STATISTICAL QUALITY CONTROL:

The field of statistical quality control can be broadly defined as those statistical and engineering methods that are used in measuring, monitoring, controlling, and improving quality. Statistical quality control is a field that dates back to the 1920s. Dr. Walter A. Shewhart of the Bell Telephone Laboratories was one of the early pioneers of the field. In 1924, he wrote a memorandum showing a modern control chart, one of the basic tools of statistical process control. Harold F. Dodge and Harry G. Romig, two other Bell System employees, provided much of the leadership in the development of statistically based sampling and inspection methods. The work of these three men forms much of the basis of the modern field of statistical quality control. World War II saw the widespread introduction of these methods to U.S. industry. Dr. W. Edwards Deming and Dr. Joseph M. Juran have been instrumental in spreading statistical quality-control methods since World War II. The Japanese have been particularly successful in deploying statistical quality-control methods and have used statistical methods to gain significant advantage over their competitors.

STATISTICAL PROCESS CONTROL:

It is impractical to inspect quality into a product; the product must be built right the first time. The manufacturing process must therefore be stable or repeatable and capable of operating with little variability around the target or nominal dimension. Online statistical process control is a powerful tool for achieving process stability and improving capability through the reduction of variability.

It is customary to think of **statistical process control (SPC)** as a set of problem-solving tools that may be applied to any process. The major tools of SPC are:

1. Histogram

2. Pareto chart

3. Cause-and-effect diagram

4. Defect-concentration diagram

5. Control chart

6. Scatter diagram

7. Check sheet

Although these tools are an important part of SPC, they comprise only the technical aspect of the subject. An equally important element of SPC is attitude—a desire of all individuals in the organization for continuous improvement in quality and productivity through the systematic reduction of variability. The control chart is the most powerful of the SPC tools.

ADVANTAGES OF STATISTICAL QUALITY CONTROL:

There are two options before a manufacturer. He should either get each and every item checked and decides about the quality or he should use the statistical quality control methods. S.Q.C involves the inspection of a small number of items and decides about the quality of the lot of the product. S.Q.C. has many advantages over 100 per cent inspection which are recorded below.

1. S.Q.C. involves inspection of only a fraction of items produced in a fixed period. Hence, it is very economical.
2. The inspection of each and every item has hardly been feasible, as the rate of production in many cases will be faster than the time required for the inspection of items. Hence, 100 per cent inspection would cost too much. Also, in cases where the unit is destroyed during inspection, 100 per cent inspection is impossible.
3. The inspection of each and every unit will reduce the efficiency of the quality inspectors because of boredom. S.Q.C. keeps the quality control personnel alert.
4. S.Q.C. can be carried by persons who do not possess a high degree in engineering or statistics. As a matter of fact, great skill and intelligence is required to develop the statistical method for quality control in a particular case rather than applying the methods set for the purpose.
5. S.Q.C keeps consistent vigilance on the quality of the product. The moment it is found that the process is out of control, the production engineer is informed about it. In this way, there is an incalculable reduction in losses.
6. Variation is inherent and unavoidable. So merely measuring the variation from the standard values does not serve the purpose. We have to decide whether the variation is within the tolerance limits or not. Such a variation is termed as chance variation. If the variation is beyond tolerance limits, it is said to be due to assignable causes. Thus, with the help of S.Q.C., the process is kept under control so that the product meets the specifications within tolerance limits.
7. Process control provides the basis to the producer, for deciding about the specifications. It makes no sense to fix up the specifications, which cannot be maintained economically.
8. S.Q.C. enables the manufacturers to know whether the changes brought in the production by installing new machines or by changing the system of the process or by employing more skilled persons has improved the quality of the product or not.

9. S.Q.C. is a basis for compromise between the machine operators and engineers. The engineers may expect a total adherence to specifications whereas the operators may emphasize their performance up to the mark, in spite of large variability in the units. Hence, S.Q.C. is a good device to keep both the sections satisfied.
10. S.Q.C. provides protection against losses to the producer as well as to the consumer.

