over time and a corresponding histogram of a series of values Q that fit this description.

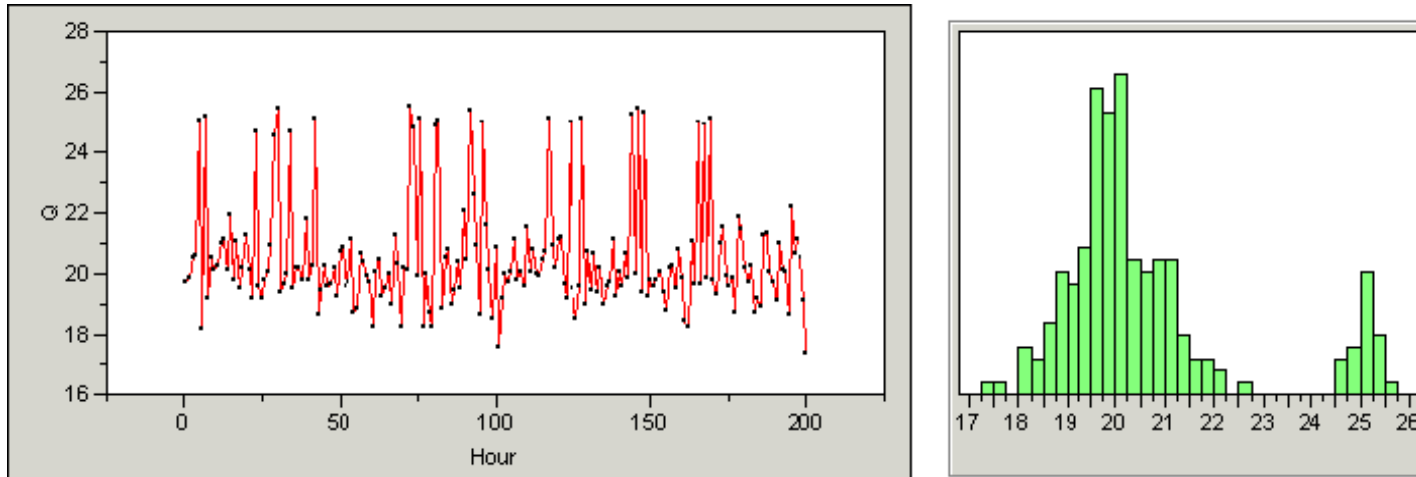


Figure 6: An Example of a Pattern that Could be Described as Exhibiting "Freaks" (and the Corresponding Histogram)

Where individual observations or values of Q of a given magnitude tend to occur together in time, the terminology **grouping** or **bunching** is common. (Different work methods employed by different operators or changes in the calibration of a measurement instrument can be responsible for grouping or bunching.) Figure 7 shows this kind of pattern.

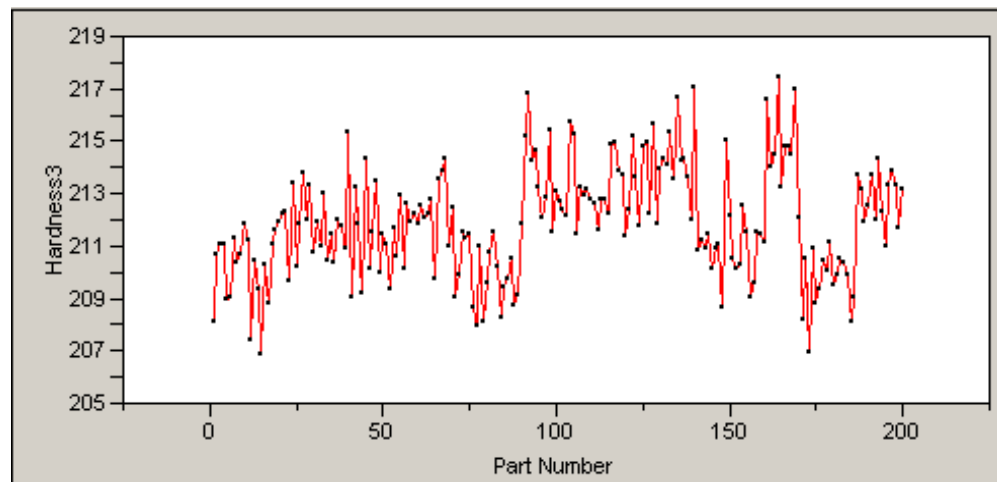


Figure 7: A Run Chart Showing Grouping/Bunching

How a mixture can lead to unexpectedly small variation in a plotted statistic (as shown in Figure 8) is more subtle. It involves a phenomenon sometimes known as **stratification**, in which an underlying distribution of observations has radically different components, each with small associated variation, and these components are sampled in a systematic fashion. One might, for example, be sampling different raw material streams or the output of different machines and unthinkingly calling the resulting values a single "sample" (in violation the notion of rational subgrouping!!).

