Unit-5
Quality Control

Contents: Concept of Quality, Quality control and quality assurance, Specification of quality, Factors controlling quality of design and conformance, Cost of quality, Balance between cost and quality and value of quality, Seven QC tools.

WHAT IS QUALITY

Quality is a relative term and used with reference to the end use of the product.Quality generally signifies the 'Degree of its excellence '. The quality of a product can bedefined as 'Fitness for the purpose'. The component is said to possess good quality, if itworks well for which it is designed. The quality is also defined as 'Grade '. The distinguishfeatures of the product are appearance, test, maintainability, performance and reliability.

Inspection

The industrial revolution introduced mass production techniques to the workplace. By the end of the19th century, production processes were becoming more complex and it was beyond the capabilities of a single individual to be responsible for all aspects of production. It is impossible to inspect quality into a product in the sense that a faulty product cannot be put right by means of inspection alone. Statistical quality control can and does provide the environment within which the product is manufactured correctly the first time. A process called acceptance sampling improves the average quality of the items accepted by rejecting those items which are of unacceptable quality. In the 1920s, mass production brought with it the production line and assembly line concepts. Henry Ford revolutionized car production with the introduction of the mass production of the 'Model T.'

Mass production resulted in greater output and lower prices, but the quality of manufacturedoutput became more variable and less reliable. There was a need to tackle the problem of theproduction of goods and parts of a fixed quality and standard. The solution was seen to be inthe establishment of inspection routines, under the supervision of a Quality Inspector. The firstinspection procedures required the testing of the entire production - a costly, time consumingand inefficient form of sorting out good and defective items.

Quality Control:

Once the design of quality has been specified the actual manufacturing process willstart as per the specification. The term quality control can be defined as the control of variousfactors that affect the quality. It mainly depends on working conditions, type of labour, measuring instruments, material, tools, machines and skill required.

OBJECTIVES OF QUALITY CONTROL

1. To produce optimum quality at economic rate.
2. To ensure satisfaction of customers with products and services of higher quality.
3. Develop a procedure for good vendor and vendee relations.

4. To improve quality and productivity.
5. Evaluation of quality standards of incoming material, product, WIP and outgoing product.
6. Judging the conformity of the process.
7. Developing quality consciousness within the organization.
8. Reduction in scrap and work.
9. Few customer complaints.
10. Reduction in inspection.

Quality Assurance

In turn, Quality Control evolved into Quality Assurance. The function of Quality Assurance is to focus on assuring process and product quality through operational audits, the supplying of training, the carrying out of technical analysis, and the giving of advice on quality improvement. The role of Quality Assurance is to consult with the departments (design and production for example) where responsibility for quality actually rests.

The activities assigned to the assurance function usually include:

- Processing of the field complaints.
- Quality rating of out-going product.
- Quality survey or audit.
- Preparation of executive report on quality.
- Setting up quality levels.
- Inspection planning.
- Disposition of non-conforming products.

Quality Assurance vs. Quality control

Quality Assurance (QA)	Quality Control (QC)
1. It is a procedure that focuses on providing assurance that quality request will be achieved	1. It is a procedure that focuses on fulfilling the quality request
2. QA aims to prevent the defect	2. QC aims to identify and fix defects
3. It does not involve executing the program	3. It always involves executing a program
4. It's a Preventive technique	4. It's a Corrective technique
5. It's a Proactive measure	5. It's a Reactive measure
6. It is performed before Quality Control	6. It is performed only after QA activity is done
7. Statistical technique applied on QA is known as SPC or Statistical Process Control (SPC)	7. Statistical technique applied on QC is known as SQC or Statistical Quality Control

Tolerance Limits and Specifications

An example of a specification for the manufacture of a short cylindrical spacer might be:
Diameter: 1 ± 0.003 cm; length: 2 ± 0.001 cm.

Even though the ± differences here are the same (±0.003 in the case of the diameters and ±0.001 in the case of the lengths), there is no reason why this should always be so. These limits are called the specification limits. During manufacture, some variation in dimensions will occur by chance. These variations can be measured by using the standard deviation of the distribution followed by the dimensions produced by the manufacturing process. Figure 5.1 below shows two normal distributions each with so-called natural tolerance limits of 3σ either side of the mean. Taking these limits implies that virtually all of the manufactured articles will fall within the natural tolerance limits. Notice that in the top part of the figure the specification limits are rather wider than the natural tolerance limits and that little if any wastage will be produced. One could argue that in this case the manufacturing process is actually better than it needs to be and that this may carry unnecessary costs. In the lower part of the figure the specification limits are narrower than the natural tolerance limits and wastage will occur In general, a production process should aim to equate the two types of limits to minimize both costs and wastage.

