USE OF GRAPHS

CONTROL CHARTS

The general approach to on-line quality control is straightforward: We simply extract samples of a certain size from the ongoing production process. We then produce line charts of the variability in those samples, and consider their closeness to target specifications.

There are a few fundamental principles, to do with statistical thinking, which underlie the construction and use of control charts:

1. Variability is all around us. No two things in this world are exactly identical. Even two measurements of the same thing will differ if the measuring instrument is
2. All processes have outputs, upon which measurements can be taken. Processes, then, must exhibit variability.
3. Any process has an inherent level of natural variability. This may be small or large, acceptable or unacceptable, depending on the process. With sufficient data we may be able to set the natural limits of variability; any observation falling outside these limits is a signal that something unusual is happening - we should investigate.
4. A well behaved process may be expected to fluctuate randomly within its natural limits of variability. Any non-random pattern, such as a steady upward trend, is again an indication that something unusual is occurring - again, we should investigate.

These types of charts are sometimes also referred to as Shewhart control charts (named after W. A. Shewhart who is generally credited as being the first to introduce these methods).

USES OF CONTROL CHARTS

Control charts are a means to describe what is meant by statistical control. The reasons why control charts are used are listed below:

1. It is a proven technique for improving productivity.
2. It is effective in defect prevention.
3. It prevents unnecessary process adjustments.
4. It provides diagnostic information.
5. It provides information about process capability.

If a single quality characteristic has been measured or computed from a sample, the control chart shows the value of the quality characteristic versus the sample number or versus time. In general, the chart contains a center line that represents the mean value for the in-control process. Two other horizontal lines, called the upper control limit (UCL) and the lower control limit (LCL), are also shown on the chart. These control limits are chosen so that almost all of the data points will fall within these limits as long as the process remains in-control. In SPCBESbert the control limits are calculated using process data (sample mean X (BAR), range mean R (BAR) and the Shewhart constant A determined by the number of observations in a subgroup. The formulae for control limits are:-

UCL = X(BAR) + R(BAR)*A AND LCL = X(BAR) - R(BAR)*A

If in a control chart you note that a sample point falls outside the control lines, one has reason to believe that the process may no longer be in control. In addition, one should look for systematic patterns of points across samples, because such patterns may indicate that the process average has shifted. These tests are also sometimes referred to as *AT&T runs rules* or *tests for special causes*. The term *assignable causes* as opposed to *chance or common* causes was used by Shewhart to distinguish between a process that is in control, with variation due to random (chance) causes only, from a process that is out of control, with variation that is due to some non-chance or special (*assignable*) factors.

The runs rules are based on "statistical" reasoning. For example, the probability of any sample mean in an X-bar control chart falling above the center line is equal to 0.5, provided

(1) that the process is in control (i.e., that the center line value is equal to the population mean),
(2) that consecutive sample means are independent (i.e., not auto-correlated), and
(3) that the distribution of means follows the normal distribution.

Simply stated, under those conditions there is a 50-50 chance that a mean will fall above or below the center line. Thus, the probability that two consecutive means will fall above the center line is equal to 0.5 times 0.5 = 0.25.

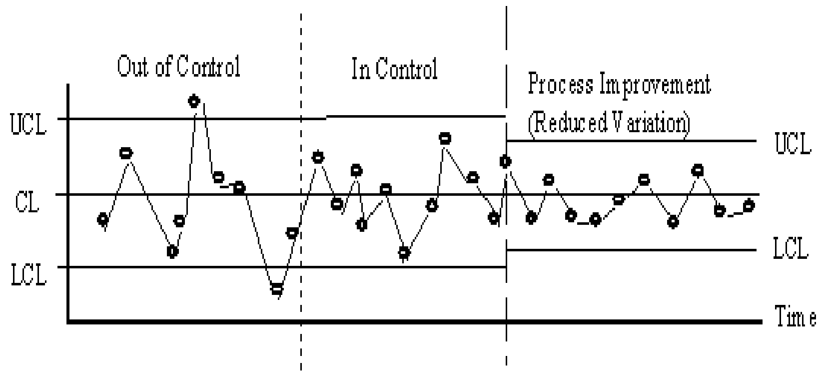
Accordingly, the probability that 9 consecutive samples (or a *run* of 9 samples) will fall on the same side of the center line is equal to 0.5**9 = .00195. Note that this is approximately the probability with which a sample mean can be expected to fall outside the 3- times *sigma* limits (given the normal distribution, and a process in control). Therefore, one could look for 9 consecutive sample means on the same side of the center line as another indication of an out-of-control condition. Some experts use "THE RULE OF 7"