TYPES OF QUALITY CONTROL:

The quality of a product manufactured in a factory may be controlled by the following two ways:

i) Process Control ii) Product Control

Process Control: In this process, the quality is controlled while the product being produced remains in process of production. It ensures that the goods produced conform to the pre-determined quality standards. It controls the quality of goods to be produced by stopping production if the quality level is not being maintained. A process is said to be in control if the variations in items produced are only due to the element of chance and not due to any assignable cause.

The object of keeping the process under control is achieved with the help of control charts, a graphical method of presenting a sequence of suitable sample characteristic thereby revealing the frequency and extent of variations from established standards or goals. As the process control involves the use of control charts, therefore, this method is sometimes called the control chart technique.

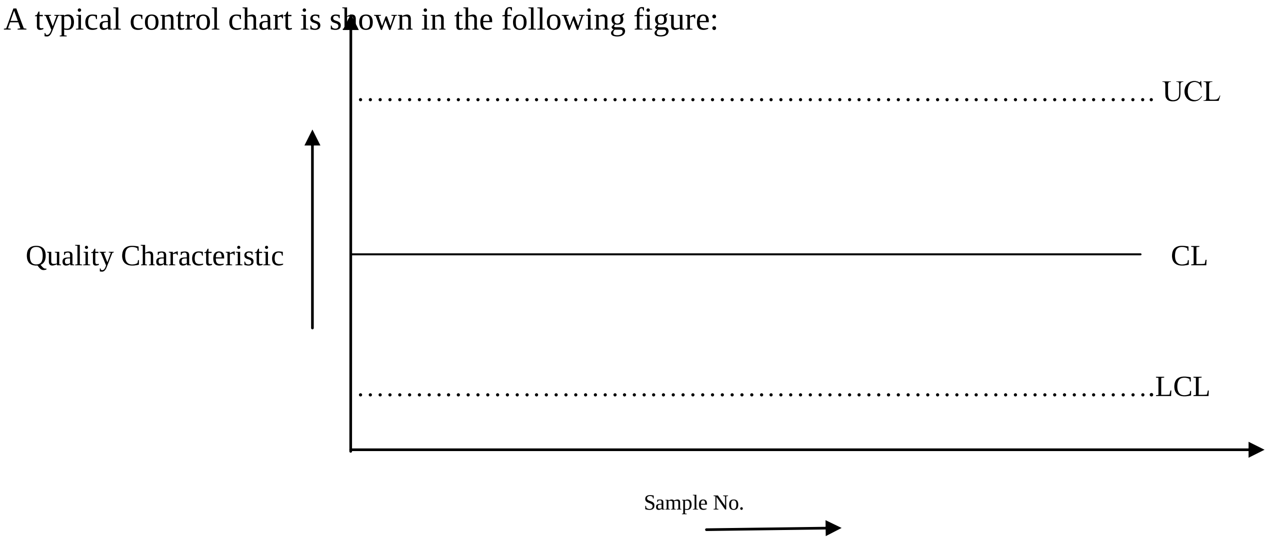
Product or Lot Control: It refers to the type of quality control of the product which has already been manufactured and which waits for sale and dispatch. By product control, we mean sampling inspection plans which is concerned with the decision to accept a lot of items conforming to a specified level of quality or to reject the lot as non-conforming. The decision is made through sampling which helps the purchases to dispense with 100% inspection of the lot of items. In this process, lot by lot sampling techniques inspection is performed and a lot is accepted or rejected on the basis of information obtained by sampling. Product control is an essential constituent of production and it may be applied to raw material, semi-furnished goods at intermediate stages of the manufacturing process. Product control aims at generating a certain quality level to the consumers.