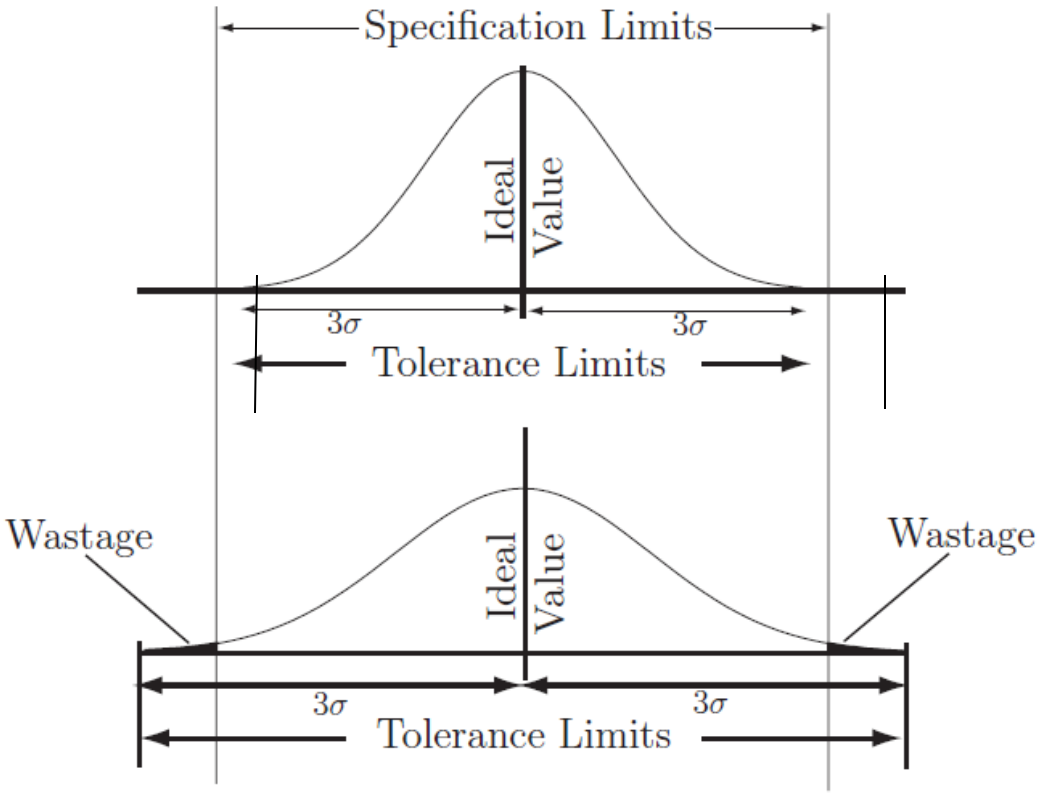

Diagram 1 - Specification and Tolerance Limits

Quality of Design

Quality of design is all about set conditions that the product or service must minimally have to satisfy the requirements of the customer. Thus, the product or service must be designed in such a way so as to meet at least minimally the needs of the consumer. However, the design must be simple and also less expensive so as to meet the customers' product or service expectations. Quality of design is influenced by many factors, such as product type, cost, profit policy, demand of the product, avail-ability of parts and materials, and product reliability.

Quality of Conformance

Quality of conformance is basically meeting the standards defined in the design phase after the product is manufactured or while the service is delivered. This phase is also concerned about quality is control starting from raw material to the finished product. Three broad aspects are covered in this definition, viz. defect detection, defect root cause analysis, and defect prevention. Defect prevention deals with the means to deter the occurrence of defects and is usually achieved using statistical process control techniques. Detecting defects may be by inspection, testing or statistical data analysis collected from process. Subsequently, the root causes behind the presence of defects are investigated, and finally corrective actions are taken to prevent recurrence of the defect.

Quality of Performance

Quality of performance is how well the product functions or service performs when put to use. It measures the degree to which the product or Service satisfies the customer from the perspective of both quality of design and the quality of conformance. Meeting customer expectation is the focus when we talk about quality of performance. Automobile industry conduct test drive of vehicles to collect information about mileage, oil consumption. Bulbs are life tested to understand its reliability during useful life. Customer survey is conducted to find customer’s perception about service delivered. If product or service does not live up to customer expectation, then adjustments are needed in the design or conformance phase.

Cost ofQuality:

Quality costs are defined as those costs that are associated with the non-achievement of product or service quality as defined by the requirements established by the organization and its contracts (agreements) with customers. In simple terms, quality cost is the cost incurred by the firm because of producing poor quality products. Measurement and analysis of various cost aids in tracking the impact of an effective quality management system. Quality costs can be summed up as costs of preventing of non-conformance of requirements, inspecting product/service for non-conformances and failure in meeting specifications.

Cost of quality involves;

- Market research cost
- Product research & development
- The design cost
- Cost of manufacturing
- Cost of inspection and test

- Cost of defect prevention
- Cost of scrap, quality prevention
- Cost of quality assurance
- Field service cost.

Fig. 5.2 Quality cost

The American Society for Quality Control (1971) has defined four major categories for quality costs, which are provided below:

PreventionCosts

Prevention costs are incurred in planning, implementing, and maintaining of a quality practice. It include salaries and developmental costs for process control approaches, information systems, and all other costs associated with making the product right the first time. Also, costs associated with education and training is included in this category. Defect identification and removal and the cost of a quality audit are included in the prevention cost.

External Failure Costs

External failure costs are incurred when the product does not perform satisfactorily after it is shipped to the end customer. If there are no defective units, the external failure cost can be zero. However, cost incurred due to customer complaints, costs of investigation and adjustments if required, and those associated with receipt, handling, repair (if possible), and replacement of defective products comes within the external failure cost. Warranty cost (failure of a product within the warranty time) which is specifically monitored in industries also fall under this category.

Appraisal Costs

Appraisal costs are related with measuring, evaluating, or inspecting products, components, or purchased materials to determine their degree of conformance to specified design

standards. Such costs include dealing with the inspection and test of incoming materials as well as product inspection and testing at various stages of manufacturing till final acceptance. Appraisal costs are associated with managing the outcome, whereas prevention costs are associated with managing the goal.

Internal Failure Costs

Internal failure costs are incurred when products, sub-assemblies, components or materials fail to meet quality requirements prior to the transfer of ownership to the internal customer. These costs will disappear if there were no defects or defective in the product while it is manufactured in-house. Internal failure costs also include labor and overhead cost associated with any internal repair.

Cost of quality and value of quality:

It can be seen from the cost curve, that as the quality of a product is improved, the cost ends to rise at an increasing rate. On the other hand, the value curve shows as opposite tendency, in that, the value of the price which the customer is willing to pay for improved quality increases at a decreasing rate. The difference between the value and the cost of product at any particular quality level, represents quality contribution.