Whether you use 7 or 9 points is not important, What is important is you are tracking trends with a preset action point. Practical experience will help you determine which number is best for your process conditions.

There are several run rules which can be used when determining if your process is in control. But the following two are commonly used in addition to the run of 9(or 7) points on the same side of mean rule.

6(or 7(rule of 7)) points in a row steadily increasing or decreasing. This test signals a drift in the process average. Often, such drift can be the result of tool wear, deteriorating maintenance, improvement in skill, etc.

14 points in a row alternating up and down. If this test is positive, it indicates that two systematically alternating causes are producing different results. For example, one may be using two alternating suppliers, or monitor the quality for two different (alternating) shifts.



THE CHART ABOVE SHOWS IN & OUT OF CONTROL PLUS PROCESS IMPROVEMENT CONDITIONS

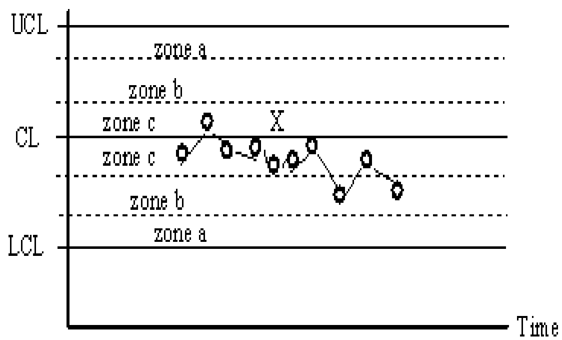


CHART ABOVE SHOWS consecutive samples on the same side (at X) of the center line

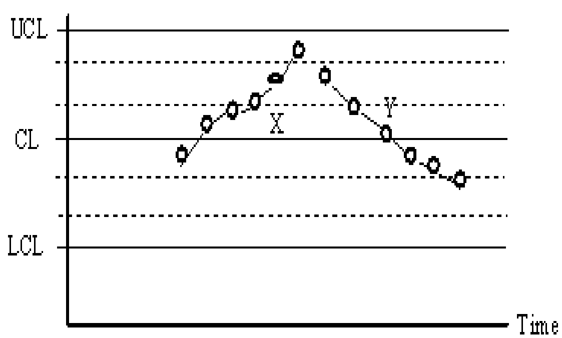


CHART ABOVE SHOWS points in a row alternating up (X) and down (Y)

ASSIGNMENT OF CAUSES - DEMING

Deming substituted the term **special cause** for the "terminology assignable cause used by Shewhart. Deming said that **uncovering** special causes was the responsibility of the local work force (those who had day-to-day contact with the process). Common causes were part of the system. The system is the responsibility of management. If the common cause variation is too large, it is the responsibility of management to change the system. Deming, stated that 85% of the problems with processes were system problems; later he increased this to over 94%, based on his own experience.

The distinction between special and common causes of variability is a useful one, and the recognition of responsibility assignments to the workforce for sporadic problems and to management for system problems is generally sound.

Here are some examples of common and special causes of variation.

Common Causes

Procedures are incorrect
Poor process and/or machine design.
Poor maintenance of machines.
Lack of clearly defined standard operating procedures.
Poor working conditions(e.g. lighting, noise, dirt, temperature, ventilation),
Machines not suited to the job.
Substandard raw materials.
Measurement error.
Vibration in industrial processes.
Ambient temperature and humidity.
Insufficient training.
Normal wear and tear.
Variability in settings.
Computer response time.

Special Causes

Shift change
Operator absent.
Poor adjustment of equipment.
Operator falls asleep.
Faulty controllers.
Machine malfunction.
Computer crashes.
Poor batch of raw material.
Power surges.