INTRODUCTION TO CONTROL CHARTS:

In any production process, regardless of how well-designed or carefully maintained it is, a certain amount of inherent or natural variability will always exist. This natural variability or "background noise" is the cumulative effect of many small, essentially unavoidable causes. When the background noise in a process is relatively small, we usually consider it an acceptable level of process performance. In the framework of statistical quality control, this natural variability is often called a "stable system of chance causes." A process that is operating with only **chance causes** of variation present is said to be in statistical control. In other words, the chance causes are an inherent part of the process. Other kinds of variability may occasionally be present in the output of a process. This variability in key quality characteristics usually arises from three sources: improperly adjusted machines, operator errors, or defective raw materials. Such variability is generally large when compared to the background noise, and it usually represents an unacceptable level of process performance. We refer to these sources of variability that are not part of the chance cause pattern as **assignable causes.** A process that is operating in the presence of assignable causes is said to be out of control. Production processes will often operate in the in-control state, producing acceptable product for relatively long periods of time. Occasionally, however, assignable causes will occur, seemingly at random, resulting in a "shift" to an out-of-control state where a large proportion of the process output does not conform to requirements. A major objective of statistical process control is to quickly detect the occurrence of assignable causes or process shifts so that investigation of the process and corrective action may be undertaken before many nonconforming units are manufactured. The control chart is an online process-monitoring technique widely used for this purpose.

Control charts may also be used to estimate the parameters of a production process and, through this information, to determine the capability of a process to meet specifications. The control chart can also provide information that is useful in improving the process. Finally, remember that the eventual goal of statistical process control is the elimination of variability in the process. Although it may not be possible to eliminate variability completely, the control chart helps reduce it as much as possible.

A typical control chart is shown in the following figure:



which is a graphical display of a quality characteristic that has been measured or computed from a sample versus the sample number or time. Often, the samples are selected at periodic intervals such as every hour. The chart contains a center line (CL) that represents the average value of the quality characteristic corresponding to the in-control state. (That is, only chance causes are present.) 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 if the process is in control, nearly all of the sample points will fall between them. In general, as long as the points plot within the control limits, the process is assumed to be in control, and no action is necessary. However, a point that plots outside of the control limits is interpreted as evidence that the process is out of control, and investigation and corrective action are required to find and eliminate the assignable cause or causes responsible for this behavior. The sample points on the control chart are usually connected with straight-line segments so that it is easier to visualize how the sequence of points has evolved over time. Even if all the points plot inside the control limits, if they behave in a systematic or nonrandom manner, this is an indication that the process is out of control. For example, if 18 of the last 20 points plotted above the center line but below the upper control limit and only two of these points plotted below the center line but above the lower control limit, we would be very suspicious that something was wrong. If the process is in control, all the plotted points should have an essentially random pattern. Methods designed to find sequences or nonrandom patterns can be applied to control charts as an aid in detecting out-of-control conditions. A particular nonrandom pattern usually appears on a control chart for a reason, and if that reason can be found and eliminated, process performance can be improved. There is a close connection between control charts and hypothesis testing. Essentially, the control chart is a test of the hypothesis that the process is in a state of statistical control. A point plotting within the control limits is equivalent to failing to reject the hypothesis of statistical control, and a point plotting outside the control limits is equivalent to rejecting the hypothesis of statistical control.