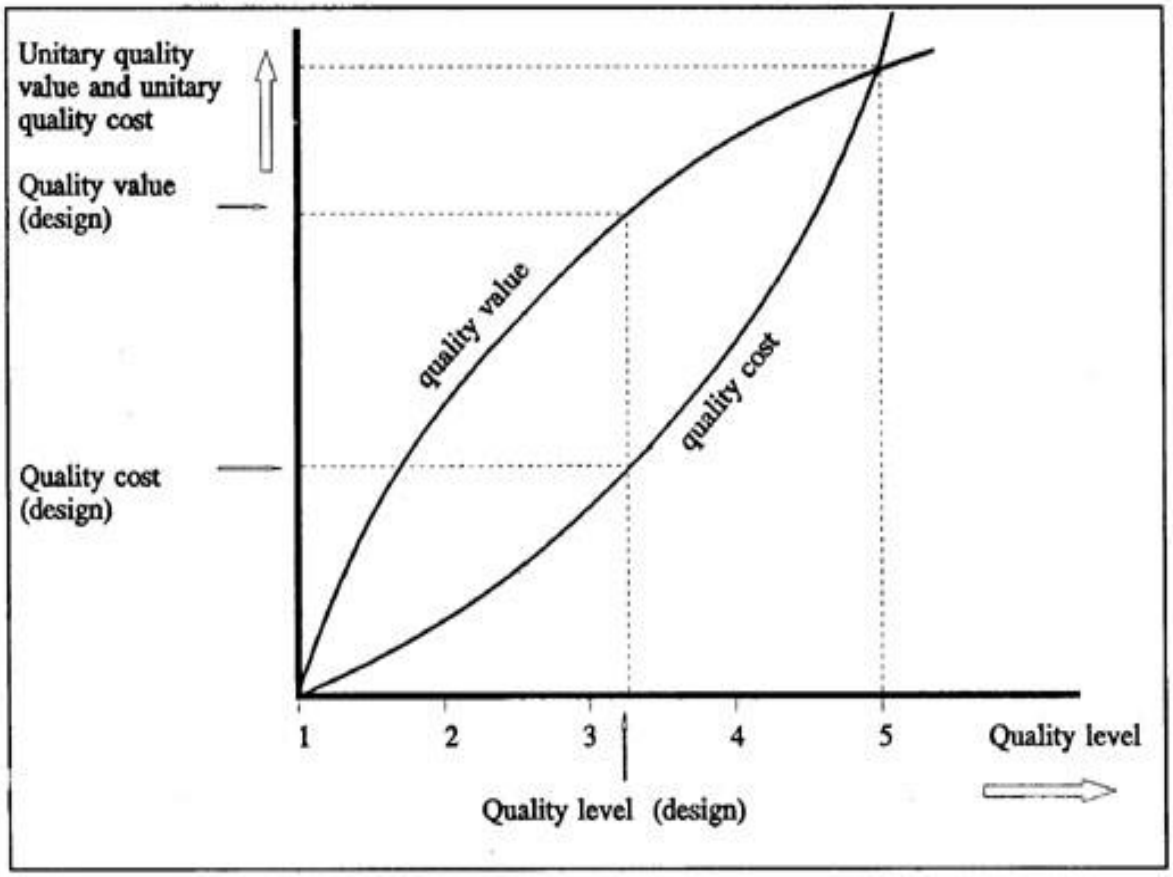

Fig. 5.3 Cost of quality and Value of quality

QUALITY AUDIT

Quality audit is an independent evaluation of various aspects of quality performance. It is asurvey of the quality system of an entire plant. OR It is an appraisal of the whole qualitycontrol. Quality audit may be conducted periodically or only when occasion demands, due toexistence of quality problem.

Purpose of Audit

1. Corrective action is taken with respect to deviation.
2. Opportunities for improvement.
3. There is conformance to specification.
4. Preparations for attaining quality system.
5. Customer quality complaints.
6. Adequacy of gauges and test equipment's used.
7. Rejection rate of the product.
8. Procedure for vendor's capacity verification.
8. Completeness and clarity of the manufacturing drawings and specifications and procedure fortheir updating.
9. To evaluate own quality performance.

Total Quality Management:

Total quality management (TQM) is a strategy for implementing and managing quality improvement activities on an organization wide basis. TQM began in the early 1980s, with the philosophies of Deming and Juran as the focal point. It evolved into a broader spectrum of concepts and ideas, involving participative organizations and work culture, customer focus, supplier quality improvement, integration of the quality system with business goals, and many other activities to focus all elements of the organization around the quality improvement goal. Typically, organizations that have implemented a TQM approach to quality improvement have quality councils or high-level teams that deal with strategic quality initiatives, workforce-level teams that focus on routine production or business activities, and cross-functional teams that address specific quality improvement issues.

TQM has only had moderate success for a variety of reasons, but frequently becausethere is insufficient effort devoted to widespread utilization of the technical tools of variabilityreduction. Many organizations saw the mission of TQM as one of training. Consequently,many TQM efforts engaged in widespread training of the workforce in the philosophy of qualityimprovement and a few basic methods. This training was usually placed in the hands ofhuman resources departments, and much of it was ineffective. The trainers often had no realidea about what methods should be taught, and success was usually measured by the percentageof the workforce that had been "trained," not by whether any measurable impact on businessresults had been achieved. Some general reasons for the lack of conspicuous success of TQM include (1) lack of top-down, high-level management commitment and involvement;(2) inadequate use of statistical methods and insufficient recognition of variability reduction asa prime objective; (3) general as opposed to specific business-results-oriented objectives; and(4)

too much emphasis on widespread training as opposed to focused technical education.Another reason for the erratic success of TQM is that many managers and executiveshave regarded it as just another "program" to improve quality. During the 1950s and 1960s,programs such as Zero Defects and Value Engineering abounded, but they had little realimpact on quality and productivity improvement. During the heyday of TQM in the 1980s,another popular program was the Quality is free initiative, in which management worked onidentifying the cost of quality (or the cost of non-quality, as the Quality is free devotees socleverly put it). Indeed, identification of quality costs can be very useful (we discuss qualitycosts in Section 1.4.3), but the Quality is Free practitioners often had noidea about what todo to actually improve many types of complex industrial processes. In fact, the leaders of thisinitiative had no knowledge about statistical methodology and completely failed to understandits role in quality improvement. When TQM is wrapped around an ineffective programsuch as this, disaster is often the result.