SUMMARY

The inherent variation present in a stable process is called **common cause** variation.

The causes of *instability* in a process are called **special** or **assignable causes**.

they account for up to 15% of process problems.

statistical techniques indicate when they are present.

they can often be removed by local action.

Control charts are designed to balance economically the risks of:

Overcontrol- taking action when the process is stable and no action is necessary, thus inflating the variation in a process and

Undercontrol- failing to take action when special causes are present and action should be taken to identify and eliminate them.

Two types of action should be taken:

action on the process to identify and remove special causes.

action on product to determine if it is out of specifications.

It is much easier to find special causes "on-the-spot" than to try to reconstruct circumstances later.

Measurement of the product quality characteristics should be made as close to the potential source of problems as possible. Do not wait until the product is completely fabricated or assembled.

NOTE: control limits reflect the natural tolerance of the process and have nothing to do with specifications.

Thus a stable process may be producing items that are consistently out of specifications.

AND, an out of control process may not be producing any items that are out of specifications.

HISTOGRAM

The histogram evolved to meet the need for evaluating data that occurs at a certain frequency. This is possible because the histogram allows for a concise portrayal of information in a bar graph format.

The histogram is a powerful engineering tool when routinely and intelligently used. The histogram clearly portrays information on location, spread, and shape that enables the user to perceive subtleties regarding the functioning of the physical process that is generating the data. It can also help suggest both the nature of, and possible improvements for, the physical mechanisms at work in the process.

When combined with the concept of the normal curve and the knowledge of a particular process, the histogram becomes an effective, practical working tool in the early stages of data analysis. A histogram may be interpreted by asking three questions:

1. Is the process performing within specification limits?
2. Does the process seem to exhibit wide variation?
3. If action needs to be taken on the process, what action is appropriate?

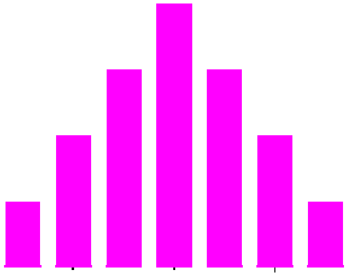
The answer to these three questions lies in analyzing three characteristics of the histogram.

1. How well is the histogram centered(skew)? The centering of the data provides information on the process aim about some mean or nominal value.
2. How wide(kurtosis) is the histogram? Looking at histogram width defines the variability of the process about the mean.

3. What is the shape of the histogram? Remember that the data is expected to form a normal or bell-shaped curve. Any significant change or anomaly usually indicates that there is something going on in the process which is causing the quality problem.

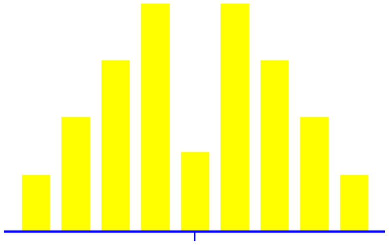
Examples of Typical Distributions

NORMAL



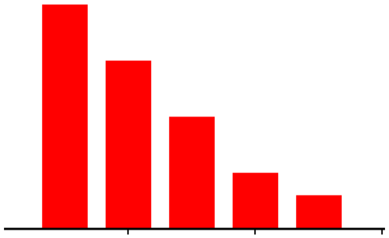
Depicted by a bell-shaped curve
most frequent measurement appears as center of distribution
less frequent measurements taper gradually at both ends of distribution
Indicates that a process is running normally (only common causes are present).

BI-MODAL



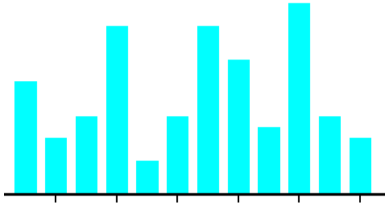
Distribution appears to have two peaks
May indicate that data from more than process are mixed together
materials may come from two separate vendors
samples may have come from two separate machines.