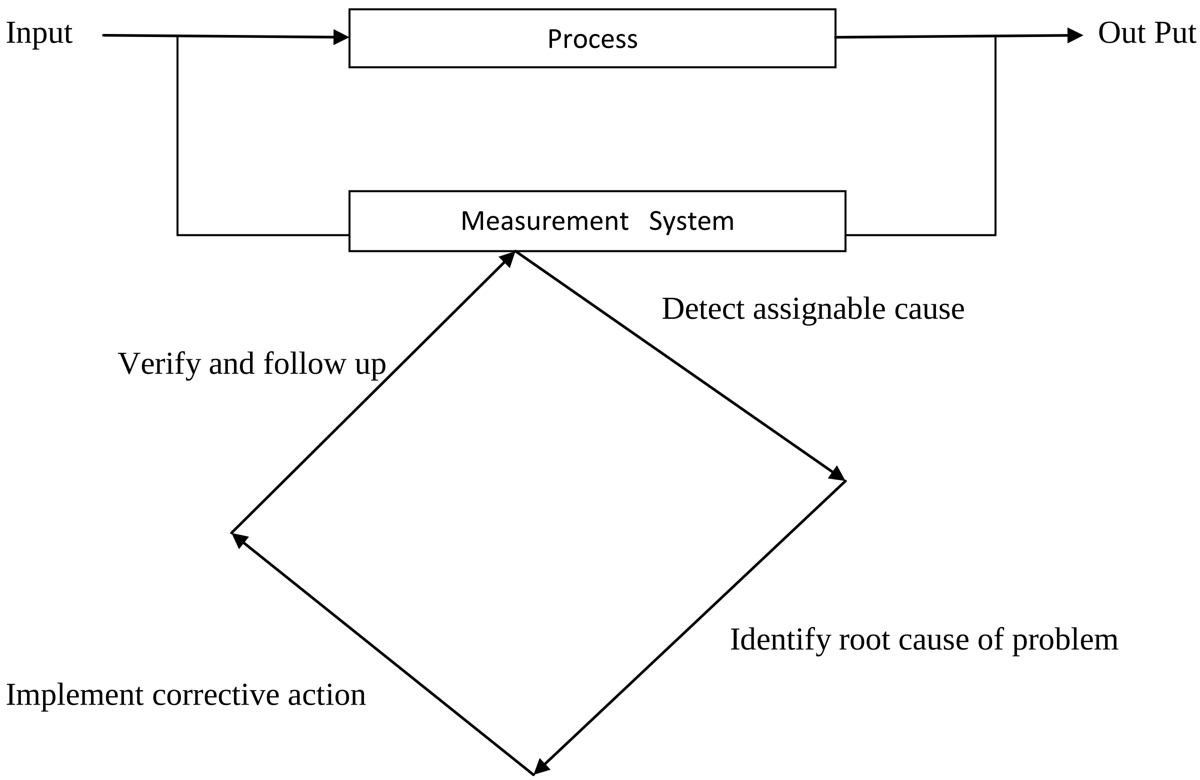


Figure showing the process improvement using the control chart

The general *model* for a control chart is given as:

Let *W* be a sample statistic that measures some quality characteristic of interest, and suppose that the mean of *W* is μ and the standard deviation of *W* is σ. Then the center line, the upper control limit, and the lower control limit become

$$UCL = \mu_w + k\,\sigma_w$$

$$CL = \mu_w$$

$$LCL = \mu_w - k\,\sigma_w$$

where *k* is the "distance" of the control limits from the center line, expressed in standard deviation units. A common choice is *k* =3. This general theory of control charts was first proposed by Dr. Walter A. Shewhart, and control charts developed according to these principles are often called **Shewhart control charts.**

The control chart is a device for describing exactly what is meant by statistical control; as such, it may be used in a variety of ways. In many applications, it is used for online process monitoring. That is, sample data are collected and used to construct the control chart, and if the sample values of (say) fall within the control limits and do not exhibit any systematic pattern, we say the process is in control at the level indicated by the chart. Note that we may be interested here in determining both whether the past data came from a process that was in control and whether future samples from this process indicate statistical control.

The most important use of a control chart is to *improve* the process. We have found that, generally

1. Most processes do not operate in a state of statistical control.

2. Consequently, the routine and attentive use of control charts will identify assignable causes. If these causes can be eliminated from the process, variability will be reduced and the process will be improved. This process-improvement activity using the control chart is illustrated in above cited figure.