Some of the approaches which is extended and used from TQM philosophies are:

- Quality Standards – International Standards Organization(ISO)
- Just-in-Time
- Lean Manufacturing
- Poka-Yoke
- Customer Focus

Therefore, TQM is the art of managing the whole to achieve excellence.

Six Sigma:

High-technology products with many complex components typically have many opportunities for failure or defects to occur. Motorola developed the six-sigma program in the late 1980s as a response to the demand for these products. The focus of six-sigma is reducing variability in key product quality characteristics, or so-called CTQ, to the level at which defects are extremely unlikely. **Figure 5.4** shows a normal probability distribution as a model for a quality characteristic with the specification limits at six standard deviations on either side of the mean.

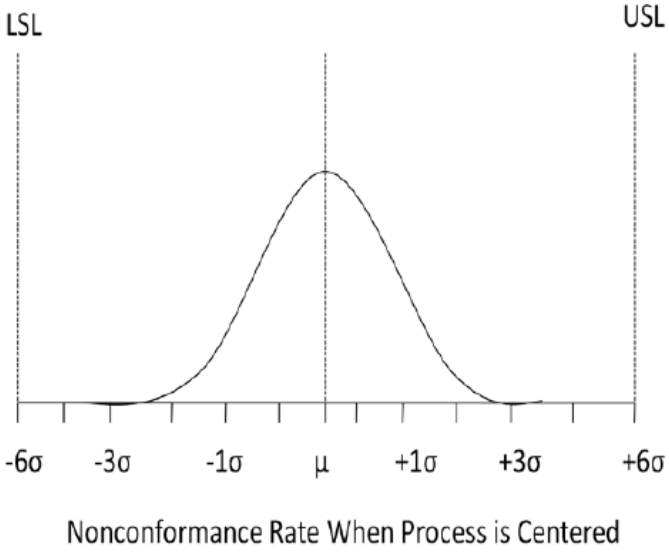

Fig. 5.4 Normal probability distribution

Now it turns out that in situation when specification lines are at three standard deviation level, the probability of producing a product within these specifications is 0.9973, which corresponds to 2700 parts per million (ppm) defective. This is referred to as three-sigma quality performance. In case we have a product that consists of an assembly of 100 components or parts and all 100 of these parts must be no defects for the product to function satisfactorily. The probability that the unit of product is having no defects is$0.9973 \times 0.9973 \times \ldots \times 0.9973 = (0.9973)^{100} = 0.7631$.

That is, about 23.7% of the products produced under three-sigma quality will be defective. This may not an acceptable situation, because many high-technology products are made up of thousands of components. An automobile has about 200,000 components and an airplane has several million. The Motorola six-sigma concept is to reduce the variability in the process so that specification limits are six standard deviations from the mean.For six-sigma quality, the probability that any specific unit of the hypothetical product is having defect is 0.9999998, or 0.2 defect parts per million.

When the six-sigma concept was initially developed, an assumption was made that when the process reached the six-sigma quality level, the process mean was still subject to disturbances that could cause it to shift by as much as 1.5 standard deviations off target. Under this scenario (shown in Figure 5.5), a six-sigma process would produce about 3.4 ppm defects.

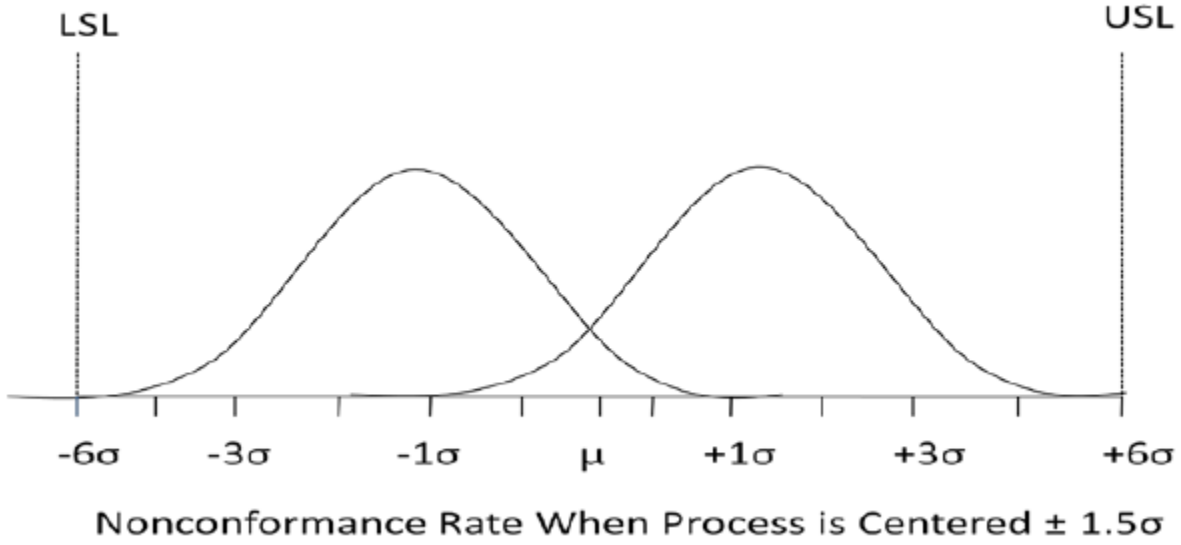

Figure 5.5 Shift in Mean

Table 5.1 PPM level vs sigma rating

Specification limit	±1 σ	±2 σ	±3 σ	±4 σ	±5 σ	±6 σ
Percent inside specs	30.23	69.13	93.32	99.379	99.9767	99.9966
ppm defective	697700	308700	66810	6210	2330	3.4

Considering shift in mean as natural phenomenon, the nonconforming and part per million (PPM) is given in Table 5.1.