CLIFF-LIKE



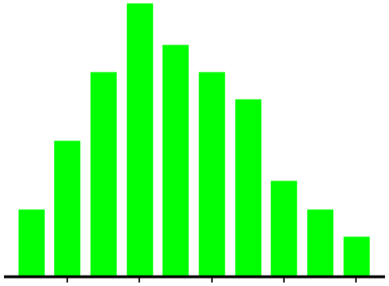
Appears to end sharply or abruptly at one end
Indicates possible sorting or inspection of non-conforming parts.

SAW-TOOTHED



Also commonly referred to as a comb distribution, appears as an alternating jagged pattern
Often indicates a measuring problem
- improper gage readings
- gage not sensitive enough for readings.

SKEWED



Appears as an uneven curve; values seem to taper to one side.

It is worth mentioning again that this or any other phase of histogram analysis must be married to knowledge of the process being studied to have any real value. Knowledge of the data analysis itself does not provide sufficient insight into the quality problem.

OTHER CONSIDERATIONS

Number of samples.

For the histogram to be representative of the true process behavior, as a general rule, at least fifty (50) samples should be measured.

Limitations of technique.

Histograms are limited in their use due to the random order in which samples are taken and lack of information about the state of control of the process. Because samples are gathered without regard to order, the time-dependent or time-related trends in the process are not captured. So, what may appear to be the central tendency of the data may be deceiving. With respect to process statistical control, the histogram gives no indication whether the process was operating at its best when the data was collected. This lack of information on process control may lead to incorrect conclusions being drawn and, hence, inappropriate decisions being made. Still, with these considerations in mind, the histogram's simplicity of construction and ease of use make it an invaluable tool in the elementary stages of data analysis.

Normal Probability Paper and the Relationship to Specifications

Background

Normal distributions have been depicted as bell shaped frequency curves, with the area under the curve corresponding to percentages of the total population.
These bell-shaped curves are useful in visualizing a distribution, but they are not well suited to graphical predict outcomes from limited data.
This predictive analysis function is served by the use of Normal Probability Paper.

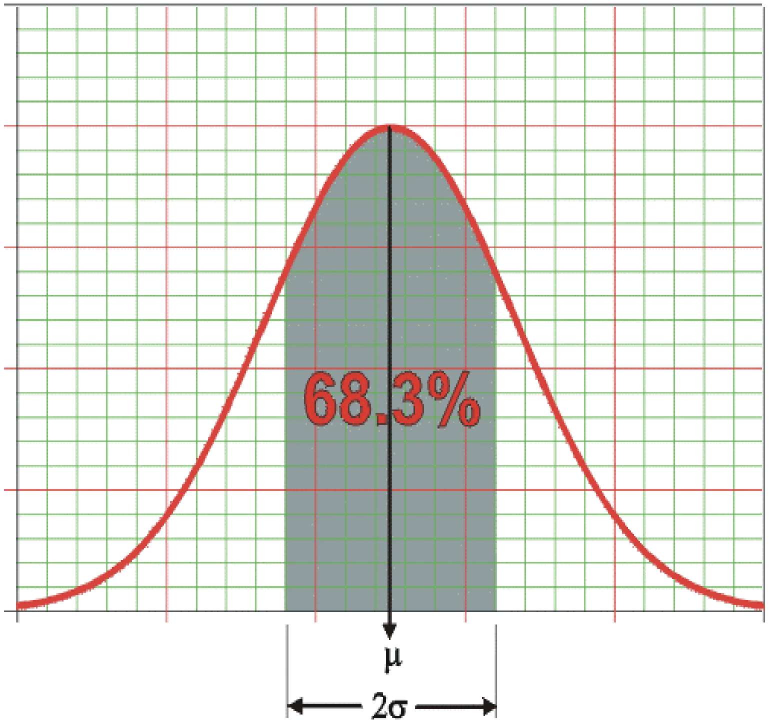
The figure below shows the relationship between the bell-shaded frequency curve or a Normal distribution and the equivalent cumulative distribution plotted on Normal Probability Paper.

Both graphs have data values as their horizontal scale, and the dashed lines for the specification limits appear in the same place on both.