3. Control chart will only *detect* assignable causes. Management, operator, and engineering *action* will usually be necessary to eliminate the assignable cause. An action plan for responding to control chart signals is vital. In identifying and eliminating assignable causes, it is important to find the underlying **root cause** of the problem and to attack it. A cosmetic solution will not result in any real, long-term process improvement. Developing an effective system for corrective action is an essential component of an effective SPC implementation. We may also use the control chart as an *estimating device*. That is, from a control chart that exhibits statistical control, we may estimate certain process parameters, such as the mean, standard deviation, and fraction nonconforming or fallout. These estimates may then be used to determine the *capability* of the process to produce acceptable products. Such **process capability studies** have considerable impact on many management decision problems that occur over the product cycle, including make-or-buy decisions, plant and process improvements that reduce process variability, and contractual agreements with customers or suppliers regarding product quality. Control charts may be classified into two general types. Many quality characteristics can be measured and expressed as numbers on some continuous scale of measurement. In such cases, it is convenient to describe the quality characteristic with a measure of central tendency and a measure of variability. Control charts for central tendency and variability are collectively called **variables control charts.** The chart is the most widely used chart for monitoring central tendency, whereas charts based on either the sample range or the sample standard deviation are used to control process variability. Many quality characteristics are not measured on a continuous scale or even a quantitative scale. In these cases, we may judge each unit of product as either conforming or nonconforming on the basis of whether or not it possesses certain attributes, or we may count the number of nonconformities (defects) appearing on a unit of product. Control charts for such quality characteristics are called **attributes control charts.**

Control charts have had a long history of use in industry. There are at least five reasons for their popularity:

1. Control charts are a proven technique for improving productivity. A successful control chart program will reduce scrap and rework, which are the primary productivity killers in *any* operation. If you reduce scrap and rework, productivity increases, cost decreases, and production capacity (measured in the number of *good* parts per hour) increases.

2. Control charts are effective in defect prevention. The control chart helps keep the process in control, which is consistent with the "do it right the first time" philosophy. It is never cheaper to sort out the "good" units from the "bad" later on than it is to build them correctly initially. If you do not have effective process control, you are paying someone to make a nonconforming product.

3. Control charts prevent unnecessary process adjustments. A control chart can distinguish between background noise and abnormal variation; no other device, including a human operator, is as effective in making this distinction. If process operators adjust the process based on periodic tests unrelated to a control chart program, they will often overreact to the background noise and make unneeded adjustments. These unnecessary adjustments can result in a deterioration of process performance. In other words, the control chart is consistent with the "if it isn't broken, don't fix it" philosophy.

4. Control charts provide diagnostic information. Frequently, the pattern of points on the control chart will contain information that is of diagnostic value to an experienced operator or engineer. This information allows the operator to implement a change in the process that will improve its performance.

5. Control charts provide information about process capability. The control chart provides information about the value of important process parameters and their stability over time. This allows an estimate of process capability to be made. This information is of tremendous use to product and process designers. Control charts are among the most effective management control tools, and they are as important as cost controls and material controls. Modern computer technology has made it easy to implement control charts in any type of process, because data collection and analysis can be performed on a microcomputer or a local area network terminal in real time, online at the work center.

NEED FOR CHANGE OF CONTROL LIMITS:

There are only three situations in which it is appropriate to change the control limits:

1. **When removing out-of-control data points.** When a special cause has been identified and removed while you are working to achieve process stability, you may want to delete the data points affected by special causes and use the remaining data to compute new control limits.
2. **When replacing trial limits**. When a process has just started up, or has changed, you may want to calculate control limits using only the limited data available. These limits are usually called *trial control limits*. We can calculate new limits every time you add new data. Once you have 20 or 30 groups of 4 or 5 measurements without a signal, you can use the limits to monitor future performance. There is no need to re-calculate the limits again unless fundamental changes are made to the process.
3. **When there are changes in the process**. When there are indications that your process has changed, it is necessary to re-compute the control limits based on data collected since the change occurred. Some examples of such changes are the application of new or modified procedures, the use of different machines, the overhaul of existing machines, and the introduction of new suppliers of critical input materials.