Six sigma also considers an important concept of opportunity to define the PPM level. Motorola established six-sigma as both an objective for the corporation and as a focal point for process and product quality improvement efforts. In recent years, six-sigma has spread beyond Motorola and has come to encompass much more. It has become a program for improving corporate business performance by both improving quality and paying attention to reducing costs. Companies involved in a six-sigma effort utilize teams to work on projects that have both quality and significant financial impact. The effort is better focused than in earlier TQM programs, and has been more successful in obtaining management commitment. However, remember Deming's point 10, which essentially says to eliminate slogans and programs to improve quality. There are many programs including zero defects, value engineering, quality is free, TQM, and so forth, which has failed due to improper implementation. A major component in successful quality improvement is driving the use of the proper statistical and engineering tools into the right places in the organization. A DMAIC (Define, Measure, Analyze, Improve and Control) approach is used to implement six sigma philosophy. However, it is to be remembered that statistical approach (say SPC, DOE) is the key theme for variation reduction in Six Sigma philosophy.

Quality Systems and Standards:

The International Standards Organization (founded in 1946 in Geneva, Switzerland), known as ISO, has developed a series of standards for quality systems. The first standards were issued in 1987. The current version of the standard is known as the ISO 9000 series. It is a generic standard, broadly applicable to any type of organization, and it is often used to demonstrate a supplier’s ability to control its processes.

ISO is an international organization for standardization, which has been formed for the development and issuing of international standards to be used across the world. Since its inception, it has published more than 19,000 standards. Standardization actually helps in the optimization of operations by proper utilization of resources. Earlier, when ISO started its operations, it was working as International Federation of the National Standardizing Associations (ISA). But this organization was dissolved during World War II. The acronym ISO is derived from the Greek word “isos” which means “equal”. The members of ISO are the recognized standard authorities, which also represents their respective nations. For example, American National Standards Institute (ANSI) is the representative of the United States in ISO, and a Bureau of Indian standard is the representative of India. The structure of ISO is comprised of technical committees, sub-committees and working groups.

The ISO 9000 Series of Standards is generic in scope. By design, the series can be tailored to fit any organization's needs, whether it is large or small, a manufacturer or a service organization. ISO 9000 series is developed to serve the quality aspects, which also include the eight principles of management systems. It can be applied to construction, engineering, health

care, legal, and other professional services as well as the manufacturing of anything from nuts and bolts to spacecraft. Its purpose is to unify quality terms and definitions used by industrialized nations and use those terms to demonstrate a supplier's capability of controlling its processes. In very simplified terms, the standards require an organization to say what it is doing to ensure quality, then do what it says, and, finally, document or prove that it has done what it said. The main reason behind establishing ISO standards is to ensure the required safety, quality, and reliability of products and services. This can raises the levels of productivity and reduce the chance of error.

The three initial standards of the series are:

ISO 9000:2000-Quality Management Systems (QMS)-fundamentals and vocabulary discusses the fundamental concepts related to the QMS and provides the terminology used in the other, two standards.

ISO 9001:2000-Quality Management Systems (QMS)-requirements is the standard used for registration by demonstrating conformity of the QMS to customers, regulatory, and the organization's own requirements. ISO 9001:2008 is further developed with the aim of establishing the requirements of quality management systems. The certification for ISO 9001 needs to be renewed by organization after a particular period as suggested by the certification body. Generally, this period is three years.

ISO 9004:2000-Quality Management Systems (QMS)-guidelines for performance improvement provides guidelines that an organization can use to establish a QMS focused on improving performance. ISO 9004:2009 was created as the latest revision to replace ISO 9004:2008 and was released in November, 2009.

The standard has eight clauses: Scope, Normative References, Definitions, Quality Management Systems, Management Responsibility, Resource Management, Product and/or Service Realization, and Measurement, Analysis, and Improvement. The first three clauses are for information while the last five are requirements that an organization must meet.

AS100

This aerospace industry quality system was officially released by the Society of Automotive Engineers in May 1997. Its development and release represents the first attempt to unify the requirements of NASA, DOD, and FAA, while satisfying the aerospace industry's business needs. In March 2001, the International Aerospace Quality Group (IAQG) aligned AS9100 with ISO 9001:2000.

QS 9000

The famous “Big Three” of US automobile sector, namely Chrysler, Ford and General Motors had their own supplier development models and associated quality assurance systems initially. However, in the late 80, a need was felt to develop a harmonized common model for the suppliers to these big-three as suppliers were faced with the problem of complying to different quality assurance models for supplies made to different buyers. Accordingly a joint Automobile Industry Action Group (AIAG) was set up to develop a harmonized supplier development and

quality assurance model, primarily meant for suppliers to the above mentioned automobiles manufacturers and subsequently also to other automobile related industries throughout the world. The basis used by the AIAG was the ISO-9000 series of standards in addition to the existing individual quality assurance standards of Chrysler, Ford and General Motors.

QS-9000 (http://en.wikipedia.org/wiki/QS9000) defines the fundamental quality system expectations of Chrysler, Ford, General Motors, Truck Manufactures and other subscribing companies for internal and external suppliers of production and service parts and materials. These organizations are committed to working with suppliers to ensure customer satisfaction beginning with conformance to quality requirements, and continuing with reduction of variation and waste to benefit the final customer, the supply base, and themselves.

In addition, **ISO 9003:2004** is another standard that is developed with the aim of improving the quality of software-related products in terms of supply, development, maintenance and support services. Whereas, **ISO 13485** standards published states all the specifications required for a comprehensive quality management system that helps in the design and manufacturing of medical devices. As quality practices also influences society at large, **ISO 14000** was created with the aim of controlling the adverse effects to environment occurring due to the processes followed by organizations. **ISO 14001** standards are designed as the representation of all the standards that are used for the successful implementation of Environmental Management System.