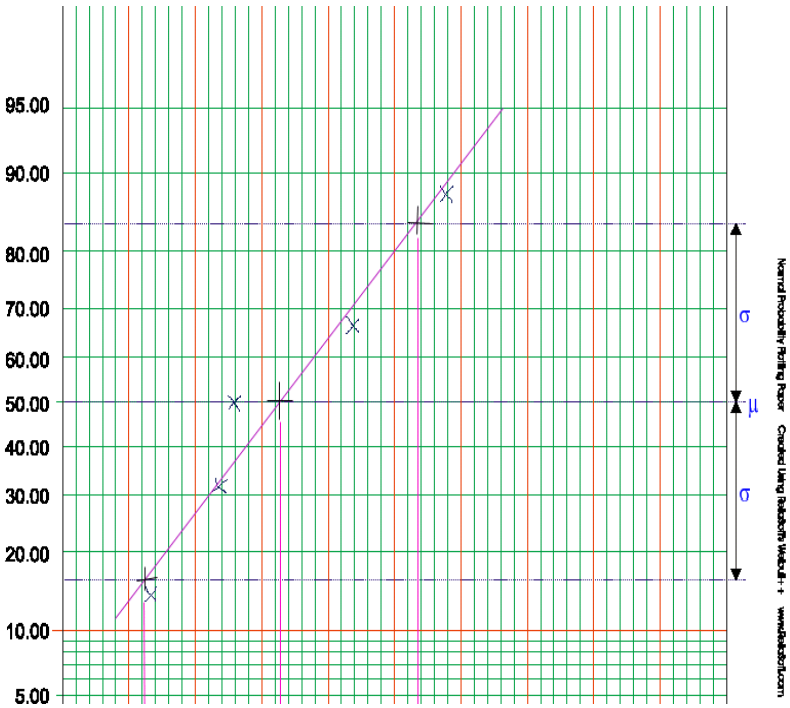
The vertical scale for the bell-shaped curve is linear with frequency (or percentage rate); as compared to the vertical scale of the Normal Probability Paper, which shows cumulative percentages, increases by equally-spaced standard deviation units on either side of the mean.

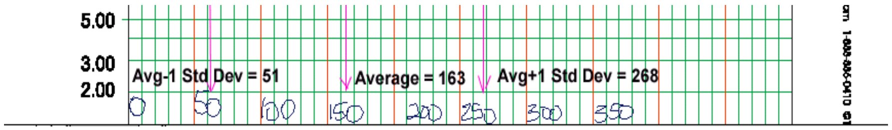
Because of this arrangement of scales, the cumulative percentages of any Normal distribution plot as a straight line on Normal Probability Paper.

The characteristic of straight-line plotting is very desirable in graphic forecasting because it is much easier to estimate a straight line than to try to draw a bell-shaped curve.



NORMAL DISTRIBUTION - "BELL CURVE"





This graph haw been drawn on Normal Probability Paper, which means that plot points which come from a normal distribution will lie approximately on a straight line. Since the fit will seldom be exact (all points <u>on</u> a line), location of the "best fit" line will require some judgment. In general, the "best fit" straight line should be located so that any points not directly on the line will be as close as possible to it and appear to lie randomly on either side of it. Be especially wary of any tendency to bias the line in either an optimistic or pessimistic direction.

are not random but appear to have a <u>pattern</u>, e.g., they start to curve to the right toward the top of the graph, this signifies two very important things:

(a) the distribution is not normal meaning that the forecasting techniques described here must be altered(regression analysis), and

(b) this evidence of non-normality may be the first clue to assignable causes in the process that may jeopardize its capability of producing consistently to specification.

In SPCBESbert the "best fit" straight line for the raw data is shown on the Linear Probability graph whereas raw data is shown on the Probability plot.

actual data values until it crosses the bold horizontal lines at plus and minus 3 sigma. Assuming the data is a Normal Distribution, one compares the graphically determined +&-3 sigma limitswith the specification limits of the process. If the 3 sigma limits are within the specification limits the process is capable of meeting the process specification. If one or both of the 3 sigma limits fall outside the process specification limits the process is not capable.

Refer to the SPCDATA sheet there are also Capability Indices which have bench mark values to indicate if the process is capable.