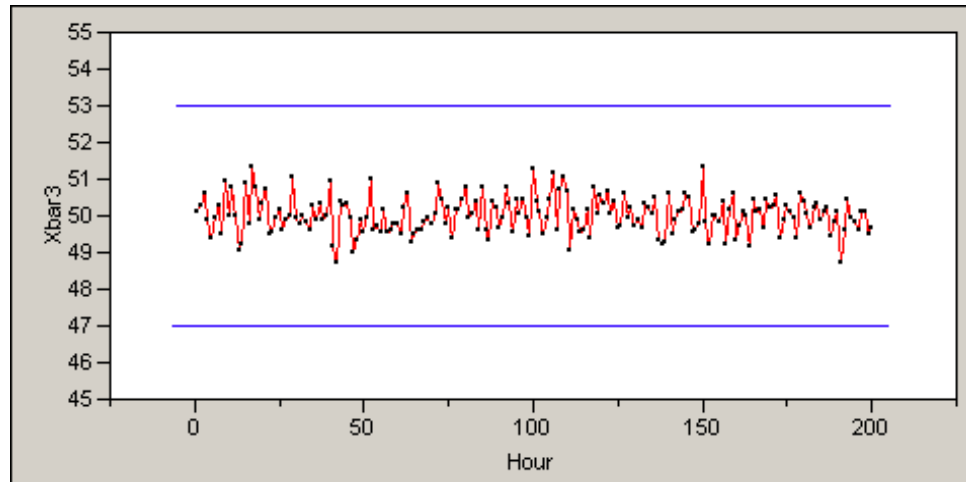


Figure 8: Unexpectedly Small Variation on an \bar{x} Chart, Potentially Due to Stratification

Consider, for example, the case of a hypothetical 10-head machine that has one completely bad head and 9 perfect ones. If the items from this machine are taken off the heads in sequence and placed into a production stream, "samples" of 10 consecutive items will have fractions defective that are *absolutely constant* at 10%. A Shewhart p chart for the process will look unbelievably consistent about a center line at .10. (A similar hypothetical example involving \bar{x} and R charts can be invented by thinking of 9 of the 10 heads as turning out widget diameters of essentially exactly 5.000, while the 10th turns out widget diameters of essentially exactly 55.000. Ranges of "samples" of 10 consecutive parts will be unbelievably stable at 50.000 and means will be "unbelievably consistent" around 10.000.)

"Special Checks" for Patterns on a Control Chart

Once one begins to look for patterns on Shewhart control charts, the question arises as to *exactly* what ought to be considered the occurrence of a pattern. This is important for two reasons. In the first place, there is the matter of consistency within an organization. Further, there is the matter that without a fair amount of theoretical experience in probability and/or practical experience in using control charts, people tend to want to "see" patterns that are in actuality very easily produced by a stable process.

Since the "one point outside control limits" rule is blind to the interesting kinds of patterns discussed here and there is a need for standardization of the criteria used to judge whether a pattern has occurred, many organizations have developed sets of "special checks for unnatural patterns" for application to

Shewhart charts. These are usually based on segmenting the set of possible Q 's into various "zones" defined in terms of multiples of σ_Q above and below the central value μ_Q . The following figure shows a generic Shewhart chart with typical zones marked on it.

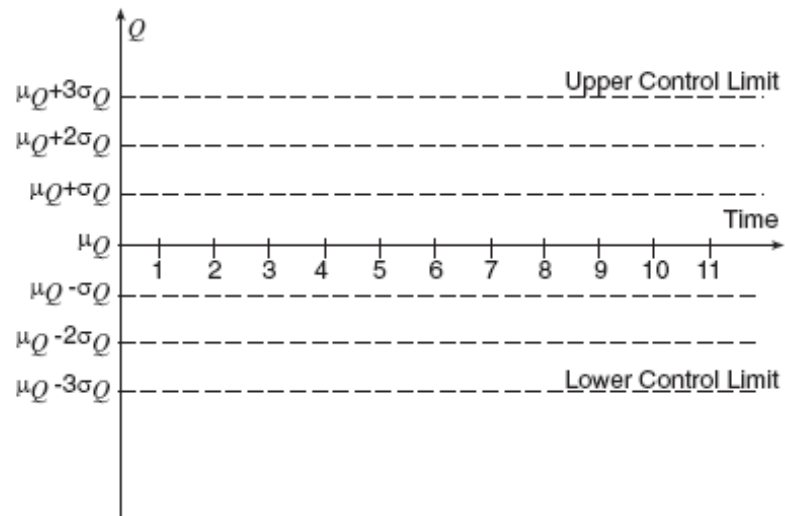


Figure 9: A Generic Shewhart Chart With "Zones" Marked on It

By far the most famous set of special checks is the set of "Western Electric Alarm Rules" given below. They are discussed extensively in the *Statistical Quality Control Handbook* published originally by Western Electric and later by AT&T. (Two other fairly famous sets of rules are presented in *SQAME*.)

Western Electric Alarm Rules

A single point outside 3 sigma control limits

2 out of any 3 consecutive points outside 2 sigma limits on one side of center

4 out of any 5 consecutive points outside 1 sigma limits on one side of center

8 consecutive points on one side of center

One should be able to see in this set of rules an attempt to provide operational definitions for "patterns" of the type just discussed. It is not at all obvious whether this set or some other set of checks should be used, or even what are rational criteria for comparing them and the many other sets that have been suggested. But the motivation for creating them should be clear.