7QC TOOLS:

Pareto Diagram

Alfredo Pareto (1848-1923) conducted extensive studies of distribution of wealth in Europe. He found that there were a few people with a lot of money and majority of the people are having little money in their hand. This unequal distribution of wealth became an integral part of economic theory. Dr. Joseph Juran recognized this concept as a universal concept which can be applied to many other fields.

A Pareto diagram is a graph that ranks data (on say types of defects) in descending order from left to right, as shown in Figure 5.6. In the diagram, data is classified as types of coating machines. Other possible data classifications include problem, complaints, causes, nonconformities types, and so forth.

The vertical scale can be dollar value (or frequency), and percentage in each category is shown on top of each bar. In this case, Pareto diagrams were constructed for both frequency and dollar value. As can be seen from the figure, machine 35 has the greatest number of nonconformities,but machine 51 has the greatest dollar value.

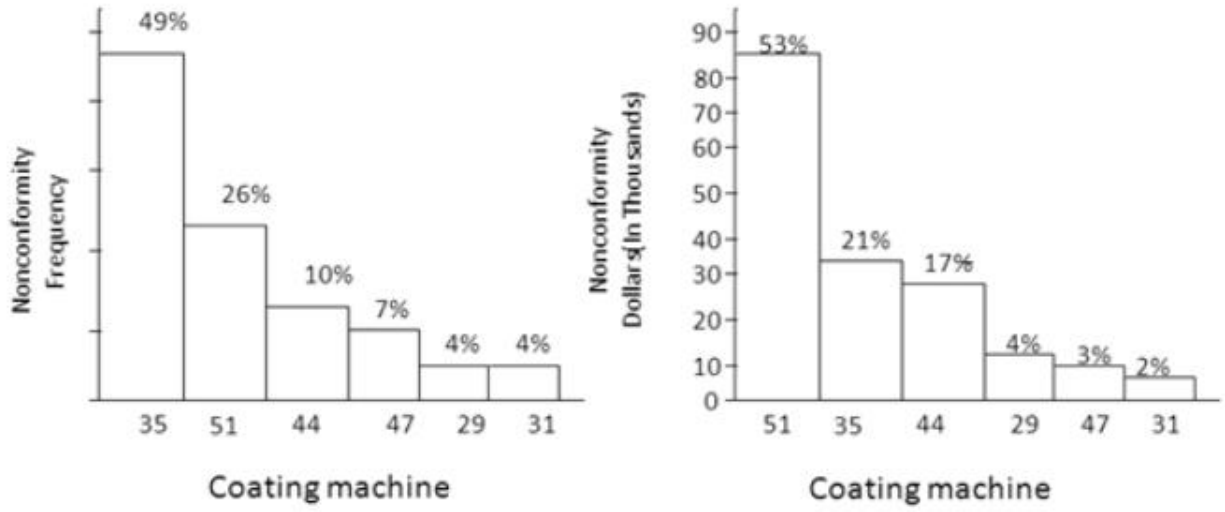

Fig. 5.6 Pareto diagram

Pareto diagrams are used to identify the most important problem type. Usually, 75% of the problems are caused by 25% of the items. This fact is shown in the above figure, where coating machines 35 and 51 account for about 75% of the total non-conformities.Actually, most important items could be identified by listing them in descending order. However, graph has an advantage of providing a visual impact, showing those vital few characteristics that need attention.

The Pareto diagram is a powerful quality improvement tool to determine the most critical problem to be considered first.

Cause and Effect Diagram

A cause-and-effect (C&E) diagram is a picture composed of lines and symbols designed to represent a meaningful relationship between an effect (say Y) and its potential causes (say X). Potential causes (which have evidence) are not all possible causes that come up in brain storming exercise. It was developed by Dr. Kaoru Ishikawa in 1968, and sometimes referred to as the 'Ishikawa diagram' or a 'fish bone diagram'. C&E diagram is used to investigate either a "bad" effect and to take action to rectify the potential causes or a "good" effect and to learn those potential causes that are responsible for the effect. For every effect, there are likely to be numerous potential causes. Figure 5.7 illustrates a simple C&E diagram with effect on right and causes on left. Effect is the quality characteristic that needs improvement. Causes are sometimes broken down into major sub causes related to work method, material, measurement, man (people), machinery (equipment), and environment (5M & 1E). It is not necessary that every diagram will always have 5M and 1 E cause and can depends also on the problem type. There can be other major causes in case of service-type problem.

Each major cause is further subdivided into numerous sub causes. For example, under work methods, we might have training, knowledge, ability, physical characteristics, and so forth. C&E diagrams are the means of picturing all these major and sub causes. The identified potential causes considered critical (say 1, 2, 3, 4 and 5 as given in the below diagram) may be further explored by experimentation to understand their impact on the house paint.

