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ENGINEERING

# QUANTUM *Series*

## Semester - 8 Mechanical Engineering

## Total Quality Management

**Session 2019-20**
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## RME 085 : TOTAL QUALITY MANAGEMENT

1 UNIT

# Quality Concepts, Control on Purchased Product and Manufacturing Quality

## PART-1

*Evolution of Quality Control, TQM Modern Concept, and Evaluation of Prototype.*

### CONCEPT OUTLINE : PART-1

**Quality :** "Quality is the conformance to requirements".
**Evolution of Quality Control :** Important steps in the evolution of quality control are :

i. Craftsmanship,

ii. Supervisor's control,

iii. Inspection, and

iv. Statistical Quality control.

**Changing Quality Concept :** Greater expectation in terms of functional efficiency, aesthetics, safety, reliability, maintainability, etc. is leading to changing quality concept.
**TQM :** It deals with the product in its totality, determining quality by the combined efforts of various departments to achieve excellence.

### Questions-Answers

**Long Answer Type and Medium Answer Type Questions**

**Que 1.1. What is quality and quality characteristics ?**

**Answer**

**A. Quality :**

1. It conveys different meanings to different people when referring to a product. It generally signifies the degree of its excellence. Therefore, the quality is defined as "fitness for use or purpose" by Joseph M. Juran.

**B. Quality Characteristics :**

1. The quality of a product consists of a number of elements and each constituent (element) has a specific task.
2. These elements, such as shape, size, physical or chemical properties are the building blocks of product quality and are called the quality characteristics.

**Que 1.2. Explain the evolution of quality control.**

**Answer**

1. The concept of quality control is not new. It is taken from the stone age.
2. Stone age man was assessing the quality of the tool which he had manufactured, by comparing it with his mental picture of a good tool.
3. At that time he was the manufacturer as well as user, due to this he made efforts to attain the quality that met his purpose.
4. This situation changed with time, and there is specialization in each field, to meet the changing requirement of society.
5. Along with the changing production system quality control practices also evolved to suit the product and method of production.
6. The evolution steps are as follow :

**A. Craftsmanship :**

1. The quality control was exercised by the craftsman.
2. The reputation for craftsmanship and the incentives of better price for a superior product were the main governing factors of product quality.

**B. Supervisor's Control :**

1. During the industrial revolution large manufacturing factories were established to meet the customer's demand.
2. That's why to control the working of more number of workers, supervisor is required.

**C. Inspection :**

1. With the advent of the manufacture interchangeability on a mass scale, it became essential to critically examine each component with the help of gauges.
2. Due to this engineering inspection came into existence.

**D. Statistical Quality Control :**

1. World War II generated a great upsurge in industrial activity.
2. The tremendous requirements of defense stores necessitate mass production on an unprecedented scale.
3. Statistical quality control enhanced the efficiency of inspection and enlarges the area of control.

**Que 1.3. Discuss the journey of quality program from "inspection and testing" era to today's most modern era.**

**UPTU 2011-12, Marks 07**

**OR**

**Detail out chronological evolution of quality control and change in concept in different era.**

**UPTU 2012-13, Marks 06**

**Answer**

1. The chronological evolution of quality control should be done in the following way :

**A. Inspection :**

| | |
|---|---|
| Primary concern | – Detection |
| View of quality | – A problem to be solved. |
| Emphasis | – Product uniformity. |
| Methods | – Gauging and measurement. |
| Role of quality professionals | – Inspecting, sorting, counting and grading. |
| Whose responsibility | – The inspection department. |
| Orientation and approach | – 'Inspect-in' quality. |

**B. Quality Control :**

| | |
|---|---|
| Primary concern | – Control. |
| View of quality | – A problem to be solved. |
| Emphasis | – Product uniformity with reduced inspection. |
| Methods | – Statistical process control. |
| Role of quality professionals | – Troubleshooting and statistical method. |
| Whose responsibility | – Manufacturing and engineering department. |
| Orientation and approach | – 'Control-in' quality. |

**C. Quality Assurance :**

| | |
|---|---|
| Primary concern | – Coordination. |
| View of quality | – A problem to be solved productively. |
| Emphasis | – Entire production chain. |
| Methods | – Programmes and systems. |
| Role of quality professionals | – Quality measurement, planning and programme design. |

7. The quality cycle begins and ends with the user. It starts when the user's need is analyzed, to design a product for its fulfillment.
8. The cycle ends with the user, because the final proof of product quality comes during its service with the user, whose satisfaction is the ultimate aim.
9. Designers, process planners, production engineers have their role to play in the achievement of primary quality objective, which is 'maximum user satisfaction at minimum cost'.

**Que 1.6. Write the principles of TQM ?**

**Answer**

1. A model management framework for total quality is prepared by excellent organisations on the basis of the following aspects :
   a. Defining and communicating missions, vision, values and objectives.
   b. Collection of external intelligence about markets, customer's needs and attitude, competitors, and business environment.
   c. Measuring internal business performance.
   d. Identification of improvement opportunities.
   e. Implementation of cultural and structural changes by using teams.
   f. Steering and coordinating the total quality programme.

**Que 1.7. Explain the quality concept of design. What are the factors that affect it ?**

**OR**

**Explain the basic principle and concept of achieving quality in design.** **UPTU 2014-15, Marks 10**

**Answer**

1. The quality of design of a product is concerned with the tightness of the specifications for manufacture of the product.
2. A good quality of design must ensure consistent performance over its stipulated life span stated as rated output, efficiency, overload capacity for specified service.
3. It must consider the possible modes of failure due to stress, wear, distortion, corrosion and vibrations etc.
4. However, product design and development is a continuous process which results into evaluation of a product based on assessed user needs, their feedback after use and development in technology at a given point of time in a given environment.

**A. Factors Affecting the Quality of Design :**

**a. Types of Customer in the Market :**

| | |
|---|---|
| Whose responsibility | – All departments with minimal top management involvement. |
| Orientation and approach | – 'Build-in' quality. |

**D. Total Quality Management**

| | |
|---|---|
| Primary concern | – Strategic impact. |
| View of quality | – A competitive opportunity. |
| Emphasis | – The market and customer needs. |
| Methods | – Strategic planning, goal setting and mobilization. |
| Role of quality professionals | – Goal setting, education and training, team work and programme design. |
| Whose responsibility | – Everyone, management provides strong leadership. |
| Orientation and approach | – 'Manage-in' quality. |

**Que 1.4. What is the changing quality concept ? Explain it.**

**Answer**

1. Up to the late 40's, product quality was considered in the form o functional efficiency and aesthetic appearance.
2. Due to this new concept of design was introduced. There are attribute such as continued fault-free service and maintenance costs which ar equally important from the customer's point of view.
3. Thus quality is a measure of user's satisfaction provided by a product.
4. This include :
   a. Functional efficiency,
   b. Appearance,
   c. Ease of installation,
   d. Ease of operation,
   e. Safety,
   f. Reliability,
   g. Maintainability, and
   h. Running and maintenance cost.

5. These factors are divided into two parts as quality of design and quality of conformance.
6. The control of both these aspects of quality is important, if the end-product has to meet customer's acceptance.

**Que 1.5. Discuss the concept of total quality management.**

**UPTU 2003-04, Marks 10**

**Answer**

1. TQM is an enhancement to the traditional way of doing business. This is a combination of three words :

   Total → Made up of the whole.

   Quality → Degree of excellence a product or service provides.

   Management → Act, art, or manner of handling, controlling, directing, etc.
2. TQM is defined as both a philosophy and a set of guiding principles that represent the foundation of a continuously improving organization.
3. It has been realized that inspection alone can not build quality into a product unless quality has been designed and manufactured into it.
4. Therefore, the quality awareness must begin at the every conception of the product and should continue during various stages of its development and manufacturing.
5. Total quality management deals with the product in its totality.
6. It has been recognized that quality is determined by the combined efforts of various departments such as design, engineering, purchase, production and inspection.

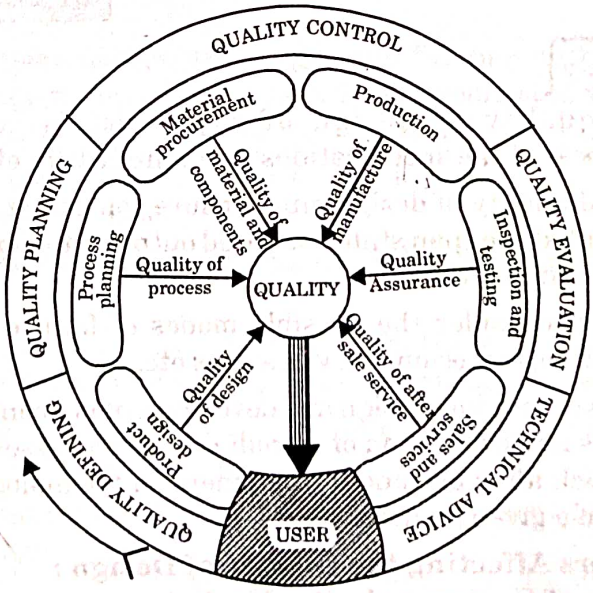



**Fig. 1.5.1.**

7. The sales manager may be able to give the customers reaction on the features provided in the design.

**A. Advantages :**

1. Such a review may make some favourable changes in the design.
2. These changes can easily be incorporated in the early stages when the design is on the drawing board. At later this may be difficult.

**Que 1.9. Explain the evaluation of the prototype ?**

**Answer**

1. The evaluation of the prototype should be carried out according to a well-planned evaluation programme, which should clearly lay down aspects that are to be studied and specific points on which information is required.
2. It is advisable that evaluation programme must be coordinated by an agency different from those of designers, so that the objective of evaluation can be maintained.
3. Generally, the task of coordinating the evaluation programme is entrusted upon the quality manager.
4. Besides the design and quality departments, representatives of other related departments, such as production and marketing may also be associated with evaluation programme necessary in the design.
5. After these changes and modifications have been carried out, those other related features should again be subjected to confirmatory evaluations to ensure that the shortcomings of the design observed earlier, have been eliminated.
6. This process of the adjustment of design and evaluation should be continued until a fully satisfactory design is evolved.

## PART-2

*Procurement of Various Products, Inspection and Control of Product, and Quality in Sales and Services.*

### CONCEPT OUTLINE : PART-2

**Quality Planning :** The quality of a product is initially created during design in the form of design particulars. Some of these considerations are :

i. Process capability,
ii. Process selection and control,
iii. Evaluation of supplies, and
iv. Inspection planning.

**Sales and Product Quality :** The two main factors which influence

purchasing decision are price and quality of a product. However, a customer considers the product quality first and factors associated to it are :

i. Warranty and guarantee,
ii. After sales services, and
iii. Maintenance and repair, etc.

## Questions-Answers

### Long Answer Type and Medium Answer Type Questions

**Que 1.10. What do you mean by "quality planning" ? How does it address the vision and mission of an organization ?**

**UPTU 2012-13, Marks 06**

**Answer**

1. The quality of a product is initially created during design in the form of design particulars.
2. However, this creation is only on paper, in the form of manufacturing drawings and specifications.
3. Quality is actually built into the product during its manufacture.
4. The manufacturing of product requires a host of activities involving different departments and sections of the manufacturing organisation, having the common aim of achieving the required quality and quantity targets.
5. Planning for manufacturing, include the following activities, all of which contribute towards the achievement of quality targets.
   a. Selection of processes, machines and tools.
   b. Process planning.
   c. Design and procurement of jigs, tools and measuring instruments.
   d. Planning of process quality controls.
   e. Planning the quality control in incoming materials.
   f. Planning of the quality appraisal of the final product.
6. The activities from *a* to *c* are normally carried out by the Process Engineering and from *d* to *f* by the Quality Engineering departments.
7. Even though there is a broad division of responsibility, all the above planning jobs will require close consultation between these two departments.
8. For some of the activities, such as process selection and controls, the production department and other sections concerned will also have to be consulted while formulating the plan, it may again be emphasised,

that the quality of the product is not the sole responsibility of the quality department alone.

9. Therefore, quality considerations have to be kept in view while planning any manufacturing activity, irrespective of who does the planning.

**Que 1.11. Explain the procurement of various products.**

**Answer**

1. Requirement of material to be procured is generally initiated by the production control in case of manufacturing concerns, and by the actual user in case of non-manufacturing concerns.
2. Some procurements are given below :

**A. Procurement of Traditional Items :**

a. Even if the requirement is of traditional items which the company has been using in past, it is still worthwhile to refer it to quality control organisation before placing actual order.

b. It is possible that improved material may have been introduced which may serve the need of the company better than the traditional item.

**B. Procurement of New Products :**

a. When the product is being purchased for the first time the indenter will normally indicate his requirement in general terms.

b. He may also give the specific product to be purchased based on manufacturer's advertisements.

c. It may also happen that none of the existing products in the market meet all the company's requirements fully.

d. In such cases additional features are provided to meet the special requirement.

e. This is done by the quality engineers.

**C. Procurement of Products as per Purchaser's Design :**

a. No manufacturer can afford to manufacture every single item which goes into making of his products.

b. It is more economical to get some of the components as per their own design manufactured by subcontractors.

**D. Determining Quantity to be Procured :**

a. Normally the quantity of store to be procured is indicated by the user, depending upon expected requirement.

b.. While deciding on the actual quantity to be purchased at a time, consideration is also given to the economy which can be achieved by bulk purchase.

**Que 1.12. What are different processes of procurement ? Explain any one procurement process in detail. UPTU 2012-13, Marks 06**

**OR**

**List the various procurement procedures in detail.**

**UPTU 2014-15, Marks 10**

**Answer**

**A. Placement of Order :**

1. After analysis of the quotations and appraisal of the vendors, the purchase department places the order to the vendor who offers the most advantageous terms.
2. A common complaint often heard when the supply is rejected is 'this is unfair, we were not told of this requirement when the order was placed'.
3. Therefore, attention of details at the time of drafting of supply order saves many embarrassing and costly situations later when the supplies start arriving.

**B. Establishment of Production :**

1. In the initial stages when the manufacture of the product is being established for the first time, the vendor may require a lot of clarifications about the drawing and the specifications.
2. In some cases he may request for minor changes in the design and use of alternative material due to non availability of specified material.
3. It should be taken as constructive suggestions to facilitate production and in some cases it may even result in improvement of the quality of the end product.
4. After the initial problems are overcome, vendor should be asked to submit preproduction samples.
5. If there are defects found, then the quality engineer may advise the vendor how to prevent the defects and improve the quality of the product.
6. In such cases fresh preproduction samples will be called for and clearance of bulk production should be given only after these sample units are found satisfactory.

**C. Inspection of Bulk Supply :**

1. While the sources of supply of the product are being investigated, the quality control organisation of the purchasing company should have formulated an inspection plan for the product and set up necessary test facilities.
2. In the beginning, few lots are inspected completely.
3. If the quality is found good, then use the sampling method.
4. If quality is found low, then inspection should be stopped until quality of the product improves.

**D. Quality Record of Purchased Material :**

1. Proper record of the quality of material received from various vendors should be kept in a manner that it can be referred when required in future.

2. The quality problems experienced with the product and how they were overcomed should also be recorded.
3. In addition to the productwise records, separate vendor performance folder should also be maintained.
4. This will be useful in assessment of the vendor's capability to execute future orders.

**Que 1.13. Why evaluation of suppliers is needed ?**

**Answer**

1. Having finalized the product specification and the quantity to be procured, next step is to locate the likely sources of supply.
2. An efficient purchase department normally maintains a comprehensive list of suppliers of the range of products which are of interest to the company.
3. For traditional items, locating sources of supply is no problem. The problem arises only when the new sources are to be established.
4. In such cases the purchase enquiries are generally sent to the firms listed in trade directories for the range of products under procurement.
5. Selection of viable sources of supply requires proper evaluation of suppliers with respect to their ability to maintain the quality of the product at the desired level, as well as their production capacity.
6. Final consideration, for placement of order should be limited to only those firms who have proved the capacity to supply product of required quality and quantity. The choice can then be made on economic considerations.

**Que 1.14. What do you mean by capacity of supplier ? What are the different measures to assess it ?** **UPTU 2011-12, Marks 07**

**Answer**

1. Capacity verification of prospective suppliers is one of the important functions of quality control organisation, which is essential for exercising control over the quality of purchased product.
2. Capacity verification generally takes the form of survey of vendor's production resources and his ability for their proper utilisation.
3. Preliminary study of the data furnished by the vendor may itself indicate that the firm is not capable of executing the order and thus rule out further consideration of the firm.
4. However, if the firm looks promising, then detailed study of the firm's capacity may be carried out by the quality engineers.
5. For accurate assessment of vendor's capability, special expertise wherever available should be utilised.
6. For example, if the manufacture by the vendor involves specialised technology such as chemical processing, heat treatment or vacuum deposition, an expert in the field from the process engineering department may also be included in the capacity verification team.

7. Similarly, if the financial standing of the vendor is in question an expert from finance department may also form part of the study team.
8. The investigators should confine themselves to only those areas which directly reflect the vendor's ability to execute the order in question.
9. Some companies have got standard questionnaire which the investigators are required to fill.
10. Important aspects to be covered in the questionnaire are given below :
    a. Does the vendor have adequate plant and machinery to ensure required production rate ?
    b. Do the machines have desired capability to maintain the important quality parameters within acceptable limits ?
    c. Does the firm have a well staffed quality organisation and a working quality control programme ? (This may be evident for the quality control techniques being used for process control).
    d. Does the company use considerable number of components purchased from trade or manufactured by subcontractors ? If so how does the company exercise quality control on the purchased product ?
    e. What are the sources of raw materials used by the company ? Does the company maintain adequate reserve stock to insulate interruptions in supply of materials ? How is the quality of raw materials assured ?
    f. Does the company have complete testing facilities for the product in question ? If not, what alternative arrangement can be made if preshipment inspection is to be carried out ?
    g. Has the firm executed an order of a product similar to the one being considered ? If so details of this order must be obtained.
    h. Financial standing of the company.
    i. Any other relevant details which can reflect the ability of the firm to successfully execute the order in question.
    j. Finally, the general attitude of the management of the vendor company towards the quality of their products and their own appreciation of their ability to execute the order are significant pointers which should be noted.

**Que 1.15. What is the role of suppliers in modern manufacturing ? Explain the criteria for selecting the suppliers.**

**UPTU 2013-14, Marks 10**

**Answer**

**A. The Role of Suppliers in Modern Manufacturing :**

1. Effective manufacturing planning and simple systems of release of planned orders, flexibility and rapid response to changes in output requirements achieved through the use of flexible manufacturing systems.

2. Quality assurance, assuring consistently good quality of components and sub-assemblies supplied, which would not only minimise inspection costs at the customer's end, but also guarantee an end (or final) product of high quality.
3. Participation in the development of new products in order to improve manufacturability and reduce time-to-market.
4. Participation in the company's cost reduction and quality improvement efforts and setting up of a joint problem-solving approach.
5. A never-ending drive for efficiency (leading to lower cost and shorter delivery times) and continuous improvement.

**B. Ten Conditions for Selection and Evaluation of Suppliers :**

1. The supplier understands and appreciates the management philosophy of the organization.
2. The supplier has a stable management system. In determining this condition, several question should be asked : Is there a quality policy statement that includes objectives for quality and its commitment to quality ? Is the policy implemented and understood at all levels of the organization ? Is there documentation that indicates who is incharge and responsible for quality in the organization ? Is there a member of top management with the authority to execute a quality system ? Does the management have scheduled reviews of its quality system to determine its effectiveness ?
3. The supplier maintains high technical standards and has the capability of dealing with future technological innovations.
4. The supplier can provide those raw materials and parts required by the purchaser, and those supplied meet the quality specifications.
5. The supplier has the capability to produce the amount of production needed or can attain that capability.
6. There is no danger of the supplier breaching corporate secrets.
7. The price is right and the delivery dates can be met. In addition, the supplier is easily accessible in terms of transportation and communication. There must also be a system to trace the product or lot from receipt and all changes of production delivery.
8. The supplier is sincere in implementing the contract provisions. Does the supplier have a system contract review, and does that system include a contract review of requirements and how differences between the contract and/or accepted order requirements should be resolved ? Further, does the system allow the inclusion of amendments ? Also, does the system include maintaining records of reviewed contracts ?
9. The supplier has an effective quality system and improvement program such as ISO 9000 or ISO/TS-16949.
10. The supplier has a track record of customer satisfaction and organization credibility.

**Que 1.16. Broadly classify methods and techniques used in**

**Answer**

Manufacturing engineering can be defined as the study of the various processes required to produce parts and to assemble them into machines and mechanisms.

**A. Methods :**

**a. Casting Process :**

1. In this the metal in the molten state is poured into a mould and allowed to solidify into a shape, e.g., sand casting, die casting etc.

**b. Deformation Process :**

1. In this the material is plastically deformed under the action of an external force, to produce the required shape, .e.g., forging, drawing etc.

**c. Machining Process :**

1. This is also known as metal cutting or chip forming process.
2. Here, material is removed from the workpiece to get final shape of the product, *e.g.*, turning, broaching, drilling etc.

**d. Powder Metallurgy :**

1. This is also known as particulate processing method.
2. Here the particles of various sizes of metals, ceramics, and polymers etc., are pressed into shape and then sintered to get the final product.

**e. Heat Treatment and Surface Treatment Processes :**

1. These are employed to improve the properties of a work piece, *.e.g.*, annealing, tempering etc.
2. Surface treatment processes include electro-plating and painting etc.

**B. Techniques :**

1. There are mainly two techniques as follows :
   a. Manual, b. Automated.
2. Computers are being increasingly used in design or production cycle of a part.
3. Computer aided design and computer aided manufacturing are performing greater role in manufacturing industry. *e.g.,*
   a. Numerical control, Computer numerical and Direct numerical control machines playing major role in manufacturing.
   b. Computer aided process planning.
   c. Flexible manufacturing system.
   d. Industrial Robots.

**Que 1.17. What is inspection ? Discuss its different aspects.**

**UPTU 2006-07, Marks 10**

**Answer**

1. Inspection is the process of checking and measuring each sampled product in its finished form during the production process and rejecting or accepting the whole lot of goods on the basis of results of sampled goods measurements.

2. It is observed in India that an average manufacturing company is operating at the cost of quality of about 25-35 % of the turnover.
3. The inspection's costs are incurred on re-checking, spotting and inspecting errors in a process or product.
4. You have to inspect the products or services for specifications before providing them to other units.
5. Inspection cost is a secondary element of the cost of quality, which includes the costs associated with maintaining quality control, is the cost of calibration, the cost of tooling and the cost associated with policy system.

**A. Aspects of Inspections :**

**a. Stage Inspection :**

1. This involves inspection of the product after every operation where important quality characteristics are developed.
2. This ensures that the defective product is appeared at the earliest stage, this will help in avoiding the expenditure on the further processing of defective components.

**b. Final Inspection :**

1. In an ideal condition, when the manufacturing operations, including process controls, are carefully planned, and supervised, there may be no necessity for final inspection.
2. But this occurs rarely, because men are liable of making mistakes, machine can be erratic and process control can never be full proof.
3. Final inspection in addition to being an appraisal function includes a decision on the acceptance of the product.

**Que 1.18. Explain the effect of quality on sales.**

**Answer**

1. The two main factors which influence the purchasing decisions are the price and the quality of product.
2. A customer considers the product quality first and later the price. It is known that in a competitive market, the sale of a product may suffer if its price is too high.
3. It is therefore essential, that the importance of product quality in creating and maintaining sales is realised by everyone in the company, and conscious efforts are made to achieve a high standard of quality to enhance the sales appeal of a product.
4. The survival of the company depends on the income it gets from selling its products and services, and the ability to sell is based on the fitness for use.
5. Hence, the company functions concerned with quality for use are known as quality functions.
6. Quality is a potent weapon in competition, sometimes even more effective than price. For instance, a particular line of a company may not be able to reduce the price of its product due to factors such as higher cost of labour, unfavourable location of the plant.

7. The use of quality as a weapon may take other forms, such as better after sales service, and longer guarantee periods.
8. Any salesman will tell you, that the quality reputation of a company is a great asset which makes selling very much easier. It also helps in growth and diversification.
9. A satisfied customer is the best advertisement for the quality image of any company.

**Que 1.19. What is service quality ? What are the factors of service quality ?** **UPTU 2010-11, Marks 07**

**Answer**

1. Strategies that have produced significant results in production are often harder to implement in a service environment.
2. Customer service is the set of activities, an organization uses to win and retain customers satisfaction.
3. It can be provided before, or after the sale of the product or may exist on its own.

**A. Factors :**

**a. Educating the Customer :**

1. It is part of the normal job of sales personnel.
2. Before a customer buys anything, he must know about characteristics and capabilities of the product, to enable him to decide whether it will meet his requirement.

**b. Maintenance and Repair :**

1. The machines and equipments are well designed and manufactured, still require attention in the form of maintenance and repairs.
2. The efficient provision of these services will require the following :

**i. Creation of Service Organization :**

1. The service organization is a branch of the sales department and is manned by technical staff, which has an intimate knowledge of the subject machines, so as to be able to provide advice regarding installation, operation, maintenance and repair.

**ii. Setting up of Repair Facilities :**

1. Service and repair centres may be set up and managed by the company itself, or it may issue licenses to other repair agencies to provide these services on its behalf.
2. It will be the company's responsibility to provide repair manuals, the training of repair agency staff, equipment, spare parts and other accessories required for efficient maintenance and repair. The company should also arrange for periodic quality audits of the repair agencies.

**iii. Feedback on Repair Problems :**

1. Quality engineers of the company should maintain close relation with the repair agencies, because many inadequacies in the quality of the product are brought out only during repair.

2. The repair agency should be encouraged to report all unusual defects.
3. The analysis of these defect reports could result in improvement in design process of manufacturing.

**Que 1.20. Explain the term guarantee and analysis of claim.**

**OR**

**What do you mean by warranty and guarantee ? How are they being analysed and set ?** **UPTU 2011-12, Marks 05**

**Answer**

**A. Warranty :**

1. A warranty acts like an insurance policy for which you must pay a premium. Sometimes a warranty is called an 'extended guarantee'.
2. May last longer than a guarantee and cover a wider range of problems.
3. A warranty is a legal contract.
4. The terms of the contract should be clear and fair.
5. Does not reduce your rights under consumer law.

**B. Guarantee :**

1. The guarantee of quality is primarily meant to protect the customer, if the product purchased by him turn out to be defective.
2. This often takes the form of an undertaking by the selling company, that it will replace the article free of charge or refund the money if the product is found to have any defect attributable to improper materials or faulty manufacture.
3. Producer often uses guarantees to convince customers about the quality of their products.
4. Therefore, guarantees which are given on a product must be carefully considered in relation to the quality inputs.
5. A guarantee card has following terms :
   a. Period of validity,
   b. Liability of the manufacturer,
   c. Procedure of submitting guarantee claims, and
   d. Conditions which make the guarantee invalid.

**C. Analysis of Claim :**

1. The adjustment of guarantee claims is generally the responsibility of sales department.
2. Since the investigation of complaints involves thorough technical knowledge of the product, this task may be entrusted to the service engineers who form part of the sales department.
3. Alternatively guarantee claim may be investigated by the quality control department.
4. Often a compromise is found, the minor claims being settled by the regional service centres and major ones being referred to the central quality department.
5. Whatever procedure is adopted, it should be simple and should ensure that the claims are speedily decided.

6. Nothing is more frustrating to a customer than a protracted correspondence about the adjustment of a guarantee claim.

**Que 1.21.** **What is after sales service ? Explain.**

**UPTU 2015-16, Marks 10**

**Answer**

1. We know that reliability and maintainability are important quality parameters for certain types of products.
2. It should be realised that however good a product may be when it is produced, it is of little use if it cannot be easily maintained in a serviceable condition during its intended life.
3. In addition to the inherent quality of a product, effective after-sales service is an important element in ensuring reliability and maintainability.
4. Therefore, customers are increasingly becoming aware of the need for an efficient after-sales service and this factor exerts considerable influence in purchasing decisions. The need for after-sales service varies from product to product.
5. The minor products for one-time use need practically no service.
6. On the other hand major mechanical and electrical products, such as automobiles, major domestic appliances, and industrial machinery require considerable service facilities to maintain them in an operational condition.
7. After-sales service does not consist only of maintenance and repair facilities. It covers all post-sale efforts aimed at ensuring maximum user satisfaction.
8. The need for these services is felt because of the fact that even with the most effective quality control measures, the product may still not meet the expectation of the user.
9. This may not necessarily be due to the poor quality of the product.
10. It can be due to various other reasons, such as the ignorance of the customer regarding product capability, incorrect usage, or maintenance, unduly harsh environmental conditions etc.
11. Whatever be the reason for the product not meeting expectations, the user will tend to put the blame on the quality of the product, unless the real cause is explained to him.
12. An unsatisfied customer is not a very desirable advertisement for the company and therefore, in its own interest, the company should take pains to ensure that the customer is satisfied as far as possible.
13. In any case, it should be realised that in all fairness a customer who had paid for the product, should get his money's worth in the form of product service.
14. Unfortunately, in India and other developing countries, most companies, due to their shortsighted policies, do not pay adequate attention to this aspect of marketing and still manage to remain in business.

15. This is due to the peculiar market conditions prevailing today, such as shortage of goods, absence of competition, and the unquestioning customer.
16. However, these conditions will not remain for long and those companies which do not change their attitude towards the customers will be forced out of business.
17. Important elements in after-sales services are :
    a. Education of the customer.
    b. Maintenance and repair where required.
    c. Looking into customer complaints.

**Que 1.22. Differentiate between quality of conformance and quality of performance.**

**Answer**

**A. Quality of Conformance :**

1. It is concerned with how well the manufactured product conforms to the quality of design.
2. When a design has been established, it is the task of all responsible personnel's for production planning and manufacturing to obtain a high level of quality of conformity.
3. The measure of truthfulness with which the product conforms to the design specifications depends upon the following factors :
    a. The incoming raw materials are of adequate quality.
    b. Proper selection of the process and adequate process control.
    c. The operators should be well trained, experienced and motivated for quality consciousness.
    d. Proper care should be taken in shipment and storage of finished goods.
    e. Feedback from both, the internal inspection and the customers, are obtained regarding the quality for taking corrective action.
    f. SQC techniques should be used to control variability in manufacturing process.

**B. Quality of Performance :**

1. The quality of performance is concerned with how well the manufactured product gives its performance.
2. It depends upon.
    a. Quality of design, and
    b. Quality of conformance.
3. It can be the best design possible, but poor conformance control can cause poor performance, conversely the best conformance control cannot make the product function correctly, if the design itself is not right.

☺☺☺

# 2 UNIT

# Quality Management and Human Factor In Quality

## PART-1

*Organization Structure and Design, Quality Function, Decentralization, Economics of Quality Value, Quality Cost, and Reduction Programme.*

## CONCEPT OUTLINE : PART-1

**Organization :** The organization is defined as, "the process of identifying and grouping the work to be performed, defining and delegating authority and establishing relationships for the purpose of enabling people to work most effectively together in accomplishing objectives".

**Quality Functions :**

a. Quality engineering, and

b. Quality control.

**Quality Organizations :**

a. Single product line at one location,

b. Multi product company at single location,

c. A single product multiplant company,

d. A large divisionalised corporation,

e. A jobbing company, and

f. A cottage industry.

**Economics of Quality :** Although quality is a laudable objective in itself, it is subjected to some economic constraints. Quality improvement can be pursued only upto the extent to which it helps to set long term profitability.

**Quality Costs :** Failure costs, Appraisal costs, and Prevention costs.

## Questions-Answers

### Long Answer Type and Medium Answer Type Questions

**Que 2.1. Explain the organization structure and designing of an organization.**

**Answer**

**A. Organization Structure :**

1. For the management of any activity, there is no single system which can be adopted.

2. Organizational structures are as varied as there are businesses of functions and the men who manage them.
3. For designing the organization structure for the management of quality, we must know the factors that influence this activity are given below :

**a. Company Policies and Objectives :**

1. Any organization exists for the purpose of achieving certain stipulated objectives, and therefore every component of the organization should strive towards their achievement.
2. A particular management may feel that their products do not require elaborate quality programme.
3. On the other hand, another company may take a long term view and may make quality as one of the major company objectives with a view to win the confidence of the customers and establishing a positive quality reputation.

**b. Types of Business :**

1. All business can be broadly categorised as :
   a. Traditional business with fixed methods of manufacturing and specific customers.
   b. Diversified business covering many product types, and requiring flexibility and constant innovations to meet changing market conditions.
2. In former case the products are well-established and few quality problems are likely to arise that's why a specialised and sizeable quality organisation will be required.

**c. Types of Products :**

1. Quality requirements and parameters very widely with different products.
2. Precision machine tools, automobile components and sophisticated electronic equipments may require elaborate measures such as design evaluation, process control and after-sale services to ensure that the product meets the customer's requirements.
3. Thus quality organization will depend upon nature and needs of the industry.

**d. Company Size and Organization :**

1. It should be clearly understood that the quality management is a staff and service function and exists for the sake of providing services to the other sections of a company.
2. The organization size should be such that expert advice on all matters related to quality is available to the higher management.
3. The organization structure of the company itself suggests the type of quality organization that may be required.

**c. Market and Customers :**

1. The circle of quality begins and ends with the customers.
2. It starts with the assessments of his requirements and ends when these requirements have been met.
3. It is necessary that he and his needs should have a market influence on the quality of organization.

**B. Design of an organization :** It consists of following three steps :

**a. Identification and Grouping of Jobs :**

1. Various tasks that have to be carried out for the achievement of objective must be identified.
2. These tasks should then be grouped into sets of similar jobs that can be carried out by one or more individuals having similar training and skills.

**b. Allocation of Authority and Responsibility :**

1. In this step allocate specific sets of jobs to the charge of individuals whose authority and responsibility are clearly defined.
2. Also an effective method for the passage of instructions and advice from the management and feedback from the lower ranges of the organization should be devised.

**c. Establishment of Co-operative Relationships :**

1. In any company different groups perform various jobs according to their responsibilities, yet the work of each and every group contributes towards the attainment of common objectives.
2. To ensure that various groups work as a team and their work is complimentary, co-operative relationships should be established between various individuals and groups.
3. This aspect is of great importance in quality managements because the quality cannot be built into the product by the quality organization alone because 'quality is every one's business'.

**Que 2.2. Advice the organization structure needed to deal with quality problems. Write the duties of quality staff.**

**Answer**

1. For a very small establishment comprising of only a few persons, there may no need for any formal organizational structure.
2. This may be so, because everyone fully understands everyone else and they know their limits of responsibility and authority.
3. On the other hand, in a relatively large company the benefit of the close proximity of the boss is absent.
4. But by the organization structure, creation of harmonious human relations and reduction in the chances of misunderstanding and error, takes place.

5. The benefits are :
   a. It provides for the optimum use of resources.
   b. It stimulates creativity by removing routine burdens from those who are supposed to do creative thinking.
   c. It aids, in the correct evaluation of individual contributions, and effective management.
6. The progress of industrialisation, development of new techniques has led to the development of large industrial organizations with multiplant and multilevel operations.
7. These days, the business has to face many problems due to :
   a. Increase in the product complexity and size of operation.
   b. Stiff competition at national and international levels.

**A. Duties of Quality Staff :**

1. To design the plans, procedures and methods for achieving quality assurance.
2. To establish controls at all stages of manufacturing this includes specifying quality control methods at incoming inspection, at stations of manufacture, at finished goods inspection, and at shipping.
3. To establish standards of quality as for appearance, uniformity, colours, to minimize the disputes between inspection and production.
4. The quality engineer specifies the inspection and test equipment which will be used for quality evaluation.
5. To develop new and improved testing methods and techniques.
6. It prepares the programme of gauge maintenance and control.
7. It is the responsibility of quality staff conduct special economic studies pertaining to quality costs with minimum total cost as the objectives.
8. It is responsible to conduct a dynamic quality orientation and training programme which meets the needs of each level of workers and supervision effectively.
9. To create quality-mindness in the organization.

**Que 2.3. What are the different types of organizational structures ? Compare them on the basis of inventories, quality, production planning and control.**

**OR**

**What are the different types of organizational structure ? Compare them on the basis of inventories, quality, production planning and control, set up and throughput issues with suitable examples.**

**UPTU 2011-12, Marks 10**

**Answer**

1. Following are the different types of organizational structures :

**A. Single Product Line at One Location :**

1. In this case, a medium sized company is having one basic product line of compressors for industrial use.

2. All company operations including design and manufacturing are carried out at one location.

3. A single product oriented quality engineering group will be more effective and economical as shown in Fig. 2.3.1.

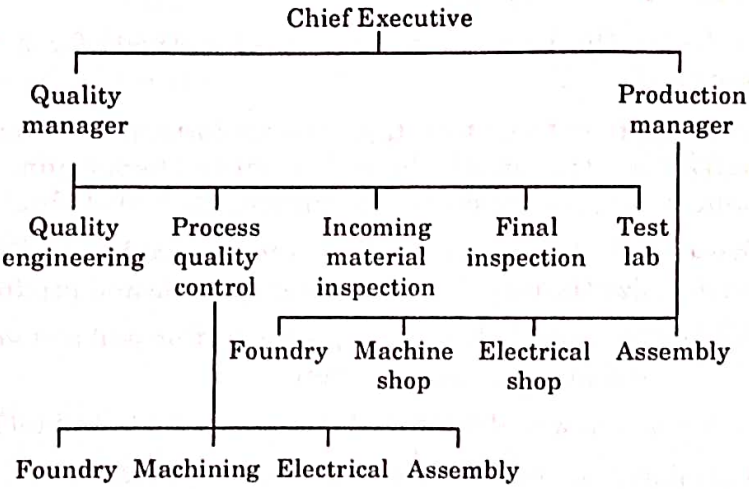



**Fig. 2.3.1.**

**B. Multiproduct Company at a Single Location :**

1. In this case the manufacturing operations of the company are organised on the product line system, rather than on a functional basis.

2. Products of a similar nature are grouped in production shops, so that the same plant may be utilized for different products.

3. In this, control also includes the final inspection of the product.

4. The design of inspection equipment, is however, centralised for reason of economy.

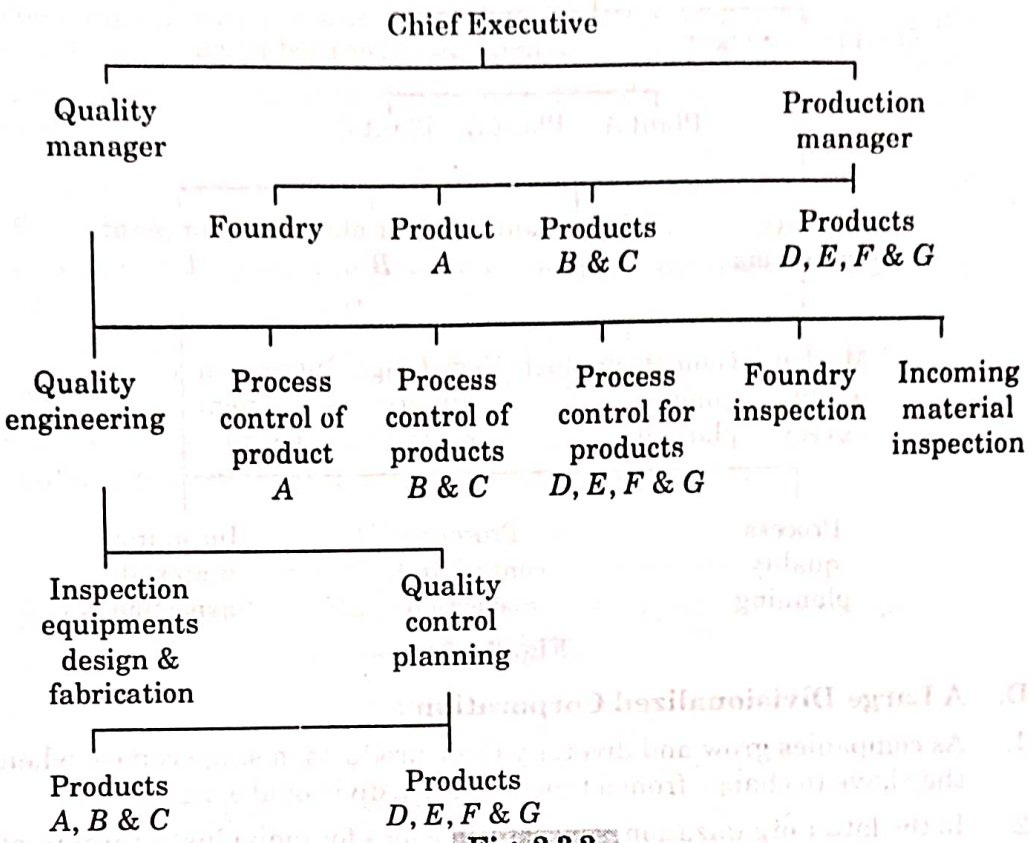



**Fig. 2.3.2.**

## C. A Single Product Multiplant Situation :

1. The Fig. 2.3.3 shows the quality organization in a relatively large company with more than one manufacturing plant for the same product.

2. It is possible that the machinery and equipment in the various plants may not be exactly similar, since the number of plants would have increased as the company grew and therefore, the plants established later are likely to have newer and more automated equipment.

3. Thus, although design, sales and other functions that are independent of production techniques have been centralised, engineering is decentralised and placed under the respective plant managers.

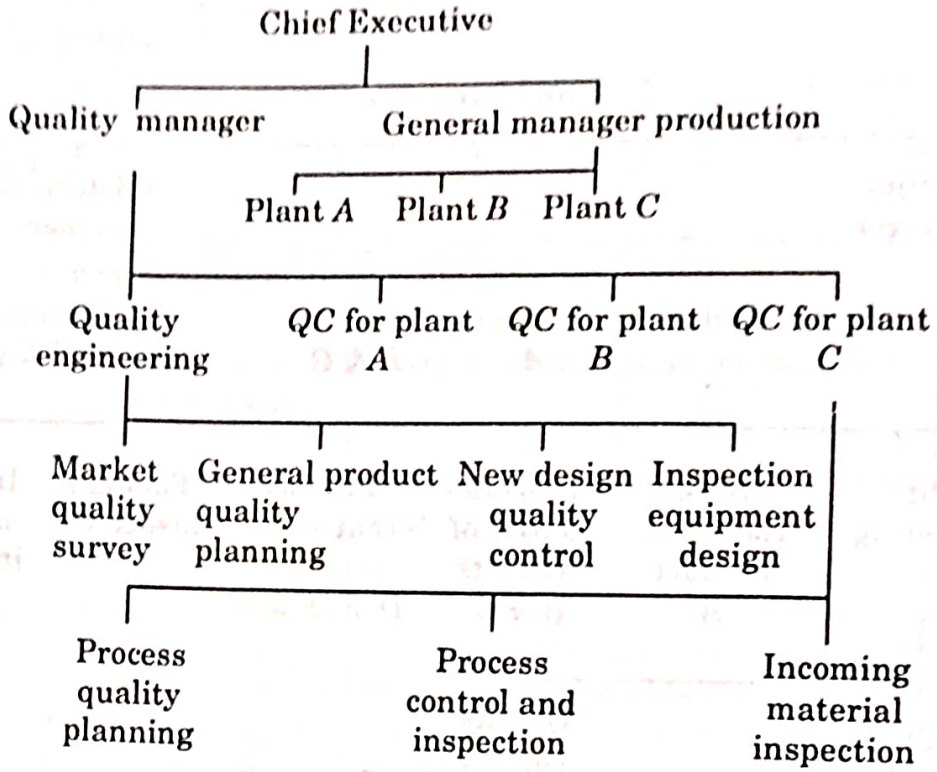



**Fig. 2.3.3.**

**D. A Large Divisionalized Corporation :**

1. As companies grow and diversify their products, a stage comes, when they have to change from a functional to a divisional organization.
2. In the latter organization, separate divisions for individual or groups of similar products are established, which are self-reliant, integrated units and have semi autonomous status within the overall company organization.
3. This also facilitates coordination and the rendering of interdivisional quality assistance.

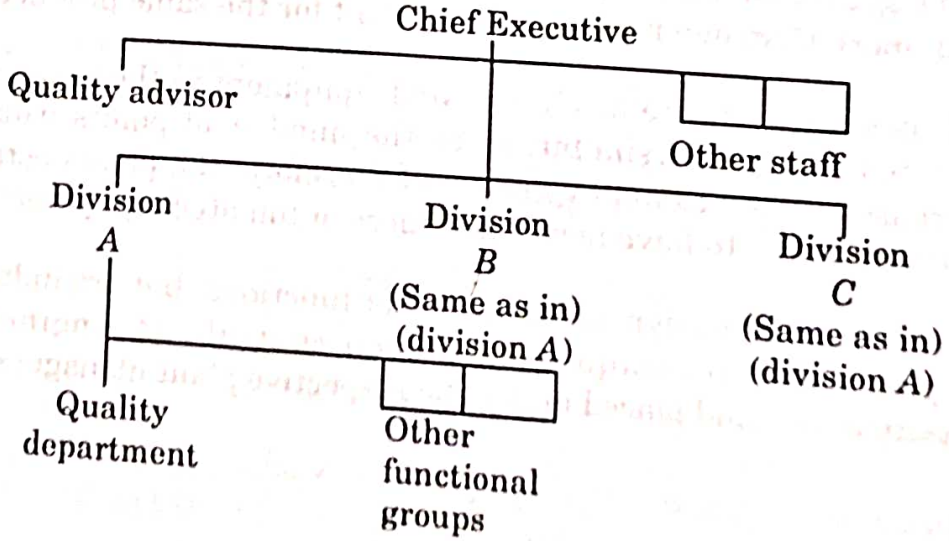
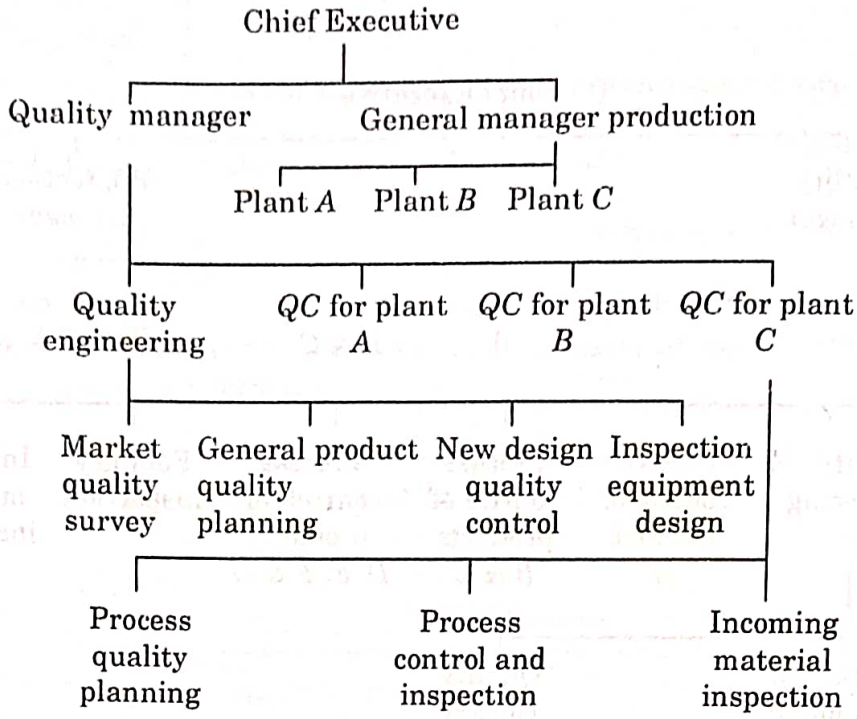



**Fig. 2.3.4.**

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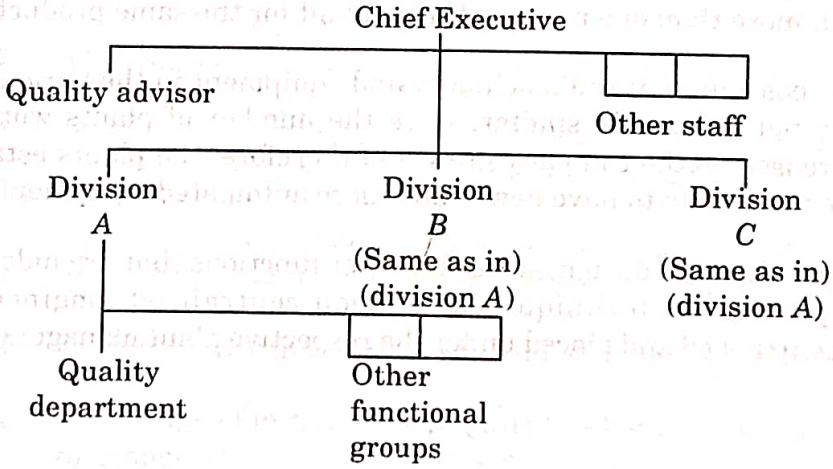



**Fig. 2.3.4.**

**E. A Jobbing Company :**

1. The main characteristic of a jobbing company is, that it has no specific line of production. It has the facilities of various specialised technologies, and is capable of undertaking any job within the capacity of the facility available.
2. The jobs undertaken are according to the customer's designs and specifications.
3. Because of wide variety of jobs it may require a considerable amount of process engineering effort.
4. Process control essentially consists of stage inspection which may be decentralised to the shops for smooth functioning.
5. Final inspection however will have to be directly controlled by the quality manager to ensure the quality of the outgoing product.

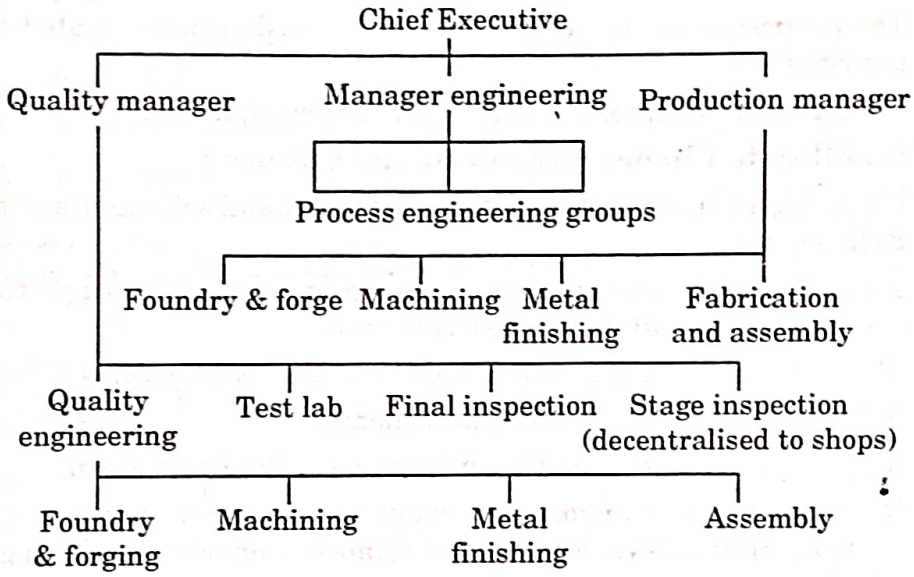



**Fig. 2.3.5.**

**F. A Small Company Working as a Cottage Industry :**

1. The size of a company often dictates the size and organization of its quality components.

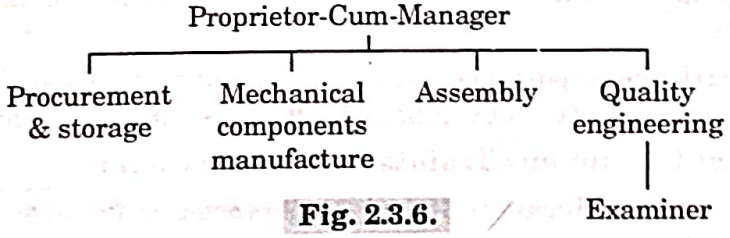



**Fig. 2.3.6.**

2. A small company neither needs nor can afford a large staff employed exclusively on quality control jobs. After that, certain quality tasks have to be performed if the quality of the final product is to be assured.
3. Firstly, by delegating some of the quality jobs to the operating staff.

4. The other method, which is followed simultaneously with the first, is the combination of various quality jobs into a few positions as possible.
5. All the quality functions may be performed by only one or two persons.

**Que 2.4. Working as an individual, determine different obstacles to implement TQM in a manufacturing organization.**

**UPTU 2011-12, Marks 04**

**Answer**

**A. Lack of Management Commitment :**

1. In order for any organizational effort to succeed, there must be a substantial management commitment of management time and organizational resources.
2. The purpose must be clearly and continuously communicated to all personnel.
3. Management must consistently apply the principles of TQM.

**B. Inability to Change Organizational Culture :**

1. Changing an organization's culture is difficult and will require as much as five years.
2. Individuals resist change they become accustomed to doing a particular process and it becomes the preferred way.
3. Management must understand and utilize the basic concepts of change.
4. Following are the basic concepts of changes :
   a. People change when they want to meet their own needs.
   b. Never expect anyone to engage in behaviour that serves the organization's values unless adequate reason (why) has been given.
   c. For change to be accepted, people must be moved from a state of fear to trust.

**C. Improper Planning :**

1. All constituents of the organization must be involved in the development of the implementation plan and any modifications that occur as the plan evolves.
2. The particular importance is the two way communication of ideas by all personnel during the development of the plan and its implementation.

**D. Lack of Continuous Training and Education :**

1. Training and education are ongoing processes for everyone in the organization.
2. Needs must be determined and a plan developed to achieve those needs. Training and education are most effective when senior management conducts the training on the principles of TQM.

**E. Incompatible Organizational Structure and Isolated Individuals and Departments :**

1. Differences between departments and individuals can create implementation problems.
2. The use of multifunctional teams will help to break down long-standing barriers.

**F. Ineffective Measurement Techniques and Lack of Access to Data and Results :**

1. Key characteristics of the organization should be measured so that effective decisions can be made.
2. In order to improve a process you need to measure the effect of improvement ideas.
3. Access to data and quick retrieval is necessary for effective processes.

**G. Inadequate Use of Empowerment and Teamwork :**

1. Teams need to have the proper training and, at least in the beginning, a facilitator.
2. Whenever possible, the team's recommendations should be followed.
3. Individuals should be empowered to make decisions that affect the efficiency of their process or the satisfaction of their customers.

**Que 2.5. Discuss the advantages of empowered teams.**

**UPTU 2012-13, Marks 04**

**Answer**

1. Team work, because many heads are more knowledgeable than one.
2. Each members of the team has special abilities that can be used to solve problems.
3. Many processes are so complex that one person cannot be knowledgeable concerning the entire process.
4. Second, the whole is greater than the sum of its members. The interaction within the team produces results that exceed the contributions of each member.
5. Third, team members develop a report with each other that allows them to do a better job.
6. Finally, teams provide the vehicle for improved communication, thereby increasing the likelihood of a successful solution.

**Que 2.6. Explain the quality functions.**

**Answer**

1. The quality functions can be considered in two distinct groups, namely :

A. Quality Engineering, and

B. Quality Control.

**A. Quality Engineering :**

1. This comprises of specialist staff functions as well as activities connected with the development defining, and planning of quality during the preproduction stage.
2. Its main work elements are given below .
   a. Advice to the management on the quality policy of the company and laying down realistic quality objectives.
   b. The analysis of the customer's quality requirements and the formulation of design specifications.
   c. The review and evaluation of product design with a view to improving quality and reducing quality costs.
   d. Defining quality standards preparation of product specifications. Planning process controls to ensure quality conformance.
   e. Development of quality control techniques and inspection methods including the design of special test equipment.
   f. Conducting process capability studies, analysis of quality costs.
   g. Quality audit and organizing training in quality programme.

**B. Quality Control :**

1. It is concerned with the interpretation and implementation of quality plans.
2. It comprises of in-process and post-production testing, which are aimed at ensuring the quality conformance of products.
3. The main works are given below :
   a. Assistance in establishing quality controls at various points of manufacturing process, maintenance and calibration process control equipment.
   b. Investigation of defects and assistance in solving quality problems during production and implementation of quality control measures.
   c. Organizing stage or interstage inspection whenever required and arranging final inspection to assess the quality of the end product.
   d. Checking the quality of packaging to ensure that the product is able to withstand transportation hazards.
   e. Feedback of defect data and customer complaints to the Quality Engineering Section.

**Que 2.7.** **Explain decentralization of quality functions and the**

**Answer**

1. It is not essential for all the quality functions are to be performed directly by the quality department.
2. Based on the overall company policy, the quality manager may recommend to the management, the allocation of various quality tasks to the sections which can perform these with maximum efficiency and economy.
3. Some sub-functions like the operation of process controls, stage and interstage inspection may be delegated to the production shops, if this measure helps in the smooth flow of production.
4. Similarly some work elements is inward material control, except actual inspection and testing may be transferred to the purchasing department if technically competent persons are available.

**A. Advantages :**

The main benefit is the smooth flow of production and less interdepartment friction.

**B. Disadvantages :**

The longer feedback loop results in slower reactions, which means that, should any defects arise in the product, a relatively longer time is taken before corrective measures are applied and thus a substantial number of defective products may be produced in the mean time.

**Que 2.8. Explain the role of "quality director". Also explain how such director coordinate among different levels through different management practice like training, auditing etc ?**

**UPTU 2012-13, Marks 06**

**Answer**

1. Develop with input from all personnel, the core values, vision statement, mission statement and quality policy statement.
2. Develop the strategic long term plan with goals and the annual quality improvement program with objectives.
3. Create the total education and training plans.
4. Determine and continually monitor the cost of poor quality.
5. Determine the performance measures for the organizations, approve those for the functional areas, and monitor then.
6. Continually determine those projects that improve the processes, particularly those that affect external and internal customer satisfaction.
7. Establish multifunctional project and department or work group teams and monitor their progress.

8. Establish or revise the recognition and reward system to account for the way of doing business.

**Que 2.9. Explain the economics of quality value and its contribution.**

**Answer**

1. Economics is the driving force for any industrial enterprise.
2. One of the main aims of an industry is to secure economic gains in the form of profit.
3. The quality of a product is subjected to the law of supply and demand in the same manner as the price.
4. The demand for higher quality goes on increasing as improved products are made available to customers.
5. Quality of a product, although an intangible factor in itself, gives the product its value.

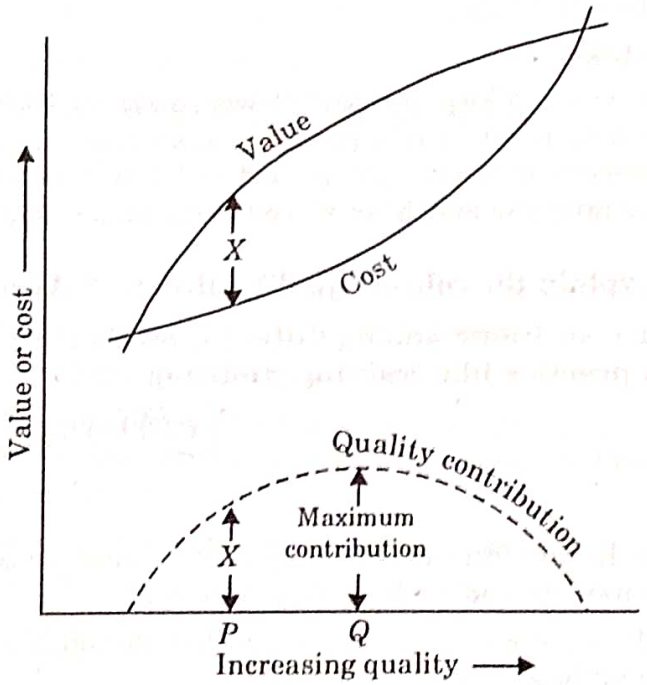



**Fig. 2.9.1.**

6. To appreciate the concept of quality value, let us suppose that a product can be manufactured at two quality levels, as grade *A* and grade *B*.
7. It can be seen from the cost curve that as the quality of a product is improved, the cost trends to rise at an increasing rate as shown in Fig. 2.9.1.
8. On the other hand, the value curve shows an opposite tendency, in that the value of the price which the customer is willing to pay for improved quality increases at a decreasing rate as shown in Fig. 2.9.1.

9. The difference between the value and the cost of a product at any particular quality level represents quality contribution.
10. Thus from the economic point of view, it is the middle quality level which gives the maximum benefit.

**Que 2.10. What do you mean by conformance of quality and economics of quality of conformance ? Discuss various types of cost related to quality ? How the total quality costs can be optimized for an organization ?**

**Answer**

**A. Economics of Quality of Conformance :**

1. Quality of conformance is an index of the extent to which the product confirms to the design.
2. All quality control activities during manufacturing are aimed to achieve quality of conformance.
3. However, quality conformance also costs money, as such the quality manager has to keep a strict watch on these costs.
4. He should plan his quality control programme in such a way as to ensure minimum overall quality costs. For this it is first necessary to know what constitutes the quality costs.
5. In quality control practice, any costs which is incurred to ensure that the outgoing product is of requisite quality termed as 'Quality Cost'. This can be divided into three parts :

**a. Failure Costs :**

1. Internal failure costs, such as cost of scrap and rectification and reduction in the sale price of 'second' quality goods.
2. External failure costs, such as replacement during warranty period, expenses on investigation and adjustment of customer complaints.

**b. Appraisal Costs :**

1. This represents cost of inspection and testing during various stages of manufacturing, as well as inspection of incoming materials.
2. The costs associated with evaluating of products, components and purchased materials to assure conformance with quality standards and performance requirements are called cost of appraisal.
3. In other words, the cost of evaluating quality and cost of identifying and segregating nonconforming parts and assemblies in known as appraisal cost.

**c. Cost of Prevention :**

1. It consists of the costs associated with personnel engaged in designing, implementing, and maintaining the quality system.

2. These costs are incurred to keep failure and appraisal costs to a minimum.
3. Maintaining the quality system includes auditing the system.
4. This includes, cost of quality planning, cost of documenting, process control cost, cost of training and costs associated with preventing recurring defects.
5. Quality costs vary considerably between products and companies.
6. In competitive industries where quality of a product is of great importance, quality costs form sizable segment of the total production cost, as such there is a great potential for cost reduction by judicious application of quality control programmes.

**B. Optimising Quality Costs :**

1. Analysis of quality costs show that these are related to the quality of conformance of the manufacturing system.
2. The quality of conformance in practical terms means, the ability of the process to manufacture a product which fully meets the design quality requirements.
3. The total quality costs comprise of the above mentioned three elements in varying proportion as shown in Fig. 2.10.1.

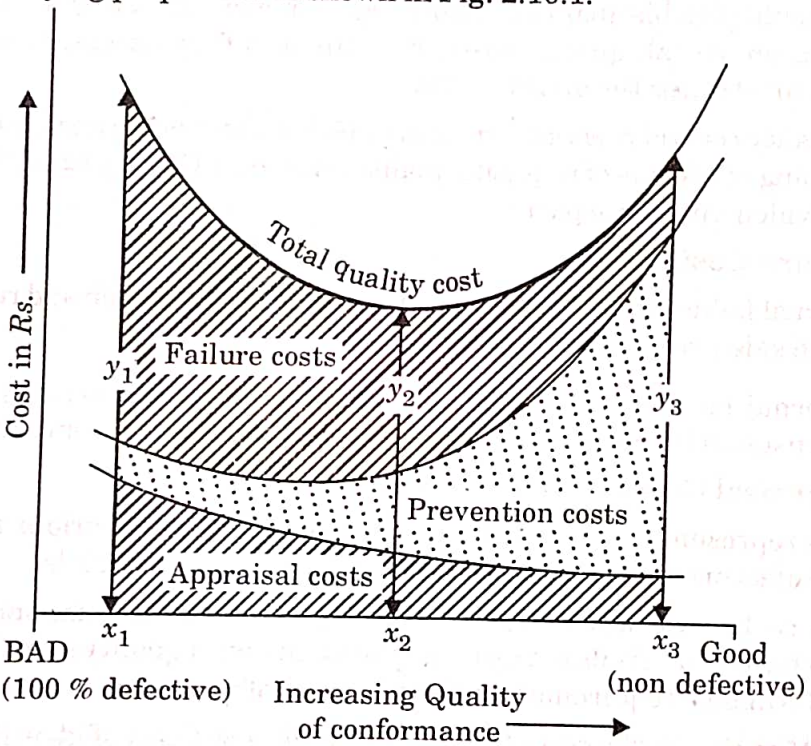



**Fig. 2.10.1.**

4. For instance at quality level $x_1$, the total quality costs is $y_1$ of which failure cost account for about 75 % and the balance 25 % is made up of prevention and appraisal costs.
5. At quality level $x_2$ the total quality cost is $y_2$, which is much less than $y_1$ and at this level, failure costs are about 50 % of the total costs.

6. At quality level $x_3$ the total quality cost is $y_3$ which again is higher than $y_2$, but it mainly comprises of preventive costs.
7. Therefore from the economic point of view, quality level $x_2$, where the total quality cost is minimum, represents the optimum level of the quality of conformance.

**Que 2.11. Explain the planning of cost reduction programmes.**

**Answer**

1. The importance of preventive quality control programmes for reducing quality costs needs no emphasis. However these programmes themselves cost money and the resources at the disposal of a quality manager are often limited.
2. Therefore, these should be utilized in such a manner as to yield maximum results.
3. Only such quality programmes should be undertaken which can quickly show results and prove their effectiveness in the cost reduction.
4. This will win the confidence of the company management and generate a great interest for quality programmes.
5. A preliminary survey, to detect weak spots in a process can be made by monitoring the frequency of failure in the process which results in the production of defective jobs.
6. In a multi product manufacturing company, it could begin with the isolation of the product having a high rate of rejection.
7. In a complex process involving many technologies the preliminary survey could start from the frequency of different types of defects and their causes. The cause showing the highest failure cost deserves first attention.
8. The immediate expenses on some quality programmes may appear good for nothing, but if they have been selected and planned properly, these are often more than justified in terms of long term gains especially in the case of continuous production processes.

## PART-2

*Attitude of Top Management, Co-operation of Groups, Operators Attitude, Causes of Operator Errors and Corrective Methods.*

### CONCEPT OUTLINE : PART-2

**Human Factor in Quality Management :**
The human element is the most important input in any industrial enterprise and it is the one, which is most difficult to control. The human problems which affect the quality of the product have been given below :

a. Attitude of top management,

b. Attitude of operators, and

c. Operators responsibility for quality.

**Causes of Operator Errors :**

1. Incompetence,
2. Lack of awareness, and
3. Carelessness and lack of interest.

**Corrective Measures for Error :**

1. Motivation of workers,
2. Education of the workers, and
3. Financial incentives.

**Quality Loss Function :**

$$L = D^2 C$$

where, $L$ = Quality loss of function,
$D$ = Deviation, and
$C$ = Proportional constant.

## Questions-Answers

### Long Answer Type and Medium Answer Type Questions

**Que 2.12. Explain the top management attitude.**

**Answer**

1. The managements of most companies in country have still not realised the true potential of quality management.
2. This attitude of the top management is reflected, at all lower levels, and the departmental heads resent an unwanted interruption by the quality department which is often accused of 'minding everybody's business except their own'.
3. Therefore the very first job of the quality manager is to convince the top management about the necessity of introducing quality control programmes.
4. The saleability of the plan could be enhanced by giving examples of the successful application of similar programmes in other plan.
5. Once the plan and the benefits which will occur from it, are clearly understood, it will be a very long sighted management.
6. After the quality plan has been accepted by the management, it is advisable that it should be introduced by the chief executive himself, by presenting the essentials of the plan to all key personnel.

7. The fact that the quality programmes, fully backed by top management will also condition the attitude of other departmental heads and make the task of the quality manager much easier.

**Que 2.13. Explain the co-operation of other functional groups.**

**Answer**

1. Mere acceptance of quality programme by the top management can not automatically assure its successful implementation.
2. Other company personnel may pay lip service to the quality programme, but unless their whole hearted co-operation can be secured, the chances of success of the programme are rather slim.
3. The first factor in this respect to be considered is the normal human reaction to any change.
4. Resistance to the introduction of the quality control programme may be made worse by the fear of loss of one's standing.
5. With the advent of mass production technology, maximizing production has become the sole aim of the production engineers and managers. Production staff has to be educated to remove this misconception.
6. As the implementation of the quality programme requires the active co-operation of other functional groups, they should be involved at the planning stage itself.
7. All affected groups and departments should be consulted during the formulation of the quality programme and they should be encouraged to put forward their points of view and suggestions, which should be given due weightage while finalising the programme.
8. The aim should be able to secure the genuine participation and involvement of other functional groups, so that they feel, it is their own programme. Under such circumstances the programme will have a much better chance of success.

**Que 2.14. Explain the attitude of operators ?**

**Answer**

1. The maximum contribution to the quality of product is contributed by the operator.
2. It is he who actually builds quality into the product.
3. His attitude to work is a decisive factor in determining the quality of the product.
4. Unfortunately, the persistent idea of modern managers for higher production has affected the attitude of the operator to the detriment of quality.

5. There is a need to redefine productivity so that it includes quality of the product also in addition to its quality.
6. Due recognition of quality will re-awaken the spirit of craftsmanship and pride in the quality of work.

**Que 2.15. Explain the role of operator in the quality ?**

**UPTU 2012-13, Marks 06**

**Answer**

1. It will be interesting to ask the questions, as to who is ultimately responsible for the quality, the management or the operator ? The answer will generally depend upon the quality situation of the company.
2. If the company is able to maintain good quality of their product, the management may take the credit for it.
3. On the other hand if the quality of their product is rather poor they will generally blame the workers and complaint about his lack of interest and loss in the pride of the workmanship.
4. It is the management's responsibility to provide the operator with the necessary means by which he can exercise effective control over the process. This involves :
   a. The operator must know what he is supposed to do.
   b. He must have means by which he can know the results of his action.
   c. He must be able to regulate the process, should the results be unsatisfactory.
5. After providing above means to operator, it now depends upon the ability and the will of the operator. If he is still not able to achieve the quality the cause must lie with him.
6. The causes of his inability to meet the quality targets must be investigated to find suitable remedial measures.

**Que 2.16. What are the causes of operator's errors ? Discuss the corrective measures.**

**OR**

**Discuss the different causes of operator errors and managerial approaches to overcome the same.** **UPTU 2011-12, Marks 10**

**Answer**

**A. Causes of Operator Errors :**

1. The operator's errors result from following three main factors :
   a. Incompetence,

b. Lack of awareness, and

c. Carelessness and lack of interest.

**a. Incompetence :**

1. Operator can be expected to achieve quality conformance only if he has the necessary skill.
2. Some operators may be able to achieve the quality targets consistently, while others may not be able to maintain the required quality level in spite of their best efforts.
3. Once this deficiency has been identified the remedy lies in training the operators to enable them to acquire necessary proficiency in their job.

**b. Lack of Awareness :**

1. There are some errors which are made by the operators without their being aware of it.
2. Such errors can be minimized by making the process as full-proof as possible.
3. Use of jig and fixtures which ensure that the job is correctly positioned for the operation.
4. Other measures to reduce such errors are proper lighting, clean working condition etc.

**c. Carelessness and Lack of Interest :**

1. The majority of the operator's errors are caused by this factor.
2. The main cause of his disinterest is the lack of knowledge about the product.
3. Seeming indifference on the part of operators to the quality of product is not due to the fact that they want to produce bad jobs.
4. It is mainly due to ignorance and lack of understanding of the implications of poor quality.
5. In the modern mass production technology, the product has been broken down into small discrete elements, and a worker may be producing thousands of small parts every day, without knowing that they are fit or not; under these circumstances he can not be blamed if he is not very much concerned about its quality.

**B. Corrective Measures :** Certain corrective measures should be taken to reduce the operator's error :

**a. Motivation of Workers :**

1. The situation is complicated when a worker is required simultaneously to attain two or more targets aimed in different directions.
2. To him quantitative output is more important.
3. Why should he then bother about quality ? However, the situation is not as hopeless as it seems.

4. We know that there is no basic conflict between quality and quantity, they are complementary, but this has to be explained to the workers and his misconception removed.
5. He must be convinced that it is his as well as the company's interest that he should attain the required quality level in addition to meeting the quantity targets.

**b. Education of Workers :**

1. It is essential that the workers are well informed about the products they are manufacturing.
2. This is done by establishing a suitable communication channel between management and the workers.
3. The workers are educated about :
   a. Company's products, their uses and the prospective customers.
   b. Company's quality policy and objectives.
   c. Effects of quality on company's sales and profitability.
   d. Responsibility for quality and methods of quality control being employed.
   e. Effect of quality errors on the product and the consumer.

**c. Financial Incentives :**

1. These are based on piece rate system, which are output oriented.
2. A worker does not get paid for a job which gets rejected due to bad workmanship.
3. Financial incentive is a major motivating factor which makes the operators work.
4. As long as financial incentives are linked with quantitative output only, the worker cannot be expected to make a serious effort for quality improvement.
5. For quality incentives to be effective the quality of the product must be measurable in quantitative terms, so that there is no dispute about quality assessment and the workers know exactly what is required of them.

**Que 2.17. What do you mean by quality loss function ? How does it explain the effect of quality and associated decision on the life of common people as well as the industrial personnel ?**

**UPTU 2011-12, Marks 06**

**Answer**

1. Taguchi defines quality of a product as the loss imparted by the product to the society from the time, the product is shipped to the customer.

2. Quality loss results from customer's dissatisfaction. The loss is measured in monetary terms and includes all costs in excess of the cost of a perfect product.
3. The loss may include various things such as a result of harmful effects to society, failure to meet customer requirements, failure to meet ideal performance, added warranty costs, damage to company's reputation etc.
4. Taguchi said that when the design parameter deviates from the target value then product performance begins to gradually deteriorate.
5. Before product goes to manufacturing, tolerances are set. Overall quality loss then increases by the square of deviation from the target value,

$$L = D^2C$$

where $L$ = Overall quality loss,
$D$ = Deviation from the target value, and
$C$ = Constant, it is determined by the cost of the counter measure that might be employed in the factory.

6. To build robust products, set ideal values for components and then minimize the average of the square of deviations for combined components averaged over the various customer user conditions.
7. Optimum customer satisfaction can be achieved by minimizing the quality loss.
8. Prevention of poor quality is less costly than rework, and yield better returns.
9. Minimization of quality loss is very much essential for survival and growth of the company in today's competitive international business environment.

**Que 2.18. Using a schematic diagram, explain the various steps in the construction of the QFD house of quality.**

**OR**

**What do you mean by house of quality ? Explain it with the help of figures and examples.** **UPTU 2012-13, Marks 06**

**Answer**

**A. House of Quality :**

1. The primary planning tool used in Quality Function Deployment (QFD) is the house of quality.
2. The house of quality translates the voice of the customer into design requirements that meet specific target values and matches those against how an organization will meet those requirements.
3. Many managers and engineers consider the house of quality to be the primary chart in quality planning.
4. The structure can be thought of as a framework of a house, as shown in Fig. 2.18.1.

5. The parts of the house of quality are described below :
   a. The exterior walls of the house are the customer requirements.
   b. On the left side is a listing of the voice of the customer, or what the customer expects in the product.

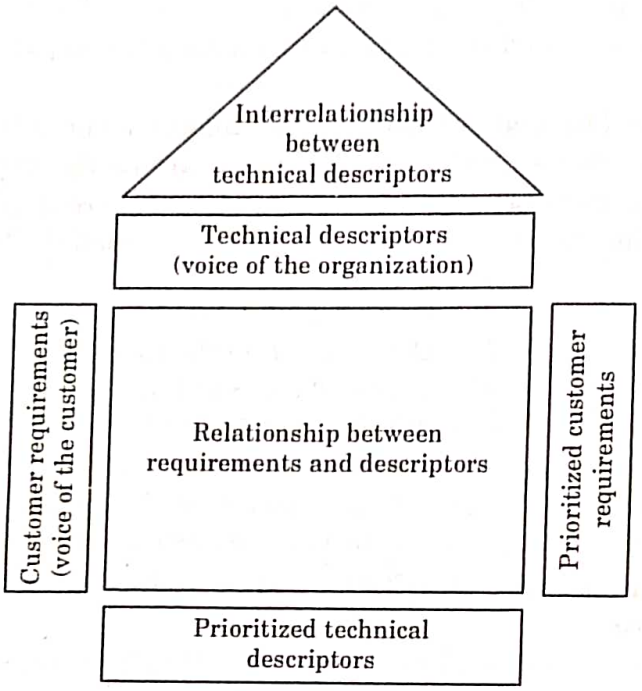



**Fig. 2.18.1.**

   c. On the right side are the prioritized customer requirements, or planning matrix. Listed items are such as customer benchmarking, customer importance rating, target value, scale-up factor, and sales point.
   d. The ceiling, or second floor, of the house contains the technical descriptors.
   e. Consistency of the product is provided through engineering characteristic, design constraints and parameters.
   f. The roof of the house is the interrelationship between technical descriptors.
   g. Trade-offs between similar or conflicting technical descriptors is identified.
   h. The interior walls of the house are the relationship between the customer requirements and technical descriptors.
   i. Customer expectations are translated into engineering characteristics.
   j. The foundation of the house is the prioritized technical descriptors.
   k. Items such as the technical benchmarking, degree of technical difficulty, and the target value are listed.
   l. This is the basic structure for the house of quality; once this format is understood, any other QFD matrices are fairly straight forward.

**Que 2.19.** **"Batch type manufacturing system has less quality problem than job shop or Mass production system". Comment on this statement whether it is right or wrong by comparing these systems on almost all issue of PPC and quality.** **UPTU 2012-13, Marks 10**

**Answer**

**Comparison between Mass Production, Job Production and Batch Production :**

| S.No. | Basis of Comparison | Mass Production | Job Production | Batch Production |
|---|---|---|---|---|
| 1. | Meaning | Mass production means production of one or two standard products on a large scale. | Job production means manufacture of products as per specifications given by the customer. It is a special order production. | Batch production means production of a number of identical items to meet a specific order or to satisfy continuous market demand. |
| 2. | Method of production | Here, the flow of materials is in a straight line. All facilities are arranged as per the sequence of operations. Standardization is the keynote of mass production method. | Job production is the manufacture of a single complete unit by an operator or a group of operatives. It is providing goods or services according to the needs of the customers. | In batch production, the work content of each unit is broken into a number of operations end operations are divided into groups for the completion of work group-wise. |
| 3. | Flexibility | Mass production method is highly inflexible. | The job production method using general purpose machines is more flexible. | Batch production is more flexible than Mass production method but less flexible than job production method. |

| | | | | |
|---|---|---|---|---|
| 4. | Capital Investment | Huge capital investment is required due to the ducplication of machineries. | The capital ivestment required differs from type of job undertaken. For e.g. a tailor undertaking stitching job requires low investment whereas a road or dam constcting comparny requires huge capital investemt. | Low capital investemt is required as compared to mass production and job production |
| 5. | Work in process Inventories | Work in process inventories is small as output of one process becomes input of the next process. | Raw materials and work in process inventories are high due to the uneven and irregular flow of work. | Work in Process inventory is high and large space is required due to production of variety of products. |

☺☺☺

# 3 UNIT

# Tools and Techniques, Control Charts and its Attributes

## PART-1

*Quality Control Tools, Theory of Control Chart, Construction and Analysis of R-chart, Process Capability and Use of Control Chart.*

### CONCEPT OUTLINE : PART-1

**Statistical Process Control :** One of the best technical tools for improving product and service quality is statistical process control (SPC). There are seven basic techniques : Pareto diagram, Process Flow diagram, Cause and Effect (Ishikawa) diagram, Check sheets, Histogram, Control charts and Scatter diagram.

**Control Chart :** A control chart is a graphical technique in which statistics computed from measured values of a certain process characteristics are plotted over time to determine if the process remains in statistical control or not.

**Control Charts for Variables :** Control charts based upon measurements of quality characteristics are called as control charts for variables.

**Types of Control Charts :**

a. $\bar{X}$ **-Chart :** Used to control central tendency of the process.

$$UCL = \overline{\overline{X}} + 3\sigma_{\bar{x}} = \overline{\overline{X}} + A_2\overline{R}$$

$$LCL = \overline{\overline{X}} - 3\sigma_{\bar{x}} = \overline{\overline{X}} - A_2\overline{R}$$

b. *R*-**Chart :** Used to control the dispersion of the process.

$$UCL = D_4\overline{R}$$

$$LCR = D_3\overline{R}$$

**Process Capability :** It is defined as 6 standard deviations.

$$\text{Process capability} = 6\sigma = \frac{\overline{R}}{d_2}$$

$$\text{Process capability index, } C_p = \frac{UCL - LCL}{6\sigma}$$

### Questions-Answers

### Long Answer Type and Medium Answer Type Questions

**Que 3.1.** **What is a histogram and establish its vitality ?**

**Answer**

1. A histogram as drawn in Fig. 3.1.1, displays the distribution of data by bar graphing the number of units of anything (for example, frequency of defectives monthwise over a year) in separate categories.
2. A histogram displays in bar-graph form showing the frequency with which events occur.
3. Since random samples of data under statistical control normally follows the pattern of a "bell shape" curve, this shape of a histogram distribution is helpful.
4. The first thing a histogram can show is the negative or positive deviation from the normal, or skewness of the curve.
5. Histograms start with an unorganised set of numbers.
6. Variable quality characteristics like dimensions of a component or silicon percentage in steel, etc., have specification limits–one-sided or two-sided. Same is the case with the process parameters like temperature, concentration, etc.
7. In order to ensure that product or process is within the specification limits, it is necessary that the "average" and "variability" levels are suitably controlled.
8. Histogram is a diagrammatic and graphical representation of a frequency distribution table. If we look at the tally bars in the following frequency distribution table, it could be seen that it represents a particular pattern, there are uniform class intervals. Interval is 10 in each case and it is called "width".

   **Frequency Distribution of Matriculation Examination Students :**

| Class Marks | Frequency |
|---|---|
| 10 – 20 | 3 |
| 20 – 30 | 5 |
| 30 – 40 | 9 |
| 40 – 50 | 19 |
| 50 – 60 | 6 |
| 60 – 70 | 5 |
| 70 – 80 | 4 |
| 80 – 90 | 3 |

9. Taking the midpoints of the columns if a curve is drawn, it takes almost a bell shape. When such a curve is obtained for certain data, it is said to have a normal distribution and the histogram is shown in Fig. 3.1.1.

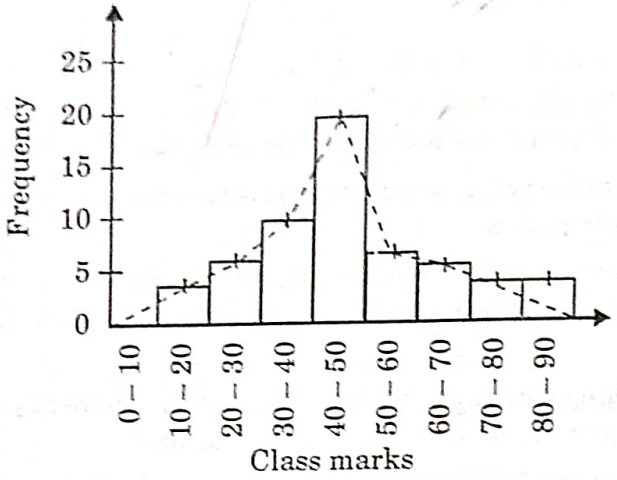



**Fig. 3.1.1.** Histogram.

**Que 3.2.** **Explain Pareto diagram and its construction ?**

**Answer**

1. Alfredo Pareto (1848 – 1923) conducted extensive studies of the distribution of wealth in Europe.
2. He found that there were a few people with a lot of money and many people with little money. This unequal distribution of wealth became an integral part of economic theory.
3. Dr. Joseph Juran recognized this concept as a universal that could be applied to many fields. He coined the phrases vital few and useful many.
4. A Pareto diagram is a graph that ranks data classification in descending order from left to right, as shown in Fig. 3.2.1.
5. In this case, the data classifications are types of coating machines. Other possible data classifications are problems, complaints, causes, types of nonconformities, and so forth.
6. The vital few are on the left, and the useful many are on the right.
7. It is sometimes necessary to combine some of the useful many into one classification called "other". When this category is used, it is placed on the far right.
8. The vertical scale is dollars (or frequency), and the percent of each category can be placed above the column.
9. In this case, Pareto diagrams were constructed for both frequency and dollars.
10. As can be seen from the Fig. 3.2.1 machine 35 has the greatest number of nonconformities, but machine 51 has the greatest dollar value.

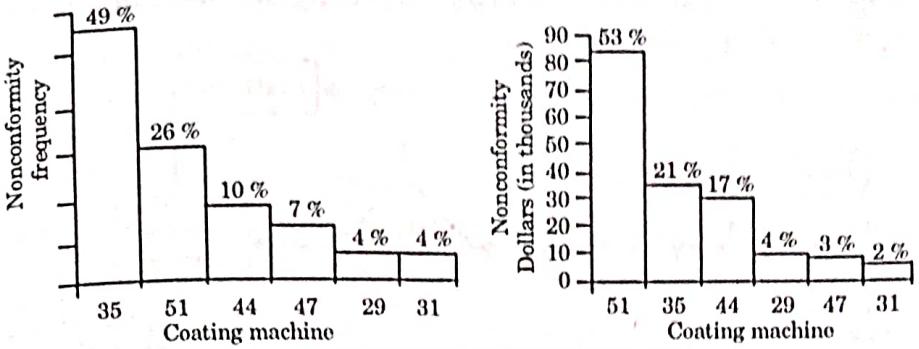



**Fig. 3.2.1.** Pareto diagram.

11. Pareto diagrams can be distinguished from histograms by the fact that the horizontal scale of a Pareto diagram is categorical, whereas the scale for the histogram is numerical.
12. Pareto diagrams are used to identify the most important problems. Usually, 75 % of the total results form 25 % of the items.
13. Examples of the vital few are :
    a. A few customer accounts for the majority of sales.
    b. A few processes account for the bulk of the scrap or rework cost.
14. Construction of a Pareto diagram is very simple. There are following five steps :
    a. Determine the method of classifying the data by problem, cause, nonconformity, and so forth.
    b. Decide if dollars (best), frequency, or both are to be used to rank the characteristics.
    c. Collect data for an appropriate time interval or use historical data.
    d. Summarize the data and rank order categories from largest to smallest.
    e. Construct the diagram and find the vital few.

**Que 3.3. Explain the following :**

**A. Process flow diagram, and**
**B. Check Sheets.**

**Answer**

**A. Process Flow Diagram :**

1. For many products and services, it may be useful to construct a process flow diagram.
2. Fig. 3.3.1 shows a flow diagram for the order entry activity of a make to order company that manufactures gasoline filling station hose nozzles.
3. The diagram shows the flow of the product or service as it moves through the various processing operations. The diagram makes it easy to visualize the entire system, identify potential trouble spots, and locate control activities.
4. It answers the question, "Who is the next customer ?"

5. Improvement can be accomplished by changing, reducing, combining, or eliminating steps.

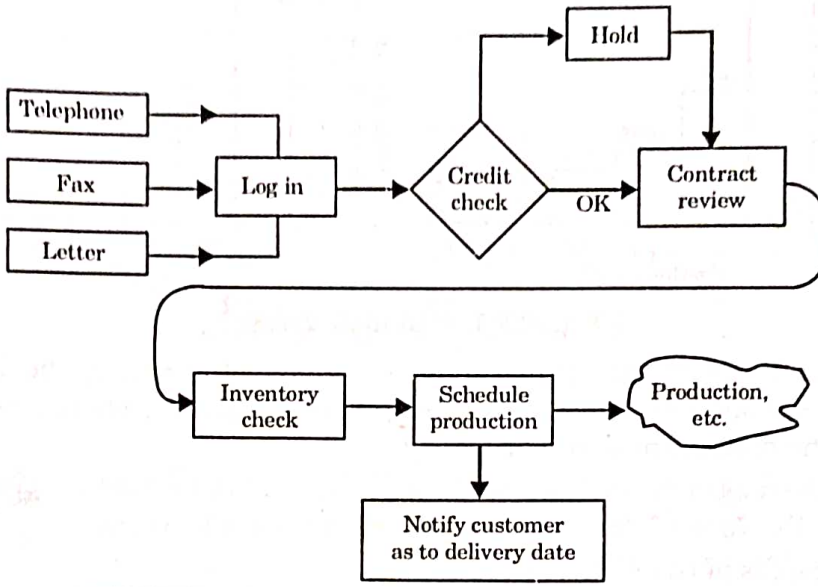



**Fig. 3.3.1.** Flow diagram for an order entry activity.

**B. Check Sheets :**

1. The main purpose of check sheets is to ensure that the data is collected carefully and accurately by operating personnel.
2. Data should be collected in such a manner that it can be quickly and easily used and analyzed.
3. The form of the check sheet is different for each situation and is designed by the project team.
4. Fig. 3.3.2 shows a check sheet for paint nonconformities for bicycles.

| | **CHECK SHEET** | |
|---|---|---|
| Product : Bicycle 32<br>Nonconformity type | Number inspected: 2217<br>Check | Total |
| Blister | 𝍸 𝍸 𝍸 𝍸 \| | 21 |
| Light spray | 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 \|\|\| | 38 |
| Drips | 𝍸 𝍸 𝍸 𝍸 \|\| | 22 |
| Overspray | 𝍸 𝍸 \| | 11 |
| Runs | 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 \|\| | 47 |
| Others | 𝍸 | 5 |
| | Total | 144 |
| Number<br>Nonconforming | 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 \|\|\| | 113 |

**Fig. 3.3.2.** Check sheet for paint nonconformities.

5. Whenever possible, check sheets are also designed to show location.
6. For example, the check sheet for bicycle paint nonconformities could show an outline of a bicycle, with *X* (cross) indicating the location of the nonconformities.
7. Creativity plays a major role in the design of check sheet.
8. It should be user-friendly and, whenever possible, include information of time and location.

**Que 3.4. Explain cause-and-effect (Ishikawa) diagram and its construction. How is this diagram used for quality improvement ?**

**Answer**

1. A cause-and-effect (C&E) diagram is a picture composed of lines and symbols designed to represent a meaningful relationship between an effect and its causes.
2. It was developed by Dr. Kaoru Ishikawa in 1943 and is sometimes referred to as an Ishikawa diagram or a fishbone diagram because of its shape.
3. C&E diagrams are used to investigate either a "bad" effect and to take action to correct the causes or a "good" effect and to learn those causes that are responsible.
4. For every effect, there are likely to be numerous causes.

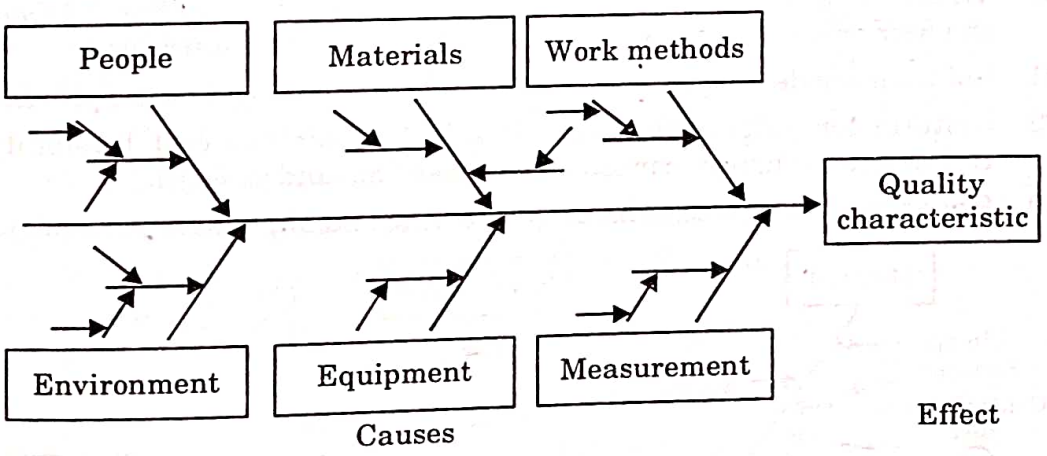



**Fig. 3.4.1.** Cause-and-Effect diagram.

5. Fig. 3.4.1 illustrates a C&E diagram with the effect on the right and causes on the left.
6. The effect is the quality characteristic that needs improvement.
7. Causes are sometimes broken down into the major causes of work methods, materials, measurement, people, equipment, and the environment. Each major cause is further subdivided into numerous minor causes.

8. For example, under work methods, we might have training, knowledge, ability, physical characteristics, and so forth.
9. C&E diagrams are the means of picturing all these major and minor causes.
10. Fig. 3.4.2 shows a C&E diagram for house paint peeling using four major causes.
11. The first step in the construction of a C&E diagram is for the project team to identify the effect or quality problem.
12. It is placed on the right side of a large piece of paper by the team leader.
13. Next, the major causes are identified and placed on the diagram.
14. Determining all the minor causes requires brainstorming by the project team.
15. Brainstorming is an idea-generating technique that is well suited to the C&E diagram. It uses the creative thinking capacity of the team.
16. Attention to a few essentials will provide a more accurate and usable result.
17. Once the C&E diagram is completed, it must be evaluated to determine the most likely causes. This activity is accomplished in a separate session.
18. The procedure is to have each person vote on the minor causes.
19. Team members may vote on more than one cause.
20. Those causes with the most votes are circled, as shown in Fig. 3.4.2 and the four or five most likely causes of the effect are determined.
21. Solution are developed to correct the causes and improve the process.
22. Criteria for judging the possible solutions include cost feasibility, resistance to change, consequences, training, and so forth.
23. Once the team agrees on solutions, testing and implementation follow.

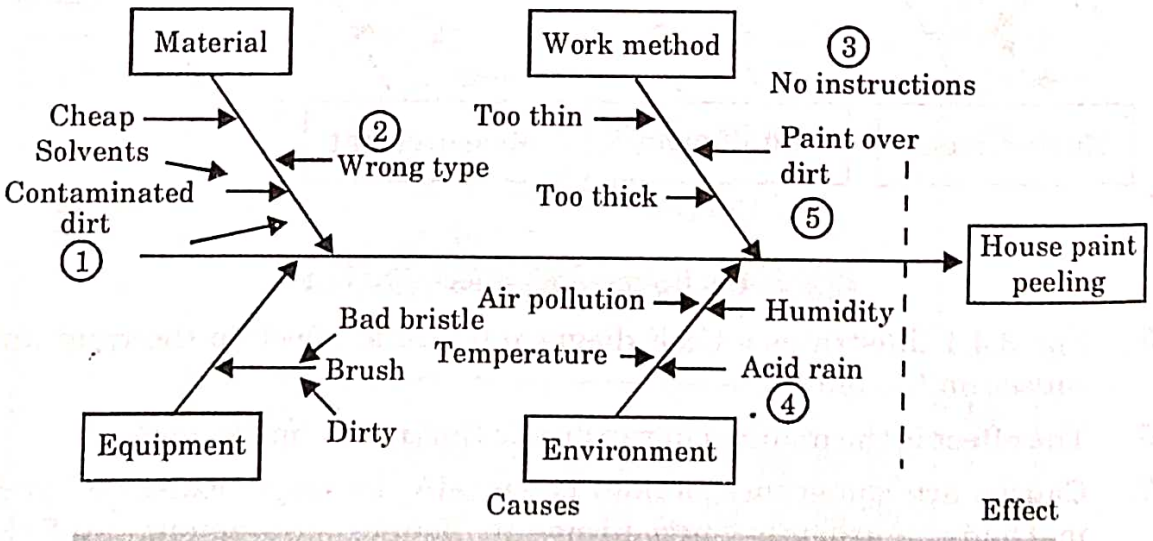



**Fig. 3.4.2.** Cause-and-effect diagram of house paint peeling.

**Answer**

1. The simplest way to determine if a cause-and-effect relationship exists between two variables is to plot a scatter diagram.

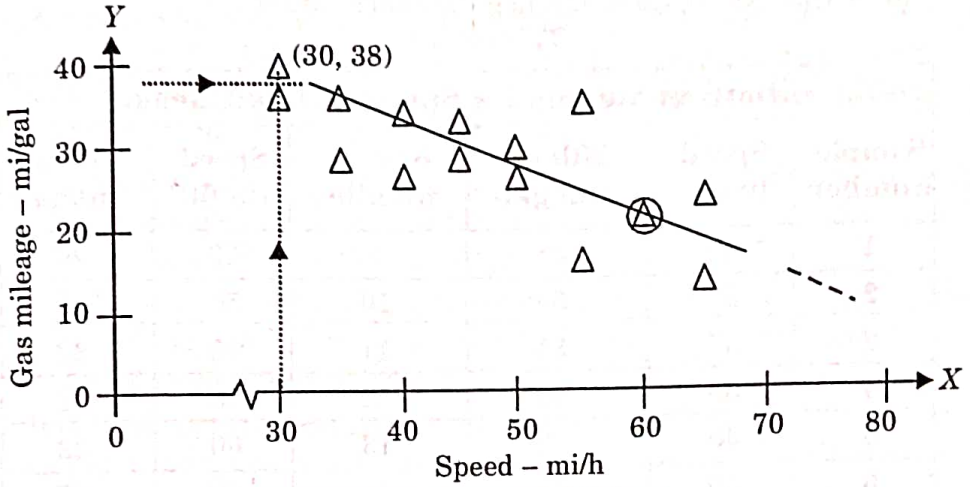



**Fig. 3.5.1.** Scatter diagram.

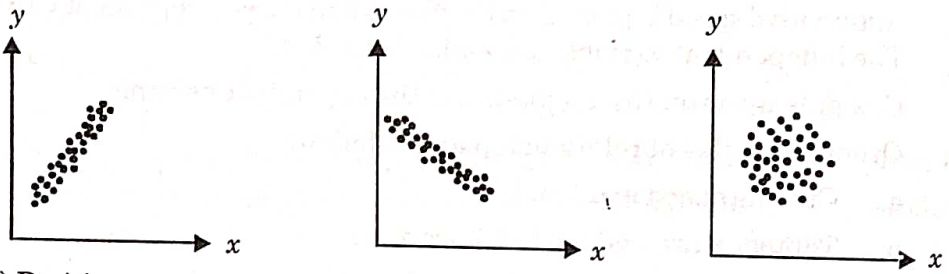
2. Fig. 3.5.1 shows the relationship between automotive speed and gas mileage. The figure shows that as speed increases, gas mileage decreases.
3. Automotive speed is plotted on the $X$-axis and is the independent variable. The independent variable is usually controllable.
4. Gas mileage is on the $Y$-axis and is the dependent variable.
5. Other examples of relationship are as follows :
   a. Cutting speed and tool life,
   b. Temperature and lipstick hardness,
   c. Striking pressure and electrical current,
   d. Temperature and percent foam in soft drinks,
   e. Yield and concentration,
   f. Training and errors,
   g. Breakdowns and equipment age, and
   h. Accident and years with the organization.
6. There are a few simple steps for constructing a scatter diagram. Data are collected as ordered pairs $(x, y)$.
7. The automotive speed (cause) is controlled and gas mileage (effect) is measured.
8. Table 3.5.1 shows resulting $x, y$ paired data. The horizontal and vertical scales are constructed with the higher values on the right for the $X$-axis and on the top for the $Y$-axis.
9. After the scales are labeled, the data are plotted.

10. Once the scatter diagram is completed, the relationship or correlation between the two variables can be evaluated.

11. Fig. 3.5.2 shows different patterns and their interpretation. At (*a*), there is a positive correlation between the two variables, because as *x* increases, *y* increases. At (*b*), there is a negative correlation.

**Table 5.3.1.**

| Data on Automotive Speed vs. Gas Mileage | | | | | |
|---|---|---|---|---|---|
| **Sample number** | **Speed (mi/h)** | **Mileage (mi/gal)** | **Sample number** | **Speed (mi/h)** | **Mileage (mi/gal)** |
| 1 | 30 | 38 | 9 | 50 | 26 |
| 2 | 30 | 35 | 10 | 50 | 29 |
| 3 | 35 | 35 | 11 | 55 | 32 |
| 4 | 35 | 30 | 12 | 55 | 21 |
| 5 | 40 | 33 | 13 | 60 | 22 |
| 6 | 40 | 28 | 14 | 60 | 22 |
| 7 | 45 | 32 | 15 | 65 | 18 |
| 8 | 45 | 29 | 16 | 65 | 24 |




(*a*) Positive correlation (*b*) Negative correlation (*c*) No correlation

**Fig. 3.5.2.** Different scatter diagram patterns.

**Que 3.6.** **Why do people rely on sampling in quality control ? Explain with proper reasoning.** **UPTU 2012-13, Marks 05**

**Answer**

1. Whenever any material or store is purchased, there is always the question of its quality. Does it confirm to the quality requirements of the purchaser ?
2. If the quantity involved is small the purchaser may take the word of the manufacturer regarding its quality.
3. However, when the store is purchased in bulk, the purchaser normally likes to assure himself by more positive means that the quality of the store does confirm to his requirements.

4. Sampling inspection is a technique for assessing the quality of a lot comprising of a large number of articles, by inspecting only some of them.
5. The group of articles chosen for inspection is called a 'SAMPLE' which may be defined as a part representing the quality of the whole lot.
6. For example, if a sample of 100 articles out of a lot of 1200 is found to have 2 articles defective, it is reasonable to expect that remaining 1100 will also contain 2 % defective articles, provided all 1200 pieces were manufactured under similar conditions.
7. Whereas an individual article is accepted on the basis of its conformance to specifications, we need another criterion for acceptance of a lot containing a large number of articles.
8. A perfectionist might say that a lot containing even one defective piece should be rejected, but we know from actual experience, that in most cases this is not practicable.
9. If we want to insist on zero percent defective lots, we should be prepared to pay a comparatively heavy price for inspection, which may prove more expensive than accepting a few defective pieces in the lot.
10. Therefore, except in case of stores of critical nature a certain percentage of defective articles are accepted in the lot.
11. The lower the percentage defective, the better is the quality of the lot.
12. The lot quality can also be expressed in terms of the number of defect counted, rather than the number of units on which the defects are found.

**Que 3.7. Exhibit the relationship between sample and population ?**

**Answer**

1. It is desirable to examine the concept of a population and a sample.
2. In order to construct a frequency distribution of the weight of steel shafts, a small portion, or sample, is selected to represent all the steel shafts.
3. The population is the whole collection of steel shafts.
4. When averages, standard deviations, and other measures are computed from samples, they are referred to as statistics. Because the composition of samples will fluctuate, the computed statistics will be larger or smaller than their true population values, or parameters.
5. Parameters are considered to be fixed reference (standard) values or the best estimate of these values available at a particular time.
6. The population may have a finite number of items, such as a day's production of steel shafts.
7. It may be infinite or almost infinite, such as the number of rivets in a year's production of jet airplanes.

8. The population may be defined differently depending, on the particular situation.
9. Thus, a study of a product could involve the population of an hour's production, a week's production pieces, and so on.
10. Because it is rarely possible to measure all of the population, a sample is selected.
11. Sampling is necessary when it may be impossible to measure the entire population; when the expense to observe all the data is prohibitive; when the required inspection destroys the product; or when a test of the entire population may be too dangerous, as would be the case with a new medical drug.
12. The sample average has the symbol $\overline{X}$ and the population mean the symbol $\mu$ (mu).
13. The symbol $\overline{X}_0$ is the standard or reference value. Mathematical concepts are based on $\mu$, which is the true value – $\overline{X}_0$ represents a practical equivalent in order to use the concept.
14. The sample standard deviation has the symbol $s$, and the population standard deviation the symbol $\sigma$ (sigma).
15. The symbol $s_0$ is the standard or reference value and has the same relationship to $s$ that $\overline{X}_0$ has to $\mu$.
16. The primary objective in selecting a sample is to learn something about the population that will aid in making some type of decision.
18. The sample selected must be of such a nature that it tends to resemble or represent the population.

**Que 3.8. Explain operating characteristics of quality curves.**

**UPTU 2015-16, Marks 10**

**Answer**

1. Effective use of sampling inspection technique requires that these risks be clearly understood, so that the selection of a particular plan is based on logical decision, rather than arbitrary choice.
2. The risk in a particular sampling plan can be determined by considering the results of samples drawn from a large number of various quality levels using the mathematical theory of probability.
3. These results can be shown in the form of graphical representation called as operating characteristics curve, generally known as OC curve.
4. Let us consider the sampling plan where,
   Sample size : 50

Acceptance number : 1
Rejection number : 2

5. Such a plan can be written in an abbreviated form, as 50 (1/2) *i.e.*, sample size (Acceptance No., Rejection No.).
6. The OC curve for this plan is shown in Fig. 3.8.1.
7. The horizontal axis of the curve shows the actual percentage of defectives in the submitted lots, and the vertical axis gives the probability of their acceptance.
8. Assuming that lots with 1 % defectives are considered just acceptable, point *P* shows that a lot with 1 % defectives has 0, 9 probability of acceptance.
9. It means that if large number of lots of the quality were inspected by this plan, about 90 % of the lots will be accepted and the remaining 10 % rejection is referred to as producer's risk.
10. Now looking from the consumer's point of view, it can be seen from point *Q* that even though the minimum acceptable quality of the lot is 1 % defective, there is a 20 % chance of a lot with 6 % defectives being accepted. This is termed as consumer's risk.

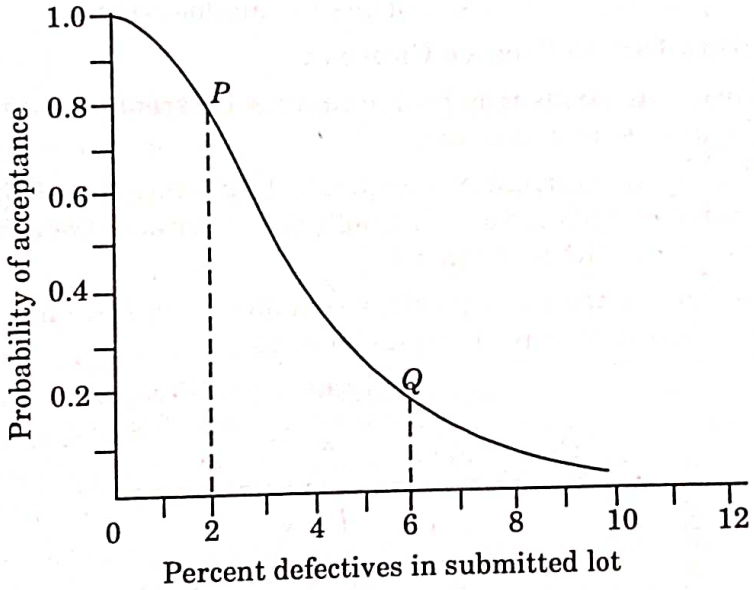



**Fig. 3.8.1.** Operating characteristic curve.

**Que 3.9. What are Shewhart's control charts ? Explain how they are used to reduce the production of defectives in a factory.**

**UPTU 2003-04, Marks 10**

**Answer**

1. A control chart is an important aid or statistical device used for the study and control of the repetitive processes. Control chart was developed by

Dr.W.A. Shewhart and it is based upon the fact that variability does exist in all the repetitive processes.

2. In nature two extremely similar things are difficult to obtain. If at all we come across exactly similar things, it must be only by chance.
3. This fact holds good for production processes as well no production process is good enough to produce all items of products exactly alike.
4. Most industrial and administrative situations involve a combination of materials, men and machines.
5. Each of these elements of combination has some inherent or natural variability, the causes of which cannot be isolated and the unnatural variability due to assignable causes which can be isolated and therefore controlled and reduced to economic minimum.
6. There exist two kinds of variations :

**a. Variations Due to Assignable Causes :**

i. The power of the Shewhart control chart lies in its ability to separate out the assignable causes of quality variation.

ii. These are caused due to change in working conditions, mistake on the part of operator, lack of quality mindness etc.

**b. Variation Due to Chance Causes :**

i. These variations may be due to some inherent characteristics of the process and machine.

ii. If the measurement of the quality characteristics of the articles produced is plotted on this graph, the upper and lower lines can be used as the limits of control.

iii. As long as the plotted points remain within the limit lines, the process can be considered under control.

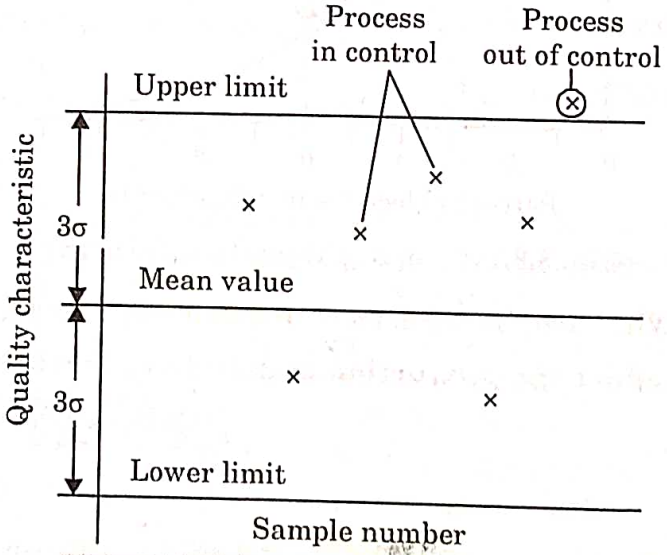



**Fig. 3.9.1.** Principle of control charts.

iv. If a point falls outsides the limit lines it can be taken as an indication that the process is out of control.

v. This is the basic principle of the control charts.

7. Following are the use of control chart :

a. The action to remove assignable causes of variation when out of control condition has been detected.

b. Action to establish the process average.

c. Action to establish the process dispersion.

d. Once the process is brought into control with satisfactory average and dispersion, an important purpose of the control chart is to help continue this happy state of affairs. This involves :

i. To leave the process alone as long as it stays in control.

ii. To hunt for and remove the assignable causes of variation where the control chart shows lack of control.

**Que 3.10. What are measurement or control limits for the control charts ?**

**Answer**

1. For plotting control charts generally $\pm 3\sigma$ limits are selected and they are termed as control limits.
2. They present a band within which the dimensions of the components are expected to fall.
3. With $3\sigma$ limits, 99.7 % of the samples from a given population will fall within these limits.
4. The remaining 0.3 % will fall outside the limits. This means that in the long run 3 samples out of every 1000 will fall outside the $\pm 3\sigma$ limits even if no change takes place in the population average. Since three out of thousand is a very small risk, $\pm 3\sigma$ limits have been found to give good practical results.
5. As long as the sample average is within $3\sigma$ limits it is assumed that any variation between the sample average and the desired population average is due to chance causes, *i.e.*, no assignable causes of variation are present.
6. When it is found that a shift has taken place, the next step is to find the assignable causes. This calls for investigating the production equipment, materials and the operator's methods.

**Que 3.11. Explain the construction and analysis of *R*-chart.**

**Answer**

**A. Construction :**

1. The construction of *R*-chart should be done in the following steps :

**Step 1 :** Sample numbers are taken along $X$-axis and range value along $Y$-axis.

**Step 2 :** Find the average range for all the samples that is

$$\overline{R} = \frac{\Sigma R}{n}$$

where, $n$ = Number of samples.

**Step 3 :** Find the control limits.

$$\text{Upper control limit} = D_4 \overline{R}$$

$$\text{Lower control limit} = D_3 \overline{R}$$

**Step 4 :** Draw the $\overline{R}$ and control limits on the graph.

**Step 5 :** Plot the points to represent the range values.

**B. Analysis of $R$-chart :**

1. An examination of the $R$-chart shows that when all the points are within control limits, the variability of the process is within control.
2. Sometimes it may happen that one or two points are lying outside the control limits. In such a case, efforts should be made to trace the cause of excessive variation in that particular sample.
3. In case if an assignable cause is found it should be eliminated and these particular values may be ignored and the control limits should be recalculated.
4. A lower range indicates less variability, which should be welcomed.
5. The reason for having $LCL$ for an $R$–chart is that under normal conditions, chance causes can account for reduction in range only up to a certain extent.
6. In case there is genuine reduction in range, it may be due to assignable causes such as the use of new material or tool.
7. The management would like to perpetuate the reduction in range by incorporating the causative factors in the process.

**Que 3.12.** **The following table gives the sample ranges for I.Q. samples each of size 6, in the production of certain component. Construct the central chart for range and comment on the nature of control.**

| Sample no. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Range | 9.5 | 12.8 | 10 | 9.1 | 7.8 | 5.8 | 14.5 | 2.8 | 3.7 | 8 |

**Answer**

1. $$\overline{R} = \frac{9.5 + 12.8 + 10 + 9.1 + 7.8 + 5.8 + 14.5 + 2.8 + 3.7 + 8}{10}$$

$$= \frac{84}{10} = 8.4$$

2. For the sample size 6,

$$D_4 = 2.004, D_3 = 0$$

$$UCL = D_4 \overline{R} = 2.004 \times 8.4 = 16.834$$

$$LCL = D_3 \overline{R} = 0$$

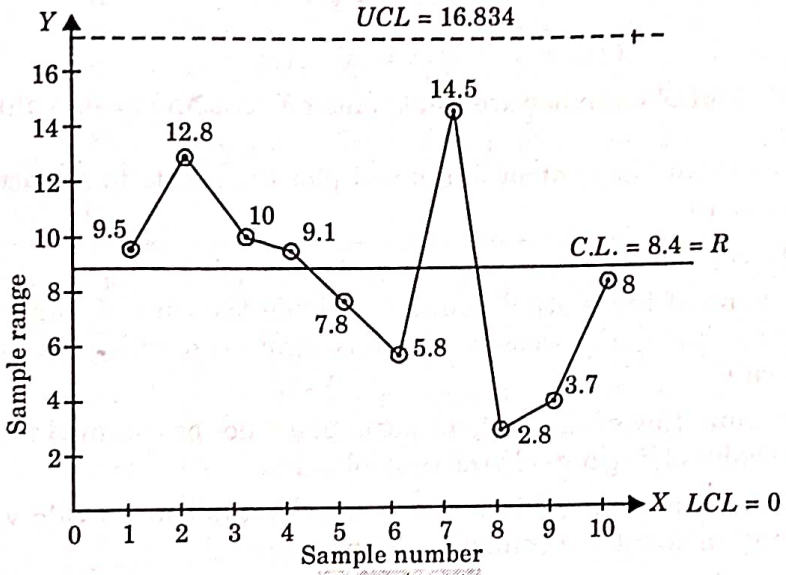



**Fig. 3.12.1.**

3. None of the values of $R$ falls outside the control limits. Hence, process variability is under control.

**Que 3.13. Explain the construction of $\overline{X}$ - chart and comment on its variability.**

**Answer**

1. $\overline{X}$ - chart is also known as mean chart and used for controlling average quality of the product.
2. A number of samples are drawn at regular interval of time and the mean calculated from each sample is used as the statistic in the control chart.

**A. Construction :**

1. This should be completed in the following steps :

**Step 1 :** Samples $X_1, X_2$.... are drawn from the process.

**Step 2 :** Find out the mean of each sample.

$$\overline{X} = \frac{\Sigma X}{n}$$

**Step 3 :** Find the mean of sample means.

$$\overline{\overline{X}} = \frac{\Sigma \overline{X}}{\text{No. of samples}}$$

**Step 4 :** Find the standard error of mean.

$$\sigma_{\overline{X}} = \frac{\overline{\sigma}}{\sqrt{n}}$$

**Step 5 :** The limits are

$$UCL = \overline{\overline{X}} + 3\sigma_{\overline{\overline{X}}} = A_2\overline{R} + \overline{\overline{X}}$$

$$LCL = \overline{\overline{X}} - 3\sigma_{\overline{\overline{X}}} = \overline{\overline{X}} - A_2\overline{R}$$

**Step 6 :** Sample number are taken along $X$-axis and mean value along $Y$-axis.

**Step 7 :** Draw the control limits and plot the points to represent the mean values.

**B. Analysis :**

1. When none of the plotted points is outside the control limits, which indicates that the process is within control even with respect to the mean value.
2. The examination of the control chart should not be confined to looking for the points lying outside the control limits.
3. Even the points lying within the control limits can provide valuable information about the behaviour of the process.
4. For example, there may be concentration of points on one side of the centre line, which indicates that the process centre has shifted.

**Que 3.14.** **If number of samples = 20, size of each sample = 5, $\overline{R} = 2.3\,\overline{\sigma}$, $\overline{\overline{X}} = 99.6$, $\overline{R} = 7$, find the values of control limits. [$n = 5$, mean range = 2.32 (population S.D.)]**

**Answer**

1. Given $\overline{\overline{X}} = 99.6$, $\overline{R} = 7$

$\overline{R} = 2.32\,\overline{\sigma}$

$n = 5$

So, $\overline{\sigma} = \dfrac{7}{2.32} = 3.0172$

2. Calculation of control limits,

$$UCL = \overline{\overline{X}} + 3\left(\frac{\overline{\sigma}}{\sqrt{n}}\right) = 99.6 + \left(3 \times \frac{3.0172}{\sqrt{5}}\right) = 103.648$$

$$LCL = \overline{\overline{X}} - 3\left(\frac{\overline{\sigma}}{\sqrt{n}}\right) = 99.6 - \left(3 \times \frac{3.0172}{\sqrt{5}}\right) = 95.552$$

$CL = 99.6$

**Que 3.15.** **The table given below gives the measurement obtained in 10 samples. Construct control charts for mean and the range. Discuss the nature of control.**

| Sample no. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | 62 | 50 | 67 | 64 | 49 | 63 | 61 | 63 | 48 | 70 |
| | 68 | 58 | 70 | 62 | 98 | 75 | 71 | 72 | 79 | 52 |
| | 66 | 52 | 68 | 57 | 65 | 62 | 66 | 61 | 53 | 62 |
| | 68 | 58 | 56 | 62 | 64 | 58 | 69 | 53 | 61 | 50 |
| | 73 | 65 | 61 | 63 | 66 | 68 | 77 | 55 | 49 | 66 |
| | 68 | 66 | 66 | 74 | 64 | 55 | 53 | 57 | 56 | 75 |

**Answer**

| Sample no. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | 62 | 50 | 67 | 64 | 49 | 63 | 61 | 63 | 48 | 70 |
| | 68 | 58 | 70 | 62 | 98 | 75 | 71 | 72 | 79 | 52 |
| | 66 | 52 | 68 | 57 | 65 | 62 | 66 | 61 | 53 | 62 |
| | 68 | 58 | 56 | 62 | 64 | 58 | 69 | 53 | 61 | 50 |
| | 73 | 65 | 61 | 63 | 66 | 68 | 77 | 55 | 49 | 66 |
| | 68 | 66 | 66 | 74 | 64 | 55 | 53 | 57 | 56 | 75 |
| $\Sigma X$ | 405 | 349 | 388 | 382 | 406 | 381 | 397 | 361 | 346 | 375 |
| $\overline{X} = \frac{\Sigma X}{n}$ | 67.5 | 58.2 | 64.7 | 63.7 | 67.7 | 63.5 | 66.2 | 60.1 | 57.7 | 62.5 |
| $R$ | 73-62 =11 | 66-50 =16 | 70-56 =14 | 74-57 =17 | 98-49 =49 | 75-55 =20 | 77-53 =24 | 72-53 =19 | 79-48 =31 | 75-50 =25 |

1. $$\overline{\overline{X}} = \frac{\Sigma \overline{X}}{n}$$

$$= \frac{67.5 + 58.2 + 64.7 + 63.7 + 67.7 + 63.5 + 66.2 + 60.1 + 57.7 + 62.5}{10}$$

$$= \frac{631.8}{10} = 63.18$$

For sample size of 6, $A_2 = 0.483, A_3 = 0.483$

2. $$CL = \overline{\overline{X}} = 63.18$$

$$\overline{R} = \frac{\Sigma R}{n}$$

$$= \frac{11 + 16 + 14 + 17 + 49 + 20 + 24 + 19 + 31 + 25}{10} = 22.6$$

3. Control limits for $\overline{X}$ -chart :

$$UCL = \overline{\overline{X}} + A_2\overline{R} = 63.18 + 0.483 \times 22.6 = 74.0958$$

$$LCL = \overline{\overline{X}} - A_2\overline{R} = 63.18 - 0.483 \times 22.6 = 52.2642$$

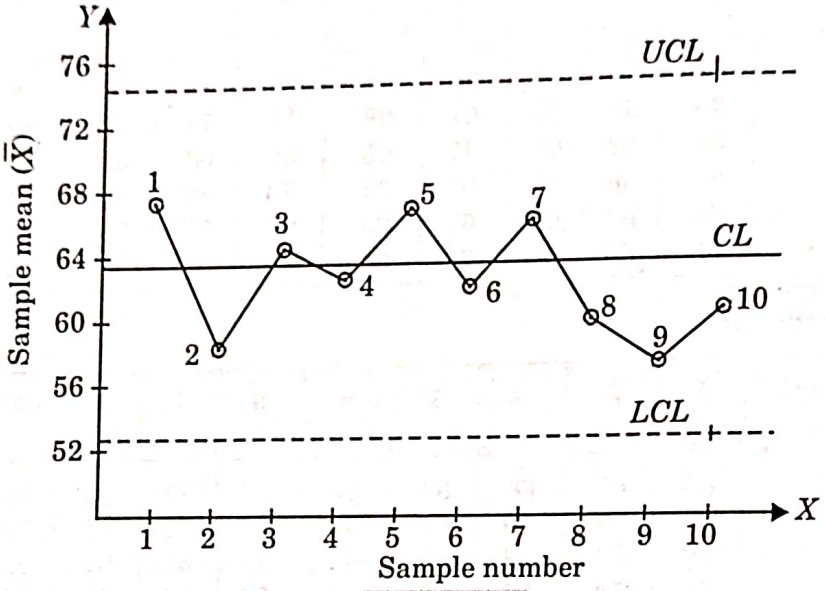



**Fig. 3.15.1.**

4. All the terms of the samples lie between *UCL* and *LCL* the process is in a state of statistical control.

5. From the table $D_4 = 2.004, D_3 = 0$

$$UCL_R = D_4\overline{R} = 2.004 \times 22.6 = 45.290$$

$$LCL_R = D_3\overline{R} = 0$$

$$CL_R = \overline{R} = 22.6$$

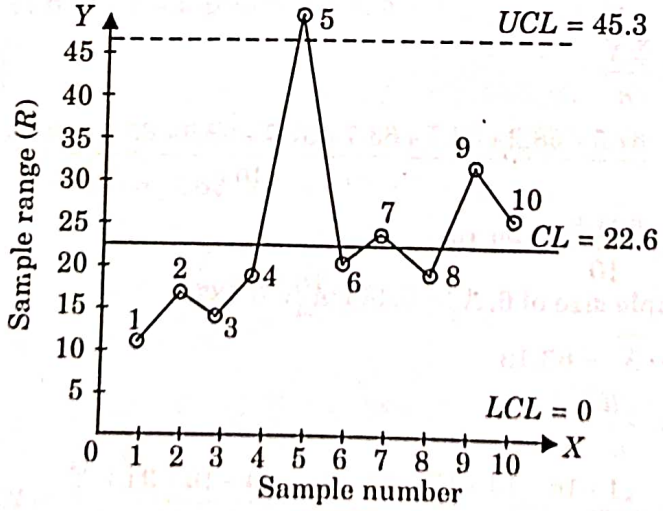



**Fig. 3.15.2.**

6. The value of $R$ corresponding to sample number 5 namely 49, lies outside the control limits. Hence the variability is out of control.

7. Therefore the process is out of control due to $R$-chart.

**Que 3.16.** **Control chart for $\overline{X}$ and $R$ are to be established on a certain dimension part, measured in mm. Data were collected in subgroup of 6 and given below. Determine trial limits. Assume assignable causes and revise the central line and limits.**

| Subgroup no. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $\overline{X}$ | 20 - 35 | 20 - 40 | 20 - 36 | 20 - 65 | 20 - 20 | 20 - 40 | 20 - 43 | 20 - 37 | 20 - 48 | 20 - 42 |
| $\overline{R}$ | 0 - 34 | 0 - 36 | 0 - 32 | 0 - 36 | 0 - 35 | 0 - 31 | 0 - 31 | 0 - 34 | 0 - 30 | 0 - 37 |
| Subgroup no. | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| $\overline{X}$ | 20 - 39 | 20 - 38 | 20 - 40 | 20 - 41 | 20 - 45 | 20 - 34 | 20 - 36 | 20 - 42 | 20 - 50 | 20 - 31 |
| $\overline{R}$ | 0 - 29 | 0 - 30 | 0 - 33 | 0 - 36 | 0 - 34 | 0 - 36 | 0 - 37 | 0 - 73 | 0 - 38 | 0 - 35 |
| Subgroup no. | 21 | 22 | 23 | 24 | 25 | – | – | – | – | – |
| $\overline{X}$ | 20 - 39 | 20 - 39 | 20 - 40 | 20 - 41 | 20 - 40 | – | – | – | – | – |
| $\overline{R}$ | 0 - 38 | 0 - 33 | 0 - 32 | 0 - 34 | 0 - 30 | – | – | – | – | – |

**UPTU 2012-13, Marks 10**

**Answer**

1. $$\Sigma\overline{X} = 510.01$$
$$\overline{\overline{X}} = \frac{\Sigma\overline{X}}{n} = 20.4004$$

2. $$\Sigma R = 8.89$$
$$\overline{R} = \frac{\Sigma R}{n} = 0.3556$$

3. The factors for a subgroup size ($n$) of 6 are $A_2 = 0.483$, $D_3 = 0$ and $D_4 = 2.004$.

4. Trial control limits for the $\overline{X}$ chart are :
$$UCL_{\overline{X}} = \overline{\overline{X}} + A_2\overline{R}$$
$$= 20.4004 + (0.483)(0.3556) = 20.572$$
$$LCL_{\overline{X}} = \overline{\overline{X}} - A_2\overline{R}$$
$$= 20.4004 - (0.483)(0.3556) = 20.228$$

5. Trial control limits for the $R$ chart are :
$$UCL_R = D_4\overline{R}$$
$$= (2.004)(0.3556) = 0.7126$$
$$LCL_R = D_3\overline{R}$$
$$= 0$$

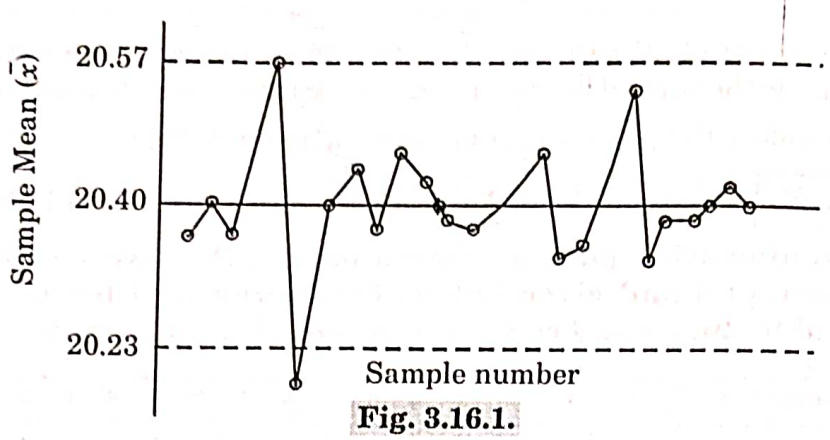



**Fig. 3.16.1.**

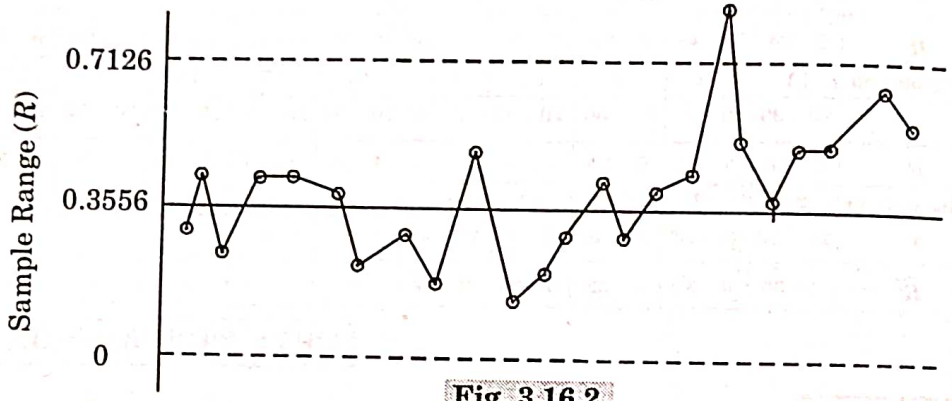



**Fig. 3.16.2.**

6. The $R$-chart is analyzed first to determine if it is stable. Because the out of control point at subgroup 18 on the $R$-chart does not have an assignable cause, it is assumed that this state is due to a chance cause and is part of the natural variation of the process.

7. Now it can be discarded from the data. The remaining plotted points indicate a stable process.

8. Similar will be in the case for $\overline{X}$ - chart, subgroups 4 and 5 are to be discarded and the recalculated values are,

$$\overline{R}_0 = \frac{8.89 - 0.73}{24} = 0.34$$

$$UCL_{R0} = (2.004)\,(0.34)$$
$$= 0.68$$

$$LCL_{R0} = 0$$

$$\overline{\overline{X}}_0 = \frac{510.01 - (20.65 + 20.20)}{23} = 20.39$$

$$UCL_{\overline{X}_0} = \overline{\overline{X}}_0 + A_2\,\overline{R}_0 = 20.39 + (0.483)\,(0.34) = 20.55$$

$$LCL_{\overline{X}_0} = \overline{\overline{X}}_0 - A_2\,\overline{R}_0 = 20.39 - (0.483)\,(0.37) = 20.22$$

9. The new $\overline{X}$ and $R$-charts are shown below after discarding the points which are out of control.

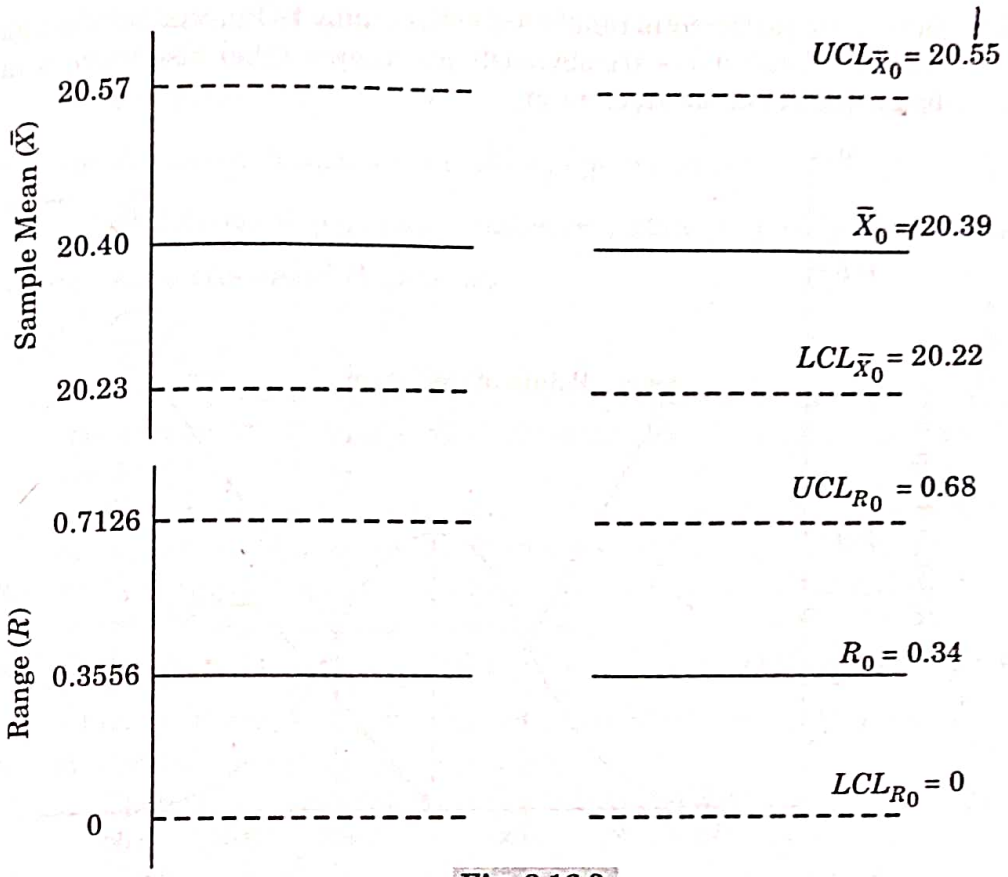



**Fig. 3.16.3.**

**Que 3.17.** **Explain central limit theorem. Enlist and explain probability distribution used for $\overline{X}$ and $R$-chart, $\overline{P}$ -chart and $C$-chart.** **UPTU 2012-13, Marks 05**

**Answer**

**A. Central Limit Theoram :**

1. It states that if a number of samples are chosen from a large population then the mean of each sample will be approximately equal to the mean of the whole population, provided sample selection is fair and is of considerable size.

**B. Probability Distribution Used for $\overline{X}$ and $R$-Chart :**

1. The definition of probability implies that, the total number of events and those with a particular characteristic are exactly known. In actual industrial situations this is hardly the case.
2. Quality control staff is often required to estimate the likelihood of occurrence of defects in equipment or a batch of articles.

3. In such cases, the total number of articles may be known, but the exact number of defectives are obviously not known, otherwise there would be no need to make an estimate.

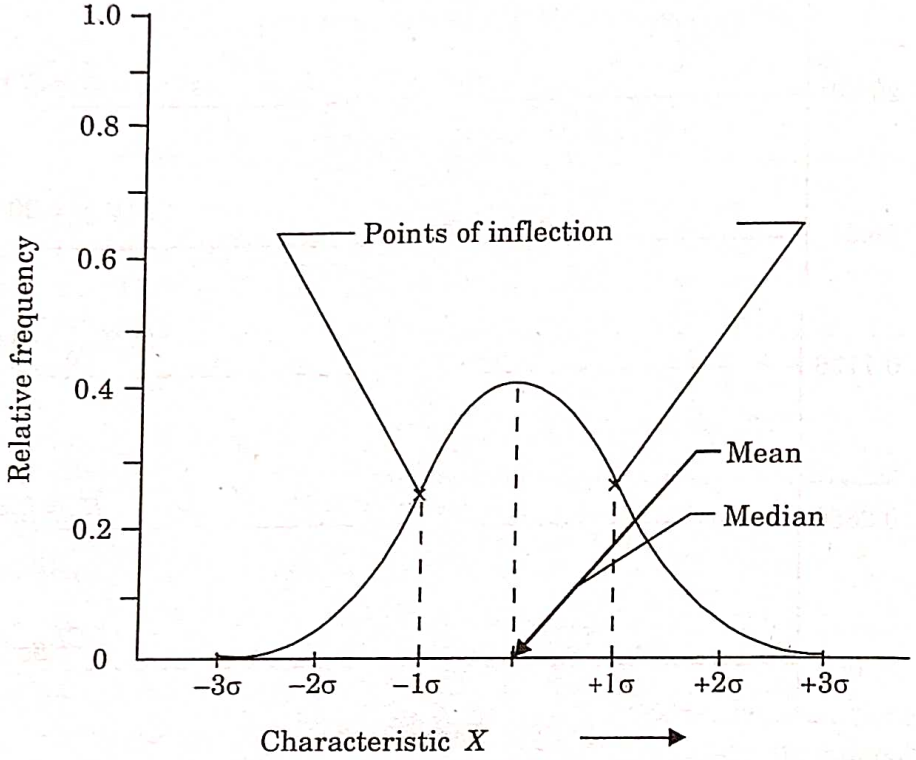



**Fig. 3.17.1.**

4. In other situations, an estimate may be required regarding the likelihood of production of defective pieces by a particular machine.
5. Here even the total number of pieces involved is not known, since they are still to be produced.
6. In such situations, the definition of probability discussed above is not of much use, and a different approach is required to determine the probability.
7. In these circumstances, we must estimate the proportion of events or objects with a particular characteristic and the total number of events or objects.
8. This can be done by repeated trials of events or drawing random samples from the lot and ascertaining the number of pieces with the particular characteristic, whose probability is to be determined. Then we can use the following definition of probability.
9. If an event has been tried or an object drawn $n$ times, and in $F_A$ of these, the event or object $A$ did occur, then the probability of event $A$ is

$$P(A) = \frac{F_A}{n}$$

10. From the above definition, it will be seen that $F_A$ is in fact the frequency of occurrence and $\frac{F_A}{n}$ is a relative frequency. This definition is also called relative frequency definition of probability.

**Que 3.18. What is process capability ? How it is measured ? And also explain the capability index.**

**Answer**

1. Process capability may be defined as the "Minimum spread of a specific measurement variation which will include 99.7 % of the measurements from the given process".
2. In other words, process capability = 6σ' since, 6σ' is taken as a measure of the spread of the process, which is also called natural tolerance.
3. Process capability study is carried out to measure that ability of the process to meet the specified tolerance.
4. By this study, it becomes possible to know the percentage of the products which will be produced within ±3σ limits on either side of mean $\overline{X}$.
5. A process capability analysis consists of :
   a. Measuring the process capability to find out whether the process is inherently capable of meeting the specified tolerance limits.
   b. Discovering why a process is failing to meet specification.

**A. Methods of Calculating Process Capability :**

**a. Standard Deviation Method :**

1. By this method process capability study may be made by gathering the required data atleast 50 observations and preferably 100 or more if possible and computing the standard deviation of this data by using the relation,

$$\sigma = \sqrt{\frac{(X_1 - \overline{X})^2 + (X_2 - \overline{X})^2 + (X_3 - \overline{X})^2 + ... + (X_n - \overline{X})^2}{n}}$$

**b. Average Range Method :**

1. This method is preferred for process capability analysis for the following reasons :
   i. It is easier to calculate as no square root is involved.
   ii. Trends occurring in the study or other abnormal conditions can be detected.
   iii. When the average range method is used the capability study can serve as a base-period analysis.

**c. Single Range Method :**

1. A rough estimate of process capability may be obtained by this method.
2. Take a certain number of observations and then find the difference between the largest and smallest readings.

3. Based on certain confidence level we can predict the percentage of the products that will lie within the observed range of the sample.
4. This method is valuable when used in conjuction with the average range method.

**B. Capability Index :**

1. Process capability and the tolerance are combined to form a capability index.

$$\text{Capability index, } (C_p) = \frac{USL - LSL}{6\sigma}$$

Where $USL - LSL$ = Upper specification – Lower specification, or
= tolerance.

2. If the capability index is greater than 1, the process is capable of meeting the specification.
3. If the index is less than 1, the process is not capable of meeting the specifications because process is continually shifting back and forth.
4. Using the capability index concept, we can measure quality, provided the process is centered.
5. The larger the capability index, better the quality.
6. This result is accomplished by having realistic specifications and continual striving to improve the process capability.

**Que 3.19.** **What do you mean by process capability index ? The specification from the manufacturing of a particular type of metal coating calls for the temperature of the drying oven to be 380 ± 15 °F. The company that is considering using coating run tests by taking a large number of reading about mean temperature setting was found to be 2.06 °F. What is the process capability index ?**

**UPTU 2011-12, Marks 05**

**Answer**

**A. Process Capability Index :** Refer Q. 3.18, Page 77E, Unit-3.

**B. Numerical :**

1. $$\text{Capability index} = \frac{USL - LSL}{6\sigma}$$

2. $USL = 380 + 15 = 395$
$LSL = 380 - 15 = 365$

3. $$\text{Capability index} = \frac{395 - 365}{6 \times 2.06} = \frac{30}{6 \times 2.06} = \frac{5}{2.06} = 2.427$$

**Que 3.20.** **Standard deviations for three samples are 9.6, 10.2, 9.8. If all these three samples are drawn as single sample, what will be the standard deviation ?**

**UPTU 2011-12, Marks 03**

**Answer**

1. Given : $\sigma_1 = 9.6, \sigma_2 = 10.2, \sigma_3 = 9.8$
2. Standard deviation of the samples taking as single sample,

$$\sigma = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2} = \sqrt{9.6^2 + 10.2^2 + 9.8^2}$$
$$= 17.095.$$

**Que 3.21.** **A fair percentage of a certain product requires costly rework operations to change a certain quality characteristic after the product has been rejected by the manufacturer's 100 % final inspection. Rework is possible whenever the value of this quality characteristic falls above the upper specification limit. If the value falls below the lower specification limit, the product must be scrapped. $\overline{X}$ and $R$ control charts have been initiated and maintained for 50 subgroups of 5 each with samples taken from production every 2 hours. The specification requirements for the measured quality are 119 ± 10 and σ' of 5. On the assumption that the quality characteristics is normally distributed, approximately what percentage of defective product is being produced ? How much of this can be reworked ?**

**Answer**

1. Process capability = $6\sigma' = 6 \times 5 = 30$
2. Specified tolerance = 129 – 109 = 20
3. Since $6\sigma'$ > specified tolerance some non-conforming products will always be made.
4. Percent defective will correspond to the area above the line for dimension 129 and also below the line for dimension 109.
5. Now, $$Z = \frac{X_1 - \overline{X}'}{\sigma} = \frac{129 - 119}{5} = 2$$
6. Area corresponding to $Z = 2$ is 0.4772.
   $$= 0.5 - 0.4772 = 0.023$$
7. Therefore the defective parts produced above the *UCL*
   $$= (0.023) = 2.3\ \%$$

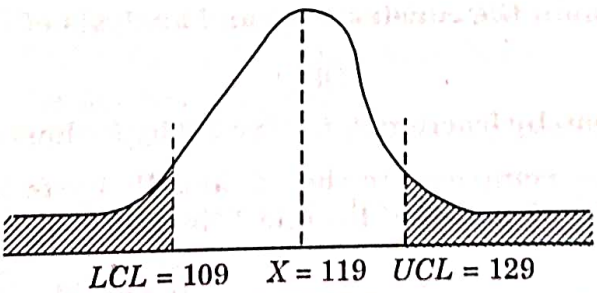



**Fig. 3.21.1.**

8. $\therefore$ Defective parts produced below $LCL$

$$= \frac{109-119}{5} = -2\ (= 2.3\ \%)$$

9. Therefore the total percentage of defective parts = 2.3 + 2.3 = 4.6 %
And the percent defective which can be reworked = 2.3 % (above $UCL$)

## PART-2

*Defects, Construction and Analysis of P-chart, Variable Sample Size and Construction and Analysis of C-chart.*

## CONCEPT OUTLINE : PART-2

**Defect :** It refers to the failure of a quality characteristic to meet the specified standard.

**Defective :** It designates an item which has one or more defects.

***P*-chart :** It is also known as fraction defective chart.

$$UCL_p = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

$$LCL_p = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}.$$

where $\bar{p}$ = Mean defective.

***C*-chart :** It is used when the number of defects per unit are counted.

$$UCL_c = \bar{C} + 3\sqrt{\bar{C}}$$

$$LCL_c = \bar{C} - 3\sqrt{\bar{C}}$$

$$\text{where } \bar{C} = \frac{\text{Total number of defects}}{\text{Total number of samples}}$$

## Questions-Answers

### Long Answer Type and Medium Answer Type Questions

**Que 3.22.** **Explain the construction and analysis of *P*-chart.**

**OR**

**What do you mean by fraction defective ? Why *P*-chart even though much inferior as compared to the $\bar{X}$ and *R*-charts is effectively used in diagnosis of causes of trouble ? Explain *P*-chart.**

**UPTU 2013-14, Marks 10**

**Answer**

**A. Fraction Defective :**

1. The overall quality of a product inspected for attributes may be expressed as fraction defective or percent defective.

2. $$\text{Fraction defective} = \frac{\text{Number of unit found defective}}{\text{Total number of unit inspected}}$$

   Percent defective = Fraction defective × 100

3. Because of lower inspection and maintenance costs of *P*-charts, they usually have a greater area of economical applications than do the control charts of variables.

**B. Construction of *P*-chart :**

1. *P*-chart is designed to control the proportion percentage or defectives per samples.

2. $$\text{Fraction defective } (p) = \frac{\text{Number of defective articles}}{\text{Size of the sample}}$$

   $$\bar{p} = \frac{\text{Number of defective in all the samples combined}}{\text{Total number of items in all the samples combined}}$$

3. The construction of *P*-chart should be completed in the following steps :

   **Step 1 :** Calculate the average fraction defective $\bar{p}$ .

   **Step 2 :** Compute σ, the standard error of $\bar{p}$ .

   $$\sigma = \sqrt{\frac{\bar{p}\bar{q}}{n}} = \sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

   **Step 3 :** Calculate the upper control limit and the lower control limit.

   $$UCL_p = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

   $$LCL_p = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

   **Step 4 :** Draw the control line at $\bar{p}$ as thick horizontal line and the two control lines *UCL* and *LCL* as dotted horizontal lines.

   **Step 5 :** Plot the individual points *p*.

4. As in the case of measurement control charts, before the control limits are finally accepted for future control, the chart is analyzed to see whether the process is within control, or not. If all the points are lie within the control limits then the process is within control otherwise out of control.

**Que 3.23. Construct a *P*-chart for the following data :**

| No. of samples (each of 100 items) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| No. of defectives | 12 | 10 | 6 | 8 | 9 | 9 | 7 | 10 | 11 | 8 |

**Answer**

| No. of samples | No. of units in a sample ($n$) | No. of defectives ($d$) | Fraction defective $p = d/n$ |
|---|---|---|---|
| 1 | 100 | 12 | 0.12 |
| 2 | 100 | 10 | 0.10 |
| 3 | 100 | 6 | 0.06 |
| 4 | 100 | 8 | 0.08 |
| 5 | 100 | 9 | 0.09 |
| 6 | 100 | 9 | 0.09 |
| 7 | 100 | 7 | 0.07 |
| 8 | 100 | 10 | 0.10 |
| 9 | 100 | 11 | 0.11 |
| 10 | 100 | 8 | 0.08 |

1. $N = 1000, \Sigma d = 90$

2. Average fraction defective

$$= \bar{p} = \frac{\text{Total number of defectives in all samples combined}}{\text{Total number of items in all samples}}$$

$$= \frac{90}{1000} = 0.09$$

3. $$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

$$= 0.09 + 3\sqrt{\frac{0.09(1-0.09)}{100}}$$

$$= 0.09 + 0.0858 = 0.1758$$

$$LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = 0.09 - 0.0858 = 0.0042$$

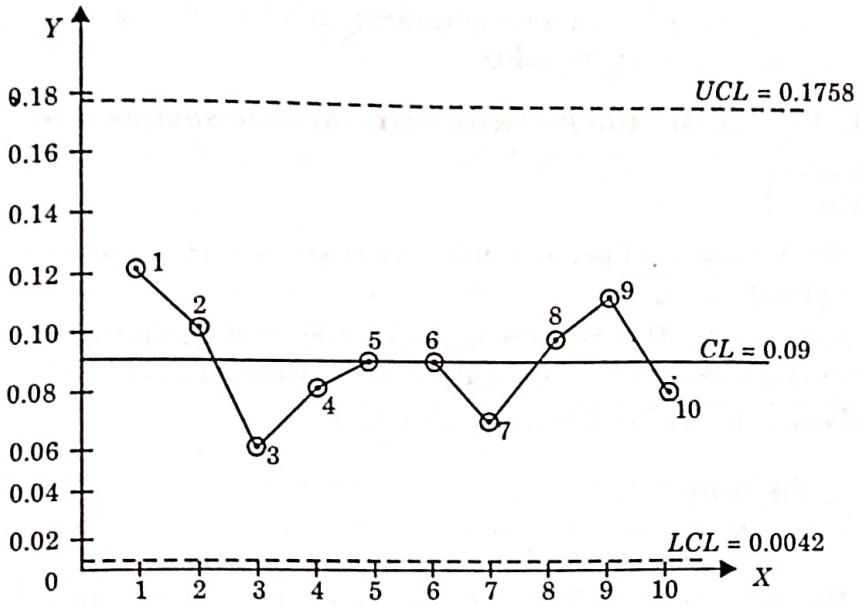



**Fig. 3.23.1.**

5. All the values lie between control limits. Hence the variability is under control.

**Que 3.24. Explain the quality improvement by control charts and utility of lower control limit.**

**Answer**

1. The main utility of the *P*-chart is that it indicates the magnitude of the quality problem and highlights the areas of weakness.
2. A control chart by itself, cannot improve the quality of the product.
3. Quality improvement can result only if follow-up action is taken to rectify the shortcomings indicated by the control chart.

**A. Utility of Lower Control Limit :**

1. The need for a lower control limit for a percent defective chart is that the lower the value of the percent defective in a sample the better will be its quality.
2. When a process is operating at a particular central value, the chance causes can explain variations only up to $3\sigma$ higher and lower than the central value.
3. If a particular point falls below the lower control limit, the first thing which should be checked is the effectiveness of inspection.
4. Quite often relaxed inspection will be found to be the cause.
5. If however the point is genuinely found to be below the lower control limit, the causative factor should be identified and efforts should be made to perpetuate the assignable cause which has been responsible for significant improvement in quality.

6. Thus it can be seen that a lower control limit has an important function in the improvement of quality.

**Que 3.25. Explain the *P*-charts with variable sample size.**

**Answer**

1. In the discussion of percent defective charts we have taken a constant sample size.
2. In many cases, *P*-charts are based on 100 % inspection of the output which may be varying from day to day or week to week.
2. We know that 3σ limit to control limits is

$$\bar{p} \pm 3\sqrt{\frac{\bar{p}(1-\bar{p})}{N}}.$$

3. In the above relation 3σ value is inversely proportional to $\sqrt{N}$. This means that the larger the sample size $N$, the smaller is the 3σ value and the narrower the control limits. Thus control limits will be different for different sample size.
4. In practice, it is inconvenient to calculate control limits for each different sample size. As long as the variation in sample size is not more than 20 %, the control limits computed on the basis of the average sample size are found to be quite satisfactory.
5. In case there is a marked difference in sample size for any particular sample and if the point corresponding to that sample lies close to the approximate control limit based on average sample size, the exact limit for that particular sample can be calculated to ascertain whether the point lies outside to limit.

**Que 3.26. Explain the construction and analysis of *C*-chart.**

**Answer**

1. *C*-charts are particularly useful where the product is a complex one, such as an engine or a machine tool, where some defects are almost found in the inspection after assembly.
2. If the conventional charts are used, it would always show 100 % defective, which will be of no use for control purposes.
3. *C*-charts are also useful in the case of low quantity production, where the changes in the quality level will show up more readily in the *C*-chart than in *P*-charts.

**A. Construction :**

**Step 1 :** Control limit line $(\bar{C}) = \dfrac{\text{Total number of defects}}{\text{Total number of samples}}$

**Step 2 :** Calculate

$$UCL = \bar{C} + 3\sqrt{\bar{C}}$$

$$LCL = \bar{C} - 3\sqrt{\bar{C}}$$

**Step 3 :** Plot all the points on the chart taking sample number on the $X$-axis and $\bar{C}$ on the $Y$-axis.

**B. Analysis :**

1. The main drawback of the basic $C$-chart is that it treats all defects alike, certain defects may be of a minor nature requiring only a slight adjustment, which could be carried out in a few minutes. There may be other defects requiring complete stripping and reassembly which may take many hours.
2. An out of control point on the $C$-chart where all defects are bulked together may cause unnecessary concern to the management when the out of control condition is due to series of defects which can be quickly rectified.

**Que 3.27. Draw a $C$-chart for the following data pertaining to the number of foreign coloured threads (considered as defects) in 15 pieces of cloth of 2 m × 2 m in a certain make of synthetic fibre and state your conclusions.**

**7, 12, 3, 20, 21, 5, 4, 3, 10, 8, 0, 9, 6, 7, 20**

**Answer**

1. Total number of defects
   = 7 + 12 + 3 + 20 + 21 + 5 + 4 + 3 + 10 + 8 + 0 + 9 + 6 + 7 + 20 = 135
2. The average number of defects

$$\bar{C} = \frac{\text{Total number of defects}}{\text{Total number of samples}} = \frac{135}{15} = 9$$

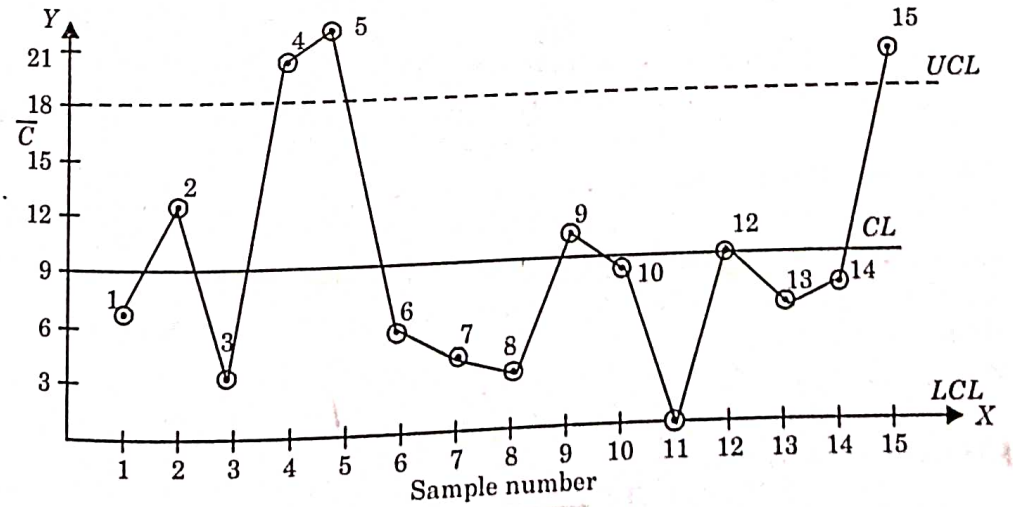



**Fig. 3.27.1.**

3. $$UCL = \bar{C} + 3\sqrt{\bar{C}} = 9 + 3 \times \sqrt{9} = 18$$
$$LCL = \bar{C} - 3\sqrt{\bar{C}} = 9 - 3 \times \sqrt{9} = 0$$

Three samples 4, 5, 15 are outside the limits, the process is not under statistical control.

**Que 3.28. What are α and β in relation to type I and type II error?**

**UPTU 2011-12, Marks 05**

**Answer**

1. Type I error also designated as α, arise when we reject a true null hypothesis. It occurs because we conclude an outcome based on points that do not exist.
2. Type II error also designated as β, arises when we fail to reject a false null hypothesis. It occurs because we are not able to recognise some of the fallacy present in the system.

| | True null hypothesis | False null hypothesis |
|---|---|---|
| Reject | Type I error ($\alpha$) | Correct ($1 - \alpha$) |
| Fail to reject | Correct ($1 - \beta$) | Type II error ($\beta$) |

4

UNIT

# Defects Diagnosis and Prevention

## PART-1

*Defect Study, Identification and Analysis of Defects, Corrective Measure, Factors Affecting Reliability, MTTF and Calculation of Reliability*

### CONCEPT OUTLINE : PART-1

**Types of Defect :**

1. Sporadic, and
2. Chronic.

**Causes of Defects :**

1. Design and specification,
2. Materials,
3. Machinery and equipment,
4. Operating and supervisory staff, and
5. Process control and inspection.

**Reliability :** The reliability of a product is the probability of performing its intended function over its specified life.

$$R(t) = \frac{N - n}{N}$$

**Factors Affecting Reliability :**

1. Complexity of product,
2. Manufacturing process,
3. Operation and maintenance,
4. Component reliability,
5. Environment conditions, and
6. Reliability and failure of a product.

$$\text{Rate of failure} = \frac{\text{Number of items which failed}}{\text{Total test hours of all items}}$$

### Questions-Answers

**Long Answer Type and Medium Answer Type Questions**

**Que 4.1. Explain which defects should be investigated and the measures to control these defects.**

**Answer**

**A. Defects :**

1. Some of the most taxing quality problems are those which are connected with defect investigation.

2. In spite of meticulous planning and proper process controls, certain defects may still be revealed during assembly or in final inspection.
3. A quality enthusiast may say that every single defect must be investigated to assure defect free production.
4. Unfortunately, this may not be practicable nor economically desirable.
5. The defects may be broadly grouped into two classes, namely, sporadic and chronic.
6. A sporadic defect generally signifies that some new factor has entered into the process, and unless the factor is identified and eliminated, the process will remain out of control.
7. Therefore, such defects have to be investigated on priority.
8. On the other hand, chronic defects are the various types of defects which have been occurring in a certain percentage of the product, due to unknown causes.
9. As these defects also cause losses to the company, their incidence has to be minimised, where possible.
10. Generally, chronic defects comprise a large number of different types of defects of varying magnitude.
11. Since all of these cannot be taken up for investigation simultaneously, it is advisable to concentrate on the 'vital few' rather than the 'trivial many'.
12. To identify the 'vital few' the resultant losses due to different defects may be evaluated.
13. The defects showing highest losses merit first attention.
14. There may be certain defects which result in serious failures of equipment in service.
15. Though direct losses (such as warranty claims) due to these defects may not be appreciable, the loss in customer goodwill may be considerable.
16. Therefore, the quality manager should be on the alert for such defects which will not figure as major defects in a purely financial analysis.

**B. Control of Defects :**

**a. Management Approval :**

1. Having identified the major defects which merit investigation, the quality manager should then make an assessment of time, resources and cost required for the investigation for each defect.
2. The cost of the study should be compared with the expected saving due to the elimination of defects.

**b. Defining Responsibility :**

1. A defect study requires proper planning and organization to be fruitful.
2. The objective and responsibility should be clearly defined.
3. The task is generally entrusted to a team rather than an individual.

4. For proper direction and coordination a study coordinator is also named.

**c. Conduct of Defect Study :**

1. Once the study team is formed and the objective of the study has been explained to them the first question which arises is how to go about it and where to start ?
2. The general approach to the organised study of defects in different products and processes is more or less the same.

**Que 4.2. Explain the identification of defective component and analysis of process.** **UPTU 2013-14, Marks 10**

**OR**

**Summarize the challenges in identification of the defects.** **UPTU 2014-15, Marks 05**

**OR**

**Explain a cause and effect (Ishikawa) diagram to identify a process defect.** **UPTU 2013-14, Marks 10**

**Answer**

**A. Identification of Defective Component :**

1. In the initial stages, a defect is generally referred to, by its apparent departure from the specified quality standard.
2. In complex equipment or a product, the defective system or process stage has to be identified before the basic cause can be found.
3. For instance, if an engine gives less power when checked at the test bench, the defect will be referred to as 'insufficient power'.
4. Insufficient power may be caused by the malfunctioning of any of the following units :
   a. Cylinder and piston unit,
   b. Fuel system,
   c. Ignition system, and
   d. Clutch assembly.
5. The assemblies or the system may be replaced one by one until the defect is removed, which will reveal the defective system.
6. Once the defective system has been identified, the same process of analysis and elimination may be followed further, until the ultimate defective component is identified.

**B. Analysis Process :**

1. Having identified the defect-causing process, the next step is to pinpoint the basic cause to which the defect can be attributed.

2. For this, the process has to be analysed to consider all variable factors which could have caused the defect.
3. For a component having only a few quality characteristics, it may be easy to examine the various features and arrive at the feature / features responsible for causing the defect.
4. Prof. Kaoru Ishikawa of Japan has developed a cause and effect diagram depicting the variables to facilitate the analysis of an electroplating process.

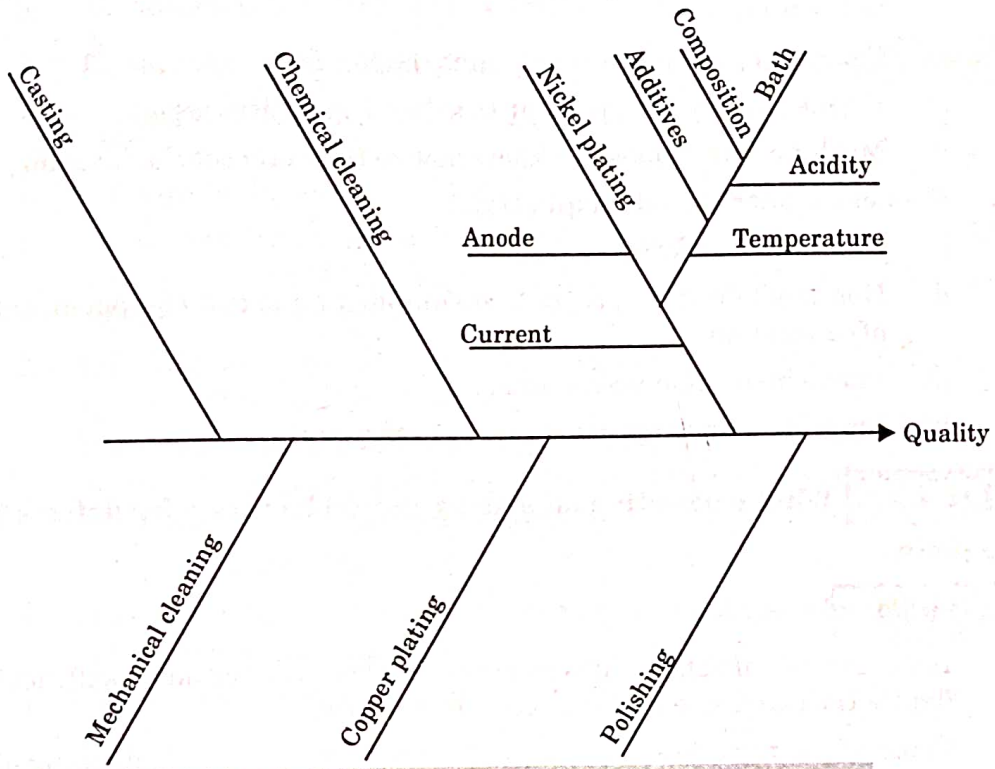



**Fig. 4.2.1.** Ishikawa diagram of nickel plated components.

5. During the analysis, the investigators should be looked on :

**a. Design and Specification :**

i. Vague or insufficient manufacturing particulars or illegible drawing prints.

ii. Impracticable design component and assembly tolerance.

iii. Obsolete drawing being used.

**b. Machinery and Equipment :**

i. Inadequate process capability and incorrectly designed tooling.

ii. Non-availability of gauges and worn tool jigs.

iii. Poor maintenance of machines and equipment affected by the environmental conditions.

c. **Materials :**

i. Use of untested materials and mix up of materials.

ii. Substandard material accepted on concession because of non availability of correct material.

d. **Operating and Supervisory Staff :**

i. Operator does not possess adequate skills for operating the process equipment.

ii. Operator does not understand the manufacturing drawing related to the process.

iii. Careless operator and inadequate supervision.

iv. Undue rush by the operator to achieve quantity targets.

v. Machine setter does not know how to correctly set the machine.

5. **Process Control and Inspection :**

i. Inadequate process controls.

ii. Non-availability of proper test equipment and test equipment out of calibration.

iii. Vague inspection instructions.

iv. Inspectors do not possess the necessary skill.

**Que 4.3.** **What corrective measures should be taken for defects ? Explain**

**Answer**

1. If the analysis of defect causing process has been carried out in sufficient depth, the cause itself will suggest the remedy.
2. Some of the remedies, such as replacement of an obsolete drawing of equipment may be quite simple and can straightway be applied.
3. For instance, if it is found that the process capability of the machine is such that it is unable to hold the specified tolerance, it may not be easy to replace the machine.
4. For this certain measures should be considered :
   a. Alternative method of manufacture.
   b. Selective assembly.
   c. 100 % inspection of the affected component before assembly to screen the defective components.
   d. Redesign the component to provide for wider tolerances.
5. During this stage, consultation with all the concerned departments will also be required to obtain their views on the various possible methods of avoiding defects.

6. The actual decision on the remedial measures to be adopted will depend upon the practicability and economics of various alternatives.
7. The process of the adjustment of remedial measures and study of their effect must be continued until the objectives of the study have been fully achieved.

**Que 4.4. Explain :**

**a. Fault isolation and self diagnostics,**
**b. Parts standardization and interchangeability,**
**c. Modularization and accessibility, and**
**d. Repair and / or replacement.** **UPTU 2011-12, Marks 10**

**Answer**

**a. i. Fault Isolation :**

1. Fault isolation is the practice of designing systems such that when "something bad" happens, the negative consequences are limited in scope.
2. Limiting the scope of problems reduces the potential for damage and makes systems easier to maintain.
3. The typical method of fault isolation is to create boundaries between system components, and ensure that the effects of faults do not cross the boundaries or that they are limited.

**ii. Self Diagnostics :**

1. It is a term that is used when the system itself gives an indication of presence of some fault in it.
2. This feature is infused into the component during their designing process and the criticality of use of this component matters.

**b. Parts Standardization and Interchangeability :**

1. It is very important for industries to practice standardization so that lesser number of pieces is rejected as defective, by the use of standard set of specification, material and process one ensures better quality control.
2. Globally there are certain rules and marks to achieve this standardization policy.
3. Tolerances and fits are associated with each precision part when being manufactured in bulk so as to have proper interchangeability.
4. Generally there are following types of fits :
   i. Interference fit,
   ii. Clearance fit, and
   iii. Transition fit.

**c. Modularization and Accessibility :**

1. The standard norms that are to be followed when a defect is diagnosed are referred as modularization.
2. It decides the further set of action and prevents the system from going into a state of complete breakdown.
3. The location of a fault in a system is essential for the speedily repair of parts, this is referred as accessibility.

**d. Repair and / or Replacement :**

1. Once the fault has been located, repair or replacement of the defective component has to be carried out to make the equipment fit for normal operation.
2. Here again, the designer can facilitate the task of the maintenance engineer by adjusting the design.

**Que 4.5. Define "reliability" and factors affecting it.**

**UPTU 2012-13, Marks 02**

**Answer**

**A. Reliability :**

1. Reliability is a characteristic which refers to the ability of a product to perform its intended function when required to do so.
2. If equipment works satisfactorily whenever it is operated, we say that it is a reliable equipment.
3. While considering reliability, it must be appreciated that no machine or equipment, however, well designed and manufactured, can continue to function satisfactorily for an indefinite period.
4. In practice, in majority of the cases, it may not be possible to test each and every product for its life or other performance requirements.
5. In view of the existence of this variation, there would always be a chance that the product would function in the intended manner for the intended length of time.
6. Reliability is the probability of a product functioning in the intended manner over its intended life under the environmental conditions encountered.
7. The reliability of a system or device is the probability that it will give satisfactory performance for a specified period of time under specified conditions.
8. Reliability can be calculated as :

$$R(t) = \frac{N - n}{N}$$

where $N$ = Number of articles, and

$n$ = Number of failed articles.

**B. Basic Elements of Reliability :**

1. Numerical value of probability.
2. Statement of defining successful product performance.
3. Statement of defining the environment in which the equipment must operate.
4. Statement of the required operating time.
5. The type of distribution likely to be encountered in reliability measurement.

**C. Factors Affecting Reliability :**

**a. Complexity of a Product :**

1. Simple products are always much more reliable than complex ones.
2. The reason is that greater the numbers of components along with their linking mechanisms, the more are the chances that one of them will fail, thereby preventing the product from performing its intended function.
3. As the number of components increases the reliability of the total system decreases in geometric progression.

**b. Component Reliability :**

1. It is said that the strength of a chain is actually the strength of its weakest link.
2. The same is for the system which is governed by the reliability of the components.
3. Even one small component of poor quality getting into the assembly, can have a disproportionately adverse effect on the overall reliability to the equipment.

**c. Manufacturing Process :**

1. Reliability of a product is determined by its design, the extent to which it is actually achieved depends upon the process of manufacturing.
2. A product with a high designed reliability may yet have an early failure because of certain factors introduced during its manufacture.

**d. Environmental Conditions :**

1. Every device or mechanism is subjected to certain environmental factors such as temperature, humidity, vibration and shock, may cause rapid deterioration of the product and thereby adversely affect its reliability.
2. Therefore these factors have to be given due consideration during the design of a product to ensure that it can withstand environmental hazards and achieve the required standard of reliability.

**e. Operation and Maintenance :**

1. The way by which machine is operated and maintained also affect the reliability that will be achieved in actual service.

2. Since this factor depends upon the user, the designer of the product does not have much control over it.
3. At best, efforts can be made to educate the user by providing detailed instructions on usage and maintenance.

**Que 4.6. Explain the Mean Time To Failure (*MTTF*).**

**Answer**

1. For one-shot systems such as missiles or other non repairable items such as bulb, fuse etc. It is more appropriate to assess reliability in terms of mean time to failure or probability of survival.
2. *MTTF* is the average time that an item or equipment may be expected to function before failure.
3. $$MTTF = \int_0^\infty tf(t)dt$$
$$= \int_0^\infty t(\lambda e^{-\lambda t})dt = \left[-te^{-\lambda t} - \left\{-\frac{e^{-\lambda t}}{\lambda}\right\}\right]_0^\infty = \frac{1}{\lambda}$$
4. Thus, *MTTF* is the reciprocal of the constant hazard rate.
5. To understand the concept of *MTTF*, let us suppose a device is being subjected to a life test in such a way that every time it fails, it is replaced with a new one.
6. On the other hand, *MTTF* is independent of the life and is better index for the comparison of the reliability of different products.

**Que 4.7. Explain the procedure of calculation of reliability.**

**Answer**

1. A basic measurement of the reliability of a product *i.e.*, its probability of survival is that of mean time between failures.
2. Suppose that $n$ products are taken at random from a large group and $n_t$ of them fail during the time period $t$, then the probability of failure during the period $t$,
$$P_t = \frac{n_t}{n}$$
3. The performance of the product over the intended length of time, say $T$ is,
$$P_t = \sum_{t=0}^{T} \frac{n_t}{n}$$
4. Reliability, $R_T = 1 - \text{Probability of failure}$
$$= 1 - P_t = 1 - \sum_{t=0}^{T} \frac{n_t}{n}$$
5. When a large number of products are tested so that the relative frequency $\frac{n_t}{n}$ becomes a smooth function $f(t)$ of times then reliability,

$$R_T = 1 - \int_0^T f(t)dt$$

6. Probability density function $f(t) = \frac{1}{\theta} e^{-t/\theta}$

where $\theta$ = Mean time between failure.

7. $$R_T = 1 - \int_0^T \frac{1}{\theta} e^{-t/\theta}\, dt$$

$$R_T = e^{-T/\theta}$$

$$\frac{1}{\theta} = \lambda$$

$$R_T = e^{-\lambda T}$$

## PART-2

*Building Reliability in the Product, Evaluation of Reliability, Interpretation of Test Results, Reliability Control, Maintainability, Zero Defects, and Quality Circle.*

### CONCEPT OUTLINE : PART-2

**Rules of Design of Reliability in a Product :**

a. Use as few parts as possible.

b. The reliability of each part should be as high as is economically feasible.

**Maintainability :** It is defined as the probability that a device will be restored to its operational effectiveness within the given period, when maintenance action is performed in accordance with the prescribed procedure.

**Zero Defect :** It is a concept which promotes a constant, conscious desire to do a job right, the first time.

**Quality Circle :** It is a small group of members working together who meet each other voluntarily with a view for analysing and resolving work related problems.

### Questions-Answers

**Long Answer Type and Medium Answer Type Questions**

**Que 4.8.** **Explain how the reliability can be built in the product.**

**Answer**

1. The reliability of a product, like other quality parameters is dictated by the customer's requirements.
2. Unfortunately this aspect is often overlooked during the design stage.
3. The product is generally designed to meet functional requirements and it is hoped that if good quality components are used, the reliability of the product will be automatically ensured.
4. Sometime it is seen that when the final product goes in the hands of users, it is found to have much too high a failure rate, which is not acceptable to the users.
5. It is at this stage that some effort is made to evaluate the reliability of the product and changes are made in the product with a view to improving reliability.
6. If the reliability were properly evaluated at the design stage itself, the design could have been easily adjusted to provide high inherent reliability.

**Que 4.9. Write short note on reliability of components assembled in series and parallel systems.** **UPTU 2013-14, Marks 05**

**Answer**

**A. Reliability of Components in Series :**

1. If the components of an assembly are connected in series the failure of any part causes the failure of the system.
2. In this type of system the reliability of the assembly is given by the product of the reliabilities of the individual components.


**Fig. 4.9.1.** Parts in series.

$$R_s(t) = R_1(t) \times R_2(t) \times R_3(t) \times R_4(t)$$

**B. Reliability of Components in Parallel :**

1. If the components of an assembly are connected in parallel the failure of all parts causes the failure of the system.
2. Reliability of the system,

$$R_s(t) = 1-(1-P_1)(1-P_2)(1-P_3)$$

where $P_i$ = Probability of successful operation.

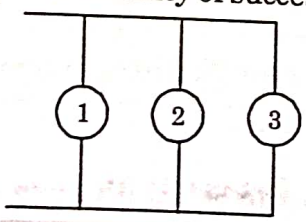



**Fig. 4.9.2.** Parts in parallel.

**Que 4.10. Explain the evaluation of reliability.**

**Answer**

1. Unlike the other quality parameters, the reliability of a product cannot be directly measured.
2. At best, an estimate of the reliability of the product lot can be made by testing a few pieces, as is done in the case of sampling inspection.
3. Reliability testing generally involves running the product units under test for the duration of their expected life.
4. Further, the life of a product may be thousands of hours.
5. To test the product for this duration may be impracticable due to limited time available.
6. This can be overcome by adopting one of the following approaches :

**A. Accelerated Testing :**

1. A device may operate intermittently in actual life.
2. In such cases, care must be taken to see that continuous operation does not lead to undue rise in temperature which may cause premature failure of the device.
3. For this adequate rest periods must be allowed for the device to cool down.

**B. Test of Increased Severity :**

1. Sometimes, it may be possible to carry out the test under more severe conditions than are met in actual service.
2. This may be achieved by increasing the loading or imposing harsher environmental conditions.
3. This approach can only be adopted if a proper correlation has previously been established between the actual observed life and the life under specified severe conditions.

**C. Testing a Larger Number of Pieces :**

1. The failure rate during the useful period of life of a product is generally constant.
2. Instead of testing a few pieces for the entire period of specified life, a larger number can be tested for a comparatively shorter life, until a few failures have occurred.

**Que 4.11. How does interpretation of test result can be done ?**

**Answer**

1. Accuracy of reliability evaluation depends upon our ability to correctly interpret the result of the reliability tests.

2. Suppose one device is tested and it fails before the specified period of life.
3. It tells us very little. We do not know whether the life given by the device is typical of the product in general, or it was an odd bad piece in the lot.
4. We want to test as few pieces as possible.
5. It is therefore essential that the reliability tests are carefully planned to obtain maximum information from the pieces which are tested.
6. The probability of survival of any particular number of product units can be obtained from the binomial expansion as given below :

$$(R+F)^n = R^n + \frac{n}{1}R^{n-1}F + \frac{n(n-1)R^{n-2}}{1\times 2}F^2 + \frac{n(n-1)(n-2)}{1\times 2\times 3}R^{n-3}F^3 \ldots + F^n$$

where $R$ = Reliability of the product.
$F$ = Probability of failure which is equal to $(1-R)$.
$n$ = Number of units tested.

7. In the above expansion, the first term gives the probability of all units surviving *i.e.*, zero failure.
8. The second, third and subsequent terms give the probability of 1, 2 and more failures respectively.
9. For example, if 10 units of a product having a reliability of 0.9 are being tested, the probability of getting various number of failure are shown in table 4.11.1.

**Table 4.11.1.**

| Number of Failures | Probability |
|---|---|
| 0 | $R^n = 0.9^{10} = 0.35$ |
| 1 | $\frac{n\,R^{n-1}}{1}F = 10(0.9)^9 \times (0.1)^1 = 0.39$ |
| 2 | $\frac{n(n-1)R^{n-2}}{1\times 2}F^2 = \frac{10\times 9}{2}(0.9)^8 \times (0.1)^2 = 0.19$ |
| 3 | $\frac{n(n-1)(n-2)R^{n-3}}{1\times 2\times 3}F^3 = \frac{10\times 9\times 8}{2\times 3}(0.9)^7 (0.1)^3 = 0.06$ |

**Que 4.12.** **Define "reliability" and factors affecting it. Explain the procedure of calculation of reliability. Explain how the reliability can be built in the product. How reliability can be controlled during manufacturing ?** **UPTU 2015-16, Marks 15**

**Answer**

A. **Reliability and Factors Affecting it :** Refer Q. 4.5, Page 92E, Unit-4.

B. **Calculation of Reliability :** Refer Q. 4.7, Page 94E, Unit-4.

C. **How reliability can be built in the product :** Refer Q. 4.8, Page 95E, Unit-4.

D. **Reliability Control during Manufacturing :**

1. Reliability is actually built into the product during its manufacturing.
2. The extent to which the inherent reliability of the design is achieved depends upon the care taken during the processing of the product.
3. However, certain minor features such as tool marks, radii at the change of sections are likely to be overlooked during processing, being unimportant, may have a marked influence on the reliability of the end product.
4. Therefore, special checks and controls must be instituted to watch this aspect for products where a high degree of reliability is required.
5. The management of reliability is of relatively recent origin.
6. Sufficient data on failure mechanisms is not available as the detailed effects of various contributory factors have not yet been studied.
7. Under these circumstances, it is possible that some of quality characteristics affecting reliability may be overlooked during manufacturing.
8. To guard against such a possibility it is advisable that a certain percentage of the finished product is specifically tested for reliability, so that any flaw or weakness observed in the manufacturing process can be rectified by suitable corrective action.

**Que 4.13. Write short notes on the following :**

a. **Maintainability,**
b. ***MTBF*,**
c. ***MTTR*,**
d. **Maintenance action rate,**
e. **Availability,**
f. ***FMECA*, and**
g. **Linear hazard model.**
h. ***FMES*.**

**Answer**

a. **Maintainability :**

1. Maintainability is defined as the probability that a device will be restored to its operational effectiveness within the given period, when maintenance action is performed in accordance with the prescribed procedure.

2. The maintainability is related to the given maintenance time, if the given maintenance time is increased the probability of its being restored to normal function will increase.
3. Since the maintenance time is an important constraint of maintainability.
4. When a new system is designed, the designer has practically no means of predicting the frequency and nature of repairs, which will be required for the equipment.
5. This problem will generally be known only after the equipment has been in service for a certain period.
6. Therefore the special efforts are required to be made by the quality engineers to collect the repair data.
7. The repair data so obtained could then be used to provide innovations for improving maintainability of the equipment.
8. Maintainability, like other quality parameters, is primarily built into the design of the product.
9. The main factors which affect maintainability are ease of fault location and ease of repair.

**b.** ***MTBF*:**

1. Mean time between failures is the mean time between successive failures of a product.
2. This definition assumes that the product can be repaired and placed back in operation after each failure.

$$MTBF = \frac{1}{\lambda} = \frac{\text{Total test time}}{\text{Number of failures during test}}$$

**c.** ***MTTR*:**

1. Mean time to repair is the arithmetic mean of the time required to perform maintenance action.
2. $$MTTR = \frac{\text{Total maintenance time}}{\text{Number of maintenance action}}$$

**d. Maintenance Action Rate (μ) :**

1. It is a numerical value representing the number of maintenance action that can be carried out on particular equipment per hour.
2. $$\mu = \frac{1}{MTTR}$$

**e. Availability :**

1. Time availability is the percentage of operating time that an equipment is operational.

$$P_A = \frac{MTBF}{MTBF + MTTR}$$

2. Equipment availability is the percentage of equipments which will be available for use after $t$ hours of operation.

3. Mission availability is the percentage of time $t$ which will have any failure which can not be restored within a specified maximum down time.

**f. *FMECA* :**

1. Failure mode, effect and criticality analysis can be explained as a group of activities intended to :
   i. Recognize and evaluate the potential failure of a product or process and its effects.
   ii. Identify actions that could eliminate or reduce the chance of potential failures.
   iii. Document the process.
2. For each potential failure, an estimate of its effect on the total system and its seriousness is made.
3. A review of the action being taken is also made to minimize the probability of failure.
4. Following are the types of *FMECA* :
   i. Design *FMECA*,
   ii. Process *FMECA*,
   iii. Equipment *FMECA*,
   iv. Maintenance *FMECA*, and
   v. Service *FMECA*.

**g. Linear Hazard Model :**

1. Many components that are under mechanical stresses, fail due to wear out or deterioration.
2. The hazard rate of such components increases with time.
3. The linear-hazard model is the simplest time dependent model and is of the form

$$h(t) = bt, t > 0$$

$$R(t) = \exp\left[-\int_0^{\infty} btdt\right] = \exp\left(-\frac{bt^2}{2}\right)$$

$$f(t) = bt \exp\left(\frac{-bt^2}{2}\right)$$

**h. *FMES* :**

1. It is a grouping of single failure modes which produce the same failure effect (*i.e.*, each unique failure effect has a separate grouping of single failure modes).
2. An *FMES* can be compiled from the aircraft manufacture's, system integrator's or equipment supplier's *FMEA*s.
3. An *FMES* should be coordinate with the user to adequately address the need for inputs to higher level *FMEA*s and/or system safety assessment *FTA*s.

**Que 4.14.** **A component has the following linear hazard rate, where $t$ is in years :**

$$\lambda(t) = 0.4\,t,\ t \geq 0$$

**a. Find $R(t)$ and determine the probability of component failing within the first month of its operation.**

**b. What is design life if a reliability of 0.95 is desired ?**

**UPTU 2011-12, Marks 10**

**Answer**

1. **Given :**

$$\lambda(t) = 0.4\,t,\ t \geq 0$$

a. 1.
$$R(t) = \exp\left(\frac{-bt^2}{2}\right)$$

here $b = 0.4,\ t = 1/12$

$$R(t) = \exp\left[\frac{-0.4(1/12)^2}{2}\right] = \exp\left(\frac{-0.2}{144}\right)$$

$$= 0.9986$$

2. Probability of the component failing in the first month

$$= 1 - R(t)$$

$$= 0.0014$$

**b. Given :** $R(t) = 0.95$

$$\Rightarrow \quad 0.95 = \exp\left(\frac{-0.4t^2}{2}\right)$$

$$\Rightarrow \quad 0.95 = \exp(-0.2t^2)$$

$$\Rightarrow \quad \log 0.95 = -0.2t^2$$

$$\Rightarrow \quad t = 0.506 \text{ years}$$

**Que 4.15.** **The time-to-failure probability density function (PDF) for a system is**

$$f(t) = \exp[-t/8750]/8750 \quad 0 \leq t \leq 100 \text{ days.}$$

**Find :**

**i. Reliability $R(t)$**

**ii. The hazard rate function**

**iii. *MTTF***

**iv. *MTBF*.**

**UPTU 2012-13, Marks 10**

**Answer**

1. **Given :** $f(t) = \exp(-t/8750)/8750\ 0 \leq t \leq 100$

2. Since, $F(t) = \int_0^T f(t)\,dt$

$$= \int_0^{100} \frac{1}{8750} \exp(-t/8750)\, dt$$

$$= 0.01136$$

i. Reliability,

$$R(t) = 1 - F(t)$$

$$= 1 - 0.1136 = 0.99864$$

ii. The hazard rate function;

$$\lambda(t) = f(t) / R(t)$$

$$\lambda(t) = \left(\frac{1}{8750} \exp(-t/8750)\right) / \exp(-t/8750)$$

$$= \frac{1}{8750}$$

iii. *MTTF,*

$$\mu = \frac{1}{\lambda(t)} = \frac{1}{1/8750} = 8750$$

iv. *MTBF,*

$$\theta = \int_0^{\infty} t\, f(t)\, dt$$

$$= \int_0^{\infty} \frac{t}{8750} \exp[-t/8750]\, dt$$

**Que 4.16. Explain the zero defects and its organization programme.**

**Answer**

1. According to its originator James F. Halpin, zero defects is a concept which "promotes a constant, conscious desire to do a job right the first time".
2. It is essentially a management technique in which job is presented as a challenge to the individual worker.
3. The successful execution of the zero defects programme requires careful preparation and an efficient organization.
4. Since it is an across the company programme, it will embrace all departments and all levels right from the chief executive to the shop floor worker.
5. The programme essentially involves :

**A. Motivation of Management :**

1. Before the motivation of the workers, it is essential to motivate the managers.
2. Unless managers have faith in the zero defects programme and they give their whole hearted cooperation, the programme just can not succeed.
3. There should be a relaxed atmosphere in which there is a genuine discussion on the merits of the programme.
4. At no stage should the impression be given that this programme is being thrust on them.
5. They should be made to feel that it is their own programme from which they and their departments will benefit.

**B. Indoctrination of Supervisors and Workers :**

1. Once the programme has been sold to managers, the indoctrination and motivation campaign should be beamed at the shop floor staff and workers.
2. In this phase efforts should be made to develop quality awareness by educating them on the company's products, their uses, the result of defects on the product performance and the customers.
3. The indoctrination campaign would require the use of posters, brochures, informal shop discussions, rallies etc.

**C. Management Action in Removing Impediments to Quality :**

1. Workers can be asked to produce defect free jobs only when management has done everything to eliminate the causes of error, which are controlled by them.
2. For this purpose a formalised technique called error cause removal has been developed in general electric which was effectively used by them in their zero defect programme.

**D. Error Cause Removal :**

1. This is a technique where by the actual or potential causes of error are identified by the workers and reported to the management so that it can take action for their elimination.
2. To facilitate reporting of causes, standardised forms are printed, which normally have three parts.
3. The workers fill in part I of the form giving in brief the cause of errors and suggestions.
4. Once the supervisor is satisfied, he signs the III part.
5. The action taken is entered in part II of the form and the worker is informed about it.

**E. Laying Down Targets :**

1. Generating quality awareness is not an end in itself.
2. This requires laying down individual and group quality targets in specific terms which can be presented to them as a challenge.

3. The targets should be carefully selected.
4. The revision of quality targets normally in the upward direction the ultimate aim being a zero defect product.

**F. Measurement of Results :**

1. Once the targets have been laid down and presented as a challenge to the operatives the need of measurement of results is obvious.
2. A good feature of the zero defects programme is that if the workers have been properly motivated, they themselves will be keen for the measurement of the results of their efforts.
3. It is positive approach which is partly responsible for the success of zero defect programme.

**G. Recognition of Achievers :**

1. Recognition, to be meaningful, should be selective.
2. A part on the back of every employee who participated in the programme would lower the esteem of recognition and it would no longer remain something special worth striving for. The fact of his achievement should be well publicised which will serve as a morale booster for the achiever and an inspiration for the others.

**Que 4.17. What are the key concept that must be followed as a part of design activity that supports the reduction in repair time to increase maintainability ?** **UPTU 2012-13, Marks 10**

**Answer**

1. Maintainability, like other quality parameters is primarily built into the design of the product.
2. The main factors which affect maintainability are ease of fault location and ease of repair.

**A. Fault Location :**

1. The location of a fault in a system is essential before it can be repaired.
2. Fault location can be made easier if this aspect is given due consideration during the design of the system.
3. Some of the measures which can facilitate the location of faults are given below :
   a. Meters or lights can be provided on the instrument panels, which indicate that a particular system or sub-system has failed.
   b. Where feasible, viewing windows or detachable cover should be provided, through which the functioning of the mechanism can be seen.
   c. In electronic equipment, as far as possible, test points should be provided in important stages, where the functioning of sub system can be checked by means of test equipment.

d. For particularly fault-prone units in a system, alternative units should be provided, which can be quickly brought into the circuit to check whether the subject units are faulty.

e. A proper colour or number code should be adopted for the wiring in the electronic equipment. This will enable easy tracing of circuits.

f. Special test equipment, where required, should be designed to enable quick location of faults in the system.

g. Well illustrated instruction manuals should be prepared, in which various fault location drills are properly explained.

**B. Repair of Equipment :**

1. Once the fault has been located, repair or replacement of the defective component of assembly has to be carried out to make the equipment fit for normal operation.

2. Here again, the designer can facilitate the task of the maintenance engineer by suitably adjusting the design.

3. Some of the points which should be considered during design, are as follows :

a. The parts can be speedily repaired only if they are easily accessible. In order to make a system compact, there will be a great temptation to cram the parts together. However, a thought must be given to the difficulty which may be faced while replacing the parts when they become defective. If a mechanic has to remove a number of assemblies to get at the defective part, the repair time would needlessly be increased. Therefore, the parts and assemblies should be laid out in such a manner that they are readily accessible. Where the parts are masked by shields or covers, detachable window plate may be provided to facilitate access.

b. Fixing and coupling devices of assemblies or units of the system should be such that they are not jammed due to corrosion or other chemical action.

c. Bolts, nut and other fastening devices should not be fitted in such places where these are likely to fall into the system during their removal.

d. Electronic systems, as far as possible, should comprise of separate units or modules which can quickly be plugged in or removed.

e. Special maintenance and repair tools should be designed where required, and detailed repair manuals should be provided to facilitate repairs.

f. System should be so designed that preventive maintenance can be easily carried out.

**Que 4.18. Explain Quality circle and objectives.**

**Answer**

1. Quality circle is a small group of members working together who meet each other voluntarily with a view to analyse and resolve work related problems.
2. The meetings are informal in nature but held regularly.
3. The group consists of 7 to 10 members, who meet each other at least once a week for one hour.
4. At the meetings, they speak only about their work and problems pertaining to it.
5. The whole organisation is voluntary by nature, nevertheless all the members are slightly motivated in their work.
6. This has the following elements :
   a. Top management,
   b. Steering committee,
   c. Coordinator,
   d. Facilitators,
   e. Leaders, and
   f. Members.

**A. Objectives :**

1. To improve quality and productivity of the products.
2. To promote consciousness among workers about quality, safety and cost of production.
3. To give opportunity to the employees to learn new techniques of identifying technical problems in the area of their production thereby improving their knowledge.
4. Giving job satisfaction and improving employee motivation.
5. To inspire more effective team work and develop leadership among some employees who have potential and also improve communications.
6. To develop a complete coherent problem solving methodology within the organization.

**Que 4.19. Explain the functioning of quality circles ?**

**Answer**

1. The members of a particular circle come from the same work area, so that the problems they select are familiar to all of them and it is easy to find solutions with their experience and knowledge.
2. An ideal size of a circle is 5 to 10 members. The size must never be so large that each member does not get sufficient time to participate and contribute in the meeting.

3. The number of circles in given work area may be more than one, to avoid duplication of activities in the same work area, good coordination should be maintained between the leaders of these circles and the facilitator.
4. As a thumb rule, the meeting should take place once a week and each meeting should be for approximately one hour.

**Que 2.20. Explain about top management and steering committee.**

**Answer**

**A. Top Management :**

1. The executives at the highest level who extend all the necessary support to the activity of the quality circles and through their personal presence at the presentations and other major quality circle activities make their support visible to all.

**a. Functions :**

1. Demonstrate unequivocally its understanding and faith in the concept of quality circles.
2. Make provision in the annual budget for meeting the expenditure of operation of quality circle.
3. Give necessary guidance to employees at different levels for making the quality circle movement a self-sustained success.
4. Attend management presentation of various circles.
5. Respond to the circle recommendations without any delays.
6. Periodically review the QC activities on a regular basis.

**B. Steering Committee :**

1. As soon as a decision is made to implement quality circles programme, the steering committee comprising the chief executive, divisional heads of departments and the coordinator is constituted.
2. The chief executive and the coordinator act as chairman and secretary of the steering committee.

**a. Functions :**

1. Establish the programme objectives and resources.
2. Promote quality circles in the organization.
3. Nominate coordinator and facilitators.
4. Develop working methodology and give the guidelines related to quality circle.
5. Provide necessary provisions in the annual budget and grade the project reports of quality circles for awards.

**Que 4.21. Explain coordinator and facilitator.**

**Answer**

**A. Coordinator :**

1. They coordinates the activities of quality circles, throughout the organization and carry out such functions as would make the operation of quality circles smooth, effective and self sustained.

**a. Functions :**

1. Registers quality circles in the division.
2. Convenes steering committee meetings and circulate record notes thereof.
3. Organises systematic documentation of quality circle case studies and publishes their compilation annually.
4. Prepare training material for facilitators and leaders in conjunction with training departments.
5. Exposes all employees at the grass-roots and different levels of executives to the concept of quality circle.

**B. Facilitator :**

1. Facilitator is usually a senior officer of the department where quality circles are working and is nominated by the management.
2. He does not only guide the quality circle activity in his area but also enthuses others to get involved in these activities.

**a. Functions :**

1. Attend quality circle meetings.
2. Coordinate with the training officer for organising necessary training programmes in SQC techniques.
3. Coordinate and obtain the support and assistance from other functional areas whenever required by the quality circles.
4. Arrange for periodical management presentations and to schedule meetings of quality circles.
5. Communicate the steering committee decisions regarding the implementation of recommendations submitted by quality circles.
6. Strengthen and promote participative culture within the organization.

**Que 4.22. Explain the role of leader and member in QC.**

**Answer**

**A. Leader :**

1. Leader is chosen by the members of a quality circle among themselves.
2. The deputy leader may also be chosen by the quality circle so as to ensure that circle meetings and other activities would go on uninterruptedly even if the leader is not present.

**a. Functions :**

1. Maintain registers regarding the proceedings of the circle meetings, problem selections etc.
2. Maintain a high degree of cohesiveness of his team with a sense of identity.
3. Set circle goals and improve performance towards the same.
4. Prepare the project report and present to the departmental heads and steering committee.
5. Interact with other functional areas in problem solving.
6. Catalyze non members to join existing circles.

**B. Members :**

1. Members are the basic element of the structure of QC.
2. The members should contribute actively to the effective functioning of their QC, aiming at better performance of their work area in every way on an ongoing basis.

**a. Functions :**

1. Meet regularly and actively participate in quality circle meeting and contribute ideas for problem solving.
2. Catalyze generation of cohesive team working in work area.
3. Strive for the highest standards of performance of the circle.
4. Involve in the improvement of the total performance of the organization.
5. Take part in the mid-term and top management presentations.

**Que 4.23. Explain the necessity of training for quality circle activities.**

**Answer**

1. For successful implementation of quality circles, it is essential that the concepts, methods and techniques are understood thoroughly.
2. Appropriate training for different sections of employees needs to be imparted.
3. It is the training that keeps the programme moving steadily towards the goal of a more effective and productive organization.
4. Such training comprises of :
   a. Brief orientation programme for top management for explaining philosophy of QC and role of management.
   b. Programme for middle level executives in the concepts, operations and support to be provided to circles.

c. Training of facilitators to involve them as teacher, promoter, catalyst and guide for the efficient functioning of QCs.

d. Training for circle leaders and members of team.

5. Along with the above aspects of QC concepts and methodology, simple problem solving techniques are covered in the training programmes.

6. The circle members should learn how to function effectively in a group, to apply statistical methods to problems and issues in their work, identify and analyse problems, gather data and to present their findings.

**Que 4.24. Write down the advantages and limitations of quality circles.**

**Answer**

**A. Advantages :**

1. Promote high level of productivity and quality mindedness.
2. Self and mutual development of employees.
3. Creating team spirit and unit of action.
4. Increased motivation, job satisfaction and pride in their work.
5. Waste and cost reduction.
6. Improved communication and safety.
7. Enhancement in consciousness and morale of employees through recognition of their activity.
8. Increased utilization of human resource potential.
9. Leadership development and trained staff.
10. Identifies work related problems and solves them effectively.

**B. Limitations :**

1. The overall productivity may decrease initially as the members turn from their daily work to the task of organising themselves and undergoing training.
2. A large investment of time and money is required for a concept that is essentially new and unproven in the organisation's context.
3. The chances of errors increase initially. Mistakes are inevitable as employees adjust to a new way of doing things.
4. Over-expectation of some employees who are too excited initially may turn to disappointment and drop out.
5. After circle implementation a period of confusion may arise. This is because people experiment with new ideas, new skills and new roles.
6. Changes in system and control may become necessary.

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# UNIT 5

# ISO-9000 and its Concept of Quality Management

## PART-1

*Standardization, Taguchi method, ISO-9000, JIT.*

## CONCEPT OUTLINE : PART-1

**Standardization :** It is temporary crystallization of the best acceptable solution to a recurring problem, formulated in a scientific and systematic fashion by pooling the knowledge of all those who are concerned with the problem and is subjected to review and revision by common consent, and one should comply to it.

**Types of Standardization :**

a. Multi tier standardization system,

b. Company / In-plant standards,

c. National standards e.g. BIS,

d. International standards e.g. ISO, and

e. Regional standards e.g. Euro-Norms.

**ISO-9000 :** Standardization in order to meet the requirements of internationally accepted quality system.

**ISO-9001 :** Model for quality assurance in design/development, production, installation and servicing.

**ISO-9002 :** Model for quality assurance in production and installation.

**ISO-9003 :** Model for quality assurance in final inspection and test.

**ISO-9004 :** Quality system and management element guidelines.

**JIT :** The objective of just in time method is to increase the inventory turnover and sometimes to reduce the inventory holding cost.

## Questions-Answers

### Long Answer Type and Medium Answer Type Questions

**Que 5.1. What is need for quality system ?**

**Answer**

1. To ensure the quality, it is necessary to make systematic controls at every stage and also take critical review of efforts and achievements of the company with respect to quality of the product.
2. For making systematic controls, cooperation of every employee is needed, since quality depends on every person working in the organization.

3. Every employee's involvement is most important in understanding the problems, finding solutions and implementing them. All these actions would lead to maintain and improve quality and reliability of the product.
4. The manufacturer can assure the quality of the product and can guarantee its performance with full confidence.
5. Sound quality assurance of the system helps to maintain the quality of the products and hence the reputation of the firm and better customer relations.
6. Hence, efforts are directed towards developing standards on quality system.

**Que 5.2. Explain the need for standardization ?**

**Answer**

1. Sound quality assurance system makes it essential for the industries to maintain uniform quality system standards.
2. Company standardization is now an important effective management tool for improving quality and productivity.
3. Quality and standardization are the two essential pre-requisites for a company, to market its products and services in the competitive business environment.
4. Quality thus begins with standards. Quality encompasses safety, reliability, durability, performance and acceptability of products by consumers.
5. Hence, quality needs are to be built in the product during research, design, development and production and in fact the foundation on which quality is built is the standards.

**Que 5.3. Explain continuous improvement and innovation.**

**UPTU 2011-12, Marks 04**

**Answer**

**A. Continuous Improvement :**

1. Quality based organizations should strive to achieve perfection by continuously improving the business and production processes.
2. Of course, perfection is impossible because the race is never over; however, we must continually strive for its attainment.
3. Improvement is made by
   a. Viewing all work as a process, whether it is associated with production or business activities.
   b. Making all processes effective, efficient, and adaptable.
   c. Anticipating changing customer needs.

d. Controlling in-process performance using measures such as scrap reduction, cycle time, control charts, and so forth.

e. Maintaining constructive dissatisfaction with the present level of performance.

f. Eliminating waste and rework wherever it occurs.

g. Investigating activities that do not add value to the product or service, with the aim of eliminating those activities.

h. Eliminating nonconformities in all phases of everyone's work, even if the increment of improvement is small.

i. Using benchmarking to improve competitive advantage.

j. Innovating to achieve breakthroughs.

k. Incorporating lessons learned into future activities.

l. Using technical tools such as statistical process control (SPC), experimental design, benchmarking quality function deployment (QFD), and so forth.

4. Continuous process improvement is designed to utilize the resources of the organization to achieve a quality driven culture.
5. Individuals must think, act, and speak quality.
6. An organization attempts to reach a single minded link between quality and work execution by educating its constituent to "continuously" analyze and improve their own work, the processes, and their work group.

**B. Innovation :**

1. Innovation in values a drastic improvement in the states of current method as a result of large investment in new technology and equipment.
2. The companies which do nothing for innovation can't face the market war.
3. The western companies worship at the altar of innovation, which is the main reason of their success.
4. Innovation brings major changes in the wake of technological breakthroughs or the introduction of the latest management concepts or production techniques.
5. It is a one shot phenomenon but results of it are seldom visible immediately.
6. The use of CAD, CAM and MRP techniques in production is an innovative idea, if it is not in use at the present time production method.

**Que 5.4. What do you mean by empowerment ? How does job enlargement and job enrichment improves quality ?**

**UPTU 2011-12, Marks 04**

**Answer**

1. By empowerment we mean that more responsibility for quality should be assigned to the production staff, as we know effective quality management require a proper organizational framework through which quality programmes are implemented.
2. The contribution of individuals to the quality of products is influenced by the following personnel factors :

a. **Quality mindedness :** This reflects an individual's mental attitude towards quality.This factor is applicable at all levels from executives to operators.

b. Knowledge of quality and its control.

c. **Quality Skills :** These represent the expertise of an operator or a tradesman in performing jobs essential to the quality of a product.

3. It helps in improving quality as the management is able to influence its workers and establish good quality culture, where the workers take pride in their job and strive for work excellence.
4. Some other reasons are as following :
   a. It improves employee motivation.
   b. Quality training enhances skills and other related attributes of the workers.
   c. It inspires more effective team work and develops some leadership among some employees who have the potential.
   d. It allows and promotes the employees to solve the problem in their work area, thereby giving job satisfaction.

**Que 5.5. What is ISO-9000 ? Explain its principle, benefits and limitations ?**

**UPTU 2011-12, Marks 06**

**OR**

**What is ISO 9000 ? Explain its salient features.**

**UPTU 2013-14, Marks 10**

**Answer**

1. ISO-9000 is a series of standards on quality system was formulated by international organization for standardization in order to meet the requirements of internationally uniform quality system.
2. The European Nation trade has reached an understanding that the post 1992 trade transaction would be dealt only with those companies who have registered ISO-9000 quality system.
3. The developed countries started producing their own standards for specifying the variety of products of manufacturers.

4. The quality assurance guide published by BSI UK MIL standards in 1972, were introduced in 1974.
5. To meet the growing awareness of quality in the industries BS 5750 standard was developed by BSI in 1979. Further in 1981, the guides were published for the usage of BS 5750.
6. ISO revised and issued BS-5750 in 1987 as ISO-9000 series of standards on quality system.

**A. Principle :**

1. ISO-9000 quality standards stipulate certain management practices as guidelines and minimum requirements for making quality of products and services conforming to the needs of customers.
2. These are developed for facilitating international exchange of goods and services.
3. All these systems are essentially self-disciplined standards based on the principles of harmonization of specification and continuous surveillance of third party.
4. This standard gives guidelines for selection and use of appropriate model.

**B. Benefits :**

1. This enables to meet the requirements of an internationally uniform quality system.
2. It enables the company to build customer confidence that it is capable of delivering the products and services of desired quality.
3. It reduces the need for assessment by multiple buyers. It thus avoids time and money spent on multiple inspections of the products for conformance.
4. If Indian industry adopts this, it would enhance foreign exchange, and compete in the international market.
5. To adopt this, it is necessary to establish and maintain sound quality assurance system. This result in improvement in efficiency and reduction in inspection, scrap and rework.
6. Adoption of this helps to enhance quality image of the company and gives a competitive edge over the other companies which do not have this quality system.
7. Motivates the employees and develops pride in them for achieving excellence.

**C. Limitations :**

1. The implementation of this series of standards is very much demanding on resources. The formulating and documenting of the system is time consuming and expensive.
2. Assessment and registration are also expensive.
3. Unless carefully interpreted and planned, the system can become burdensome and expensive, quite often impending normal operations.

4. The need to change attitudes and accept new working practice may strain the management capability of the company beyond its ability to cope.

**Que 5.6. Write about ISO-9001 and its elements.**

**Answer**

1. A product or a service has to pass through several stages after it is conceived and before it is supplied to the customer. Even after it is supplied to the user, a necessity may arise to keep a follow up action, so that the user does not face any problem in using the product.
2. ISO-9001 standard gives a model for quality assurance at all stages starting from designing the product and continuing even after the product is delivered to the customer.
3. This applies to industries that design, produce, install product and provide service after sales as per the requirements of the customer.
4. In these cases the customer states his application and the supplier works out the final design, makes changes if required.
5. A set of specifications is then prepared. The manufacturer has to open his manufacturing stages to the customer so as to enable the customer to judge the supplier's capability of manufacturing the product as per his requirements.
6. After the product is manufactured and inspected for conformance with specifications it should be installed by the supplier at the customer's premises and a trial run should be conducted. Even after installation, the supplier has to provide necessary services for maintenance of equipment for trouble free performance.

**A. Elements :**

1. Management responsibility,
2. Control review,
3. Quality system,
4. Design control,
5. Documents control,
6. Purchasing,
7. Purchaser supplied product,
8. Product identification and traceability,
9. Process control,
10. Inspection and testing,
11. Inspection, measuring and test equipment,
12. Inspection and test status,

4. The need to change attitudes and accept new working practice may strain the management capability of the company beyond its ability to cope.

**Que 5.6. Write about ISO-9001 and its elements.**

**Answer**

1. A product or a service has to pass through several stages after it is conceived and before it is supplied to the customer. Even after it is supplied to the user, a necessity may arise to keep a follow up action, so that the user does not face any problem in using the product.
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6. After the product is manufactured and inspected for conformance with specifications it should be installed by the supplier at the customer's premises and a trial run should be conducted. Even after installation, the supplier has to provide necessary services for maintenance of equipment for trouble free performance.

**A. Elements :**

1. Management responsibility,
2. Control review,
3. Quality system,
4. Design control,
5. Documents control,
6. Purchasing,
7. Purchaser supplied product,
8. Product identification and traceability,
9. Process control,
10. Inspection and testing,
11. Inspection, measuring and test equipment,
12. Inspection and test status,

13. Control of non-conforming products,
14. Corrective action,
15. Handling, storage, packaging and delivery,
16. Quality records,
17. Training,
18. Internal quality audit,
19. Statistical techniques,
20. Servicing.

**Que 5.7. Write short notes on the following :**

**A. ISO-9002**
**B. ISO-9003**
**C. ISO-9004**

**Answer**

**A. ISO-9002 :**

1. Some products require quality assurance only during production and till they are delivered to the customer in his premises.
2. It gives a model quality assurance for such products.
3. In such cases the manufacturer gives his own design to meet the customer's requirements and has to only prove the production process is capable of producing the product as per the requirements of the customer and that the supplier can install the product at the customer's premises satisfactorily.
4. Civil structures, construction of bridge etc, are the examples.
5. So, this model is applicable where the assurance on quality is required only during production and upto satisfactory installation.

**B. ISO-9003 :**

1. Certain products require quality assurance only after they are manufactured *i.e.*, at the time of supply.
2. The customer is not concerned with how they are manufactured.He is interested only in getting the product of desired quality as stated by the supplier.
3. ISO-9003 standard gives a model of quality assurance in such cases.
4. Examples of such products are domestic appliances, petroleum products, components used in the assembly of manufacture of bigger items such as automobiles etc. Most of the customer items also fall in this category.

**C. ISO-9004 :**

1. ISO-9001, 9002, and 9003 apply where a contract between supplier and contractor exists.

2. In non-contractual situations companies may adopt ISO-9004 which gives guidelines for quality managements.
3. It is essential to build confidence of the customer that the organization can supply the desired quality of the product.
4. The organization has to take several integrated steps in managing all matters which have direct or indirect effect on its image to deliver the products of desired quality.
5. These integrated efforts of the organization towards maintaining the quality culture is quality management.
6. All these elements of quality management taken together make the quality system.

**Que 5.8. Explain the Taguchi method in quality engineering.**

**Answer**

1. The term quality engineering encompasses a broad range of engineering and operational activities whose aim is to ensure that a product's quality characteristics are at their target values.
2. Taguchi has an important influence on its development, especially in the design area-both product and process design.

**A. Robust Design :**

1. An important Taguchi principle is to set specifications on product and process parameters to create a design that resists failure or reduced performance in the face of variations.
2. Taguchi calls the variations, noise factors.
3. A noise factor is a source of variation that is difficult to control and that affects the functional characteristics of the product.
4. Three types of noise factors can be distinguished as follow :

**a. Unit to Unit Noise Factors :**

i. These are inherent random variations in the process and product caused by variability in raw materials, machinery, and human participation.

ii. They are associated with the production process that is in statistical control.

**b. Internal Noise Factors :**

i. These sources of variation are internal to the product or process.

ii. They include time dependent factors such as wear of mechanical components, spoilage of raw materials and fatigue of metal parts and operational errors such as improper setting on the products or machine tool.

**c. External Noise Factors :**

i. An external noise factor is a source of variation that is external to the product such as outside temperature, humidity, raw material supply, and input voltage.

ii. Internal and external noise factors constitute what we have previously called assignable variations.

5. A Robust design is one in which the function and performance of the product are relatively insensitive to variations in any of the noise factor.

6. In process design, robustness means that the process continue to produce good product with minimal effect from uncontrollable variation in its operating environment.

**Que 5.9.** **What do you mean by orthogonal array ? Explain its properties.** **UPTU 2011-12, Marks 05**

**Answer**

1. Experiment design usually involves attempting to optimize a process which can involve several factors at several levels.

2. Orthogonal arrays represent a simplified method of putting together an experiment.

3. The original development of the concept was by Sir R.A. Fischer of England in 1930.

4. Taguchi constructed a special set of orthogonal arrays. His approach takes each of the factors at two levels and works out which has the greatest contribution to the end result.

5. Taguchi method gives a fast and pragmatic approach to the optimization of products and processes. It can also be used for tolerance design in setting of statistically based tolerances, allowing either improved performance through tighter tolerances or cheaper designs in non-critical areas.

**A. Properties :**

1. The 8 in the designation OA8 represents the number of rows, which is also the number treatment conditions (TC) and the degrees of freedom.

2. Across the top of the orthogonal array is the maximum number of factors that can be used, which in this case is seven.

3. The levels are designated by 1 and 2. If more levels occur in the array, then 3, 4, 5 and so forth , are used. Other schemes such as '–' , 0, and '+' can be used.

4. The orthogonal property of the OA is not compromised by changing the rows or the columns.

**Orthogonal Array (OA8)**

| *TC* | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| 3 | 1 | 2 | 2 | 1 | 1 | 2 | 2 |
| 4 | 1 | 2 | 2 | 2 | 2 | 1 | 1 |
| 5 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| 6 | 2 | 1 | 2 | 2 | 1 | 2 | 1 |
| 7 | 2 | 2 | 1 | 1 | 2 | 2 | 1 |
| 8 | 2 | 2 | 1 | 2 | 1 | 1 | 2 |

**Fig. 5.9.1.**

**Que 5.10. What is the concept of JIT ? Explain its genesis.**

**UPTU 2011-12, Marks 10**

**OR**

**Write short note on JIT Technique.** **UPTU 2013-14, Marks 10**

**Answer**

1. JIT is a Japanese production management philosophy which has been applied in practice since the early 1970s in many Japanese manufacturing organizations.
2. This approach was first developed in Japan by Toyota Company that's why called the 'Toyota manufacturing system.'
3. Just in time emphasizes waste reduction, total quality control and devotion to the customer.
4. One of the central ideas of this system is the elimination of waste from the manufacturing process. Its goal is to optimize processes and procedures by continuous pursuing waste reduction.
5. This involved reducing waste and using materials and resources in the most efficient possible manner. The input of sustained effort over a long period of time within the framework of continuous improvement is key.
6. This is achieved by a focus on a continuous stream of small improvements known in Japan as 'Kaizen' and has been recognised as one of the most significant elements of JIT philosophy.
7. JIT production is defined as a :

"Philosophy that focuses attention on eliminating waste by purchasing or manufacturing just enough of the right items just in time".

8. This involves having the right items of the right quality and quantity in the right place and at the right time.

9. Toyota motor company identifies seven wastes as being the targets of continuous improvement in production processes. By attending to these wastes, improvement is achieved. They are :

**a. Waste of Overproduction :**

1. Eliminate by reducing setup times, synchronizing quantities and timing between processes, compacting layout, visibility, and so forth, make only what is needed now.

**b. Waste of Waiting :**

1. Eliminate through synchronizing work flow as much as possible and balance uneven loads by flexible workers or equipments.

**c. Waste of Transportation :**

1. Establish layouts and locations to make transport and handling unnecessary, if possible.
2. They rationalize transport and material handling that can not be eliminated.

**d. Waste of Processing Itself :**

1. First question why this product should be made at all, then why each process is necessary.
2. Extend thinking beyond economy of scale or speed.

**e. Waste of Stocks :**

1. Reduce by shortening setup times and reducing lead times, by synchronizing work flows and improving work skills, and even by smoothing fluctuations in demand for the product.
2. Reducing all the other wastes reduces the waste of stocks.

**f. Waste of Motion :**

1. Study motion for economy and consistency.
2. Economy improves productivity and consistency improves quality.
3. First improve the motions, then mechanize or automate.
4. Otherwise there is danger of automating waste.

**g. Waste of Making Defective Products :**

1. Develop the production process to prevent defects from being made so as to eliminate inspection.
2. At each process accept no defects and make no defects. Make processes fail-safe to do this.
3. From a quality process comes a quality product automatically.

**Que 5.11. Explain the characteristics of JIT system.**

**Answer**

1. JIT system displays certain unique characteristics that help to achieve a smooth flow of production and benefits. This includes :

**A. Pull System :**

1. Purchase of the final product by the customer pulls output from the final stage of production, which in turn pulls output from the preceding stages of production.
2. Each production stage pulls output from the preceding stages when it is needed. Hence, a JIT system is considered a pull system.

**B. Quality :**

1. JIT systems require high quality levels for product design, production process and raw materials supplied by the vendors.
2. Also, workers are provided with adequate tools, training, support, encouragement and authority for ensuring production of high quality goods.

**C. Small Lot Sizes :**

1. This system use small lot sizes in the production process. It requires small deliveries from suppliers.
2. Small lot sizes permit greater flexibility in scheduling and reduce in-process inventory.
3. Flexibility enables quick response to changing customer demands.
4. Reduced inventory levels help to minimize holding costs, space and clutter.
5. Also smaller lots require less inspection and lower rework costs.

**D. Quick Setups :**

1. Setup procedures are simple and standardized to enable frequent and quick setups due to smaller lot sizes.

**E. Production Smoothing :**

1. To ensure a smooth flow of goods from the supplier to the final stage of production, all activities are carefully coordinated and changes to the production plan are minimized.

**F. Suppliers :**

1. Since this system requires high quality materials delivered on time and uses small lot sizes, it also requires reliable suppliers who are willing to ship high quality materials and parts on a regular basis.

**F. Kanban Card :**

1. Communication between a production stage and the preceding stages is carried out in various ways to ensure timely and smooth movement of parts and materials.

2. The Kanban card is a commonly used tool for communicating the need for the parts from a preceding production stage.
3. Without this card, which serves as an authorization, no part or lot can be moved.

**Que 5.12. Write down the advantages and limitations of JIT system.**

**Answer**

**A. Advantages :**

1. Reduced inventory levels and manufacturing lead times.
2. Encouragement of worker participation in problem solving.
3. Improved relations with suppliers and smooth production flow by removing disruptions and in efficiency.
4. Overall better quality of whatever is produced.
5. Less scrap and less raw material, less work–in–process inventory.
6. Increased employee and equipment efficiency.
7. Less finished goods sitting.
8. Facility floor space is saved because there are no rework lines to correct production mistakes.

**B. Disadvantages or Limitations :**

1. Not able to meet any unforeseen demand.
2. Needs establishment of long term business partnership with suppliers.
3. Needs continuous and close evaluation and follow up of the whole process.
4. High risk is involved due to short term planning and a minimum level of inventory.
5. Suppliers of input materials need to be educated about the quality by the customers/company.

**Que 5.13. Give historical background of ISO. Give its significance also.**

**UPTU 2015-16, Marks 15**

**Answer**

1. Increased pressure on quality improvements led to the development of standards for assessing the way in which quality was managed within a supplier company.
   a. Increased international competition, particularly for Japanese competitors;
   b. The proliferation of multiple assessments whereby supplier companies would be assessed by many different customers;

c. Increasing product liability concerns and the limitations of product standard in providing supplier protection.

2. The development in the world in general and in the UK in particular during World War II and thereafter, there were typical international trends in the adoption of quality system standards.

3. This historical development leading to present day quality system standard is given table.

| S.No. | Period | Development |
|---|---|---|
| 1. | 1945-1950 | America's MIL-Q-9858A and MIL-Q-45208A were used as quality system specifications and inspection standard respectively in the defense contracts. |
| 2. | 1950-1955 | British defense standards series–DEFSTAN 05 operationalized. |
| 3. | 1955-1960 | Development of three series of standards designed for NATO use and called Allied Quality Assurance Publication (AQAP.) |
| 4. | 1960-1968 | The American Society for Quality Control (ASQC) was set up and ASQC-Std-1968 established. |
| 5. | 1960-1970 | Emphasis increased on quantity and quality was inspected by product standards. |
| 6. | 1970-1973 | American National Standards Institute (ANSI) was established and started operations. In the UK publication of BS 5173 completed. |
| 7. | 1970-1974 | Guide to the operation and evaluation of quality system was published. |
| 8. | 1974-1978 | ANSI/ASQC standard A3(1978) was established on quality systems terminology. |
| 9. | 1978-1979 | ANSI/ASQC standard Z-1.15 (1978) was established which were the generic guidelines for corporate industry standards. |
| 10. | 1978-1979 | Publication of BS 5750 by the British Standards Institution which is written by industry for industry as the national third-party assessment standard. |
| 11. | 1978-1979 | Canadian Standard Association (CSA) was established and came out with standard Z.229.1 to Z.229.4 on Quality Assurance Programme Requirements. |

| | | |
|---|---|---|
| 12. | 1979-1982 | The UK Government published a white paper in which it was proposed to specify conformance to BS 5750 as a requirement in government contracts. |
| 13. | 1982-1983 | The International Standard Organisation (ISO) under the chairmanship of Canada recognised widespread interest in quality system standards and began work on International Quality system and began work on International version based on the UK national standard. |
| 14. | 1983-1985 | The launching of the National Accreditation Council for Certification Bodies (NACCB) to establish competencies and impartiality for bodies providing certification to BS 575/ISO 9000. |
| 15. | 1985-1987 | The British Consumer Protection Act provided an incentive to businesses to ensure the quality of their product or service in order to limit liability. |
| 16. | 1987 | The publication of a range of common national and international quality system standards entitled "Quality System Model for Quality Assurance". |
| 17. | 1987-1992 | The European community moved towards a common trading market which highlighted the need for a community-wide supplier assessment standards. |
| 18. | 1992-94 | Revision of international quality system standards was completed during this period. |
| 19. | 1994 | Revised ISO 9000 standard were finalised and are being followed throughout the world. |
| 20. | 1994 onwards | Developing countries like India, Hong Kong, Singapore, Thailand etc. established their own national standard agencies for ISO 9000 certification (e.g., BIS in India) |
| 21. | 1994-1998 | Bureau of Indian Standard (BIS), a National Standards Body, started certification to ISO 9000 for companies in India. BIS today has trained lead assessors and auditors operating all over the country. BIS recently has got accreditation by Dutch Council for Certification (Rvc). Netherlands. Other foreign certification agencies operating in India, *viz.*, BVQI, TUV, NQA, IRQS are also doing accreditation job. |

**Answer**

1. Six sigma is a business concept that answers customers demand high quality and defect free business processes.
2. Customer satisfaction and its improvement should be the high priorities of any business.
3. There have always been many statistical methods for measuring a improving quality.
4. Six sigma was born when Motorola published its six sigma quali programme in 1987.
5. Six sigma was developed by Mikel J. Harry.
6. The programme gained publicity when Motorola won the Malcol Baldrige quality award.
7. Sigma ($\sigma$) is a character of the Greek alphabet which is used mathematical statistics to define standard deviation.
8. The standard deviation indicates how tightly the various examples a clustered around the mean in a set of data.
9. Six sigma is a business method of improving quality by removing defec and their causes in business activities.
10. It concentrates on those outputs which are important to customers.
11. This method uses various statistical tools to measure business processe
12. Six sigma is carried out as projects.
13. Most common type is the DMAIC (Define, Measure, Analyze, Improv Control) method.

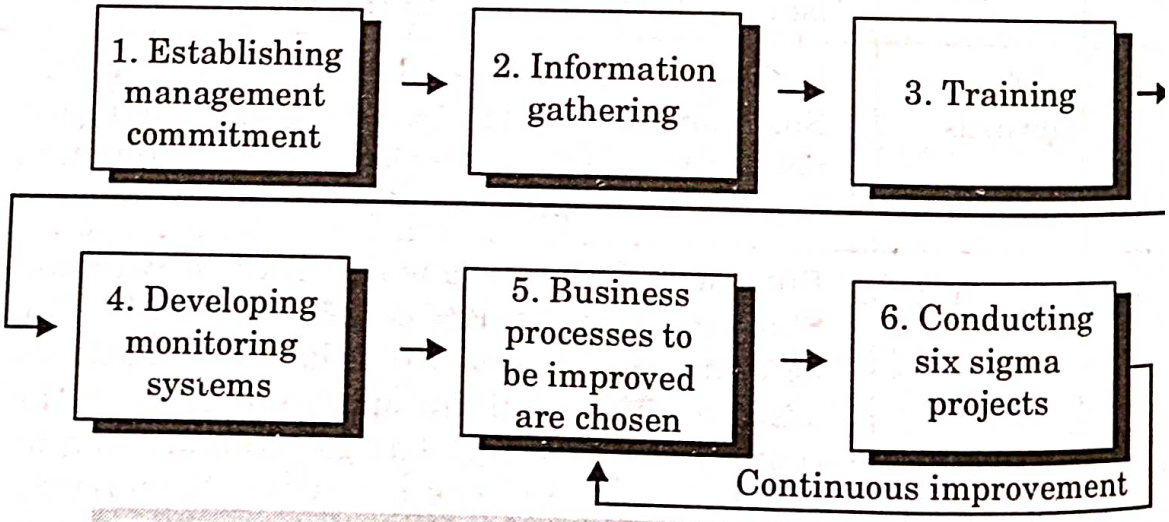


**Fig. 5.14.1.** Six Sigma implementation model - general level

14. Six sigma and ISO both require data and are focused on improvemen

15. One focuses on the "Voice of the Customer" while the other focuses on "Customer Satisfaction."
16. One taught that you should analyze data while the other insists you to perform data analysis.
17. Six sigma focus is on specific projects and is designed to drill down into the process using analytical and statistical tools.
18. ISO reviews the entire quality management system and ensures that bare minimum requirements are established in each segment of the business.

## PART-2

*ISO 14000, Documentation, Quality Information System, Auditing.*

### CONCEPT OUTLINE : PART-2

**ISO 14000 Series :** The ISO 14000 family of environmental management standards, according to the present plan, comprises 23 individual standards, guidelines and technical report related to