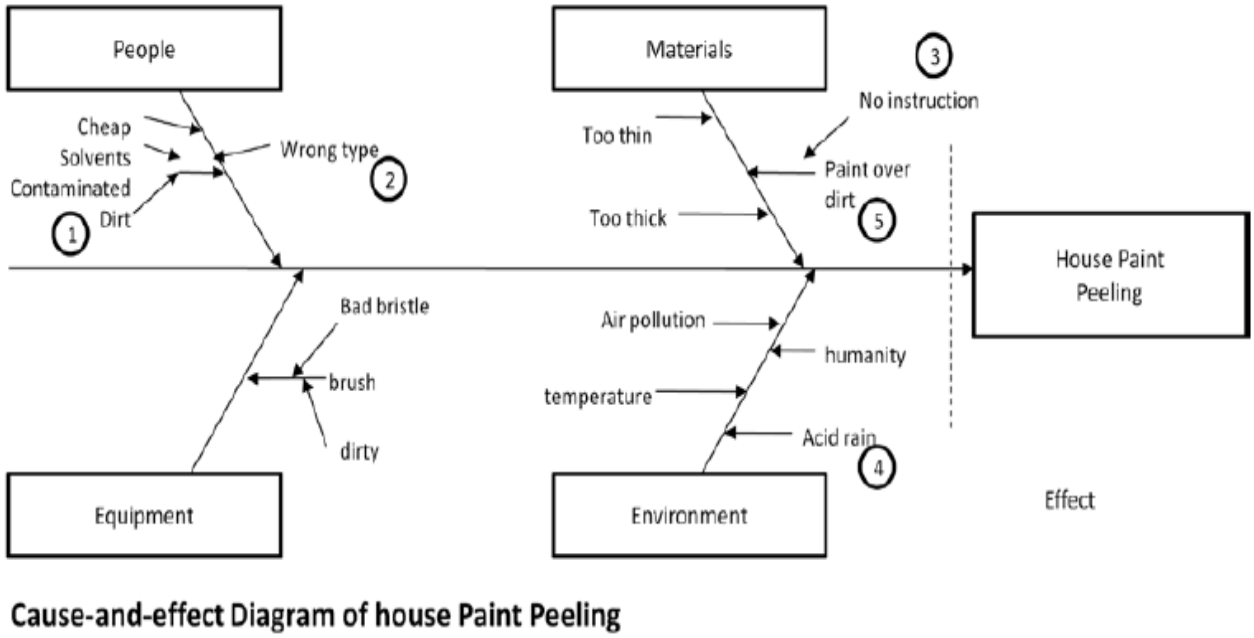

Fig.5.7 Cause and Effect diagram

C & E diagrams are useful to

1) Identify potential causes and not all possible causes,
2) Analyze actual conditions for the purpose of product or service quality improvement
3) Eliminate conditions which cause nonconformities and customer complaints.
4) Statistical Experimentation, Decision-making and corrective-action activities.

Check Sheets

Main purpose of check sheets in earlier days is to ensure that data was collected carefully and accurately by concerned personnel. Data is to be collected in such a manner that it can be quickly and easily used and analyzed. The form of check sheet is individualized for each situation and is designed by the project team. Figure 5.8 shows a check sheet for paint nonconformities for bicycles.

Check sheets can also be designed to show location of defects. For example, check sheet for bicycle paint non conformities could show an outline of a bicycle, with 'X's indicating location of nonconformities. Creativity plays a major role in design of a check sheet. It should be user-friendly and, whenever possible, include information on location.

CHECK SHEET

Product Bicycle 32 — Number inspected: 2217

Nonconformity type	Check	Total
Blister	𝍸 𝍸 𝍸 𝍸 I	21
Light spray	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 III	38
Drips	𝍸 𝍸 𝍸 𝍸 II	22
Overspray	𝍸 𝍸 I	11
Runs	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 II	47
Others	𝍸	5
	Total	144
Number	𝍩 𝍩 𝍩 𝍩 𝍩 𝍩 𝍩 𝍩 𝍩 𝍩	113
Nonconforming	𝍩 𝍩 𝍩 𝍩 𝍩 𝍩 𝍩 𝍩 𝍩 𝍩 𝍩 𝍩 III	

Fig. 5.8 Check Sheet

Histogram

A histogram is a graphical representation of the distribution of numerical data. It is an estimate of the probability distribution of a continuous variable (quantitative variable) and was first introduced by Karl Pearson. To construct a histogram, the first step is to "bin" the range of values—that is, divide the entire range of values into a series of intervals—and then count how many values fall into each interval. The bins are usually specified as consecutive, non-overlapping intervals of a variable. The bins (intervals) must be adjacent, and are often (but are not required to be) of equal size.

Histogram provides variation information of the characteristic of interest, as illustrated by Figure 5.9. It suggests probability distribution shape of the sample observation and also indicates possible gap in the data. Horizontal axis in Figure 5.9 indicates scale of measurement and vertical axis represents frequency or relative frequency.

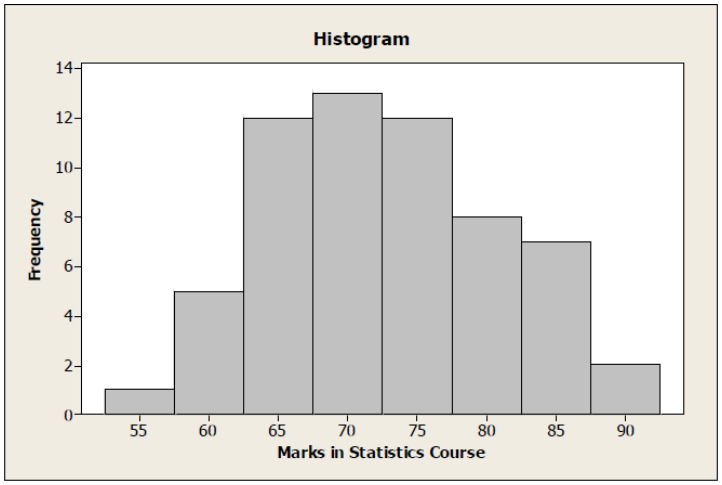

Fig 5.9 Histogram

Scatter Diagram

A scatter plot is a type of plot or mathematical diagram using Cartesian coordinates to display values for typically two variables for a set of data. If the points are color-coded, one additional variable can be displayed. The data is displayed as a collection of points, each having the value of one variable determining the position on the horizontal axis and the value of the other variable determining the position on the vertical axis. A scatter plot can be used either when one continuous variable that is under the control of the experimenter and the other depends on it or when both continuous variables are independent.The simplest way to determine if a relationship exists between TWO variables is to plot a scatter diagram. Figure 5.10 shows a sample scatter plot.

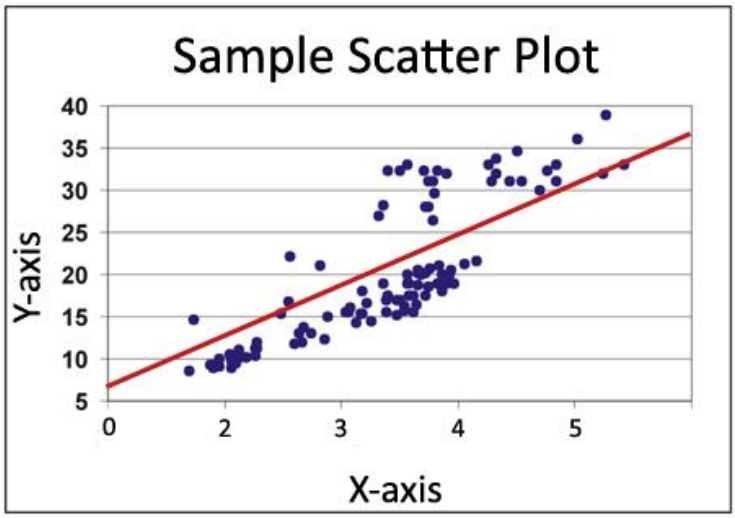

Fig. 5.10 Scatter Plot

Control Chart

Quality control is one approach that any organization adopts to detect defects and to take corrective actions. Quality control is employed to ensure the desired level of quality in the final goods and services. Quality control is about analysis of data for rectification of errors with respect to time. Walter Shewhart developed the control charts in 1924. It focuses on monitoring the performance of characteristic of interest over a period of time by looking at the variability in the data. There are two broad categories of control charts: control charts for attributes and control charts for variables. A variable control chart consists of a centre line (CL) that represents the mean value of the characteristic of interest. In addition, two other horizontal lines, namely the Upper Control Limit (UCL) and the Lower Control Limit (LCL), are also shown in the control chart. A typical variable control chart on mean and range of a characteristic, so-called X-bar and R is shown below.

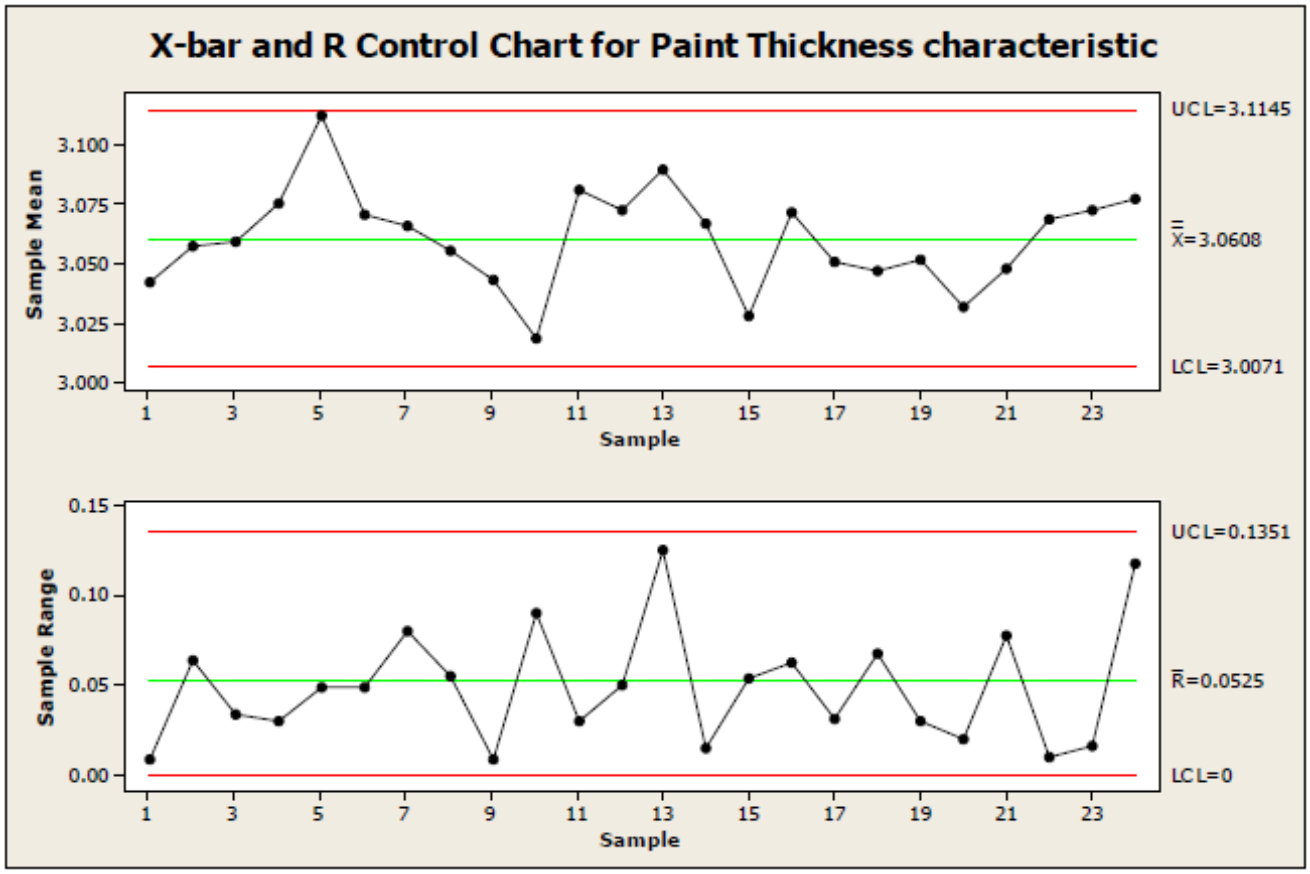

Fig. 5.11 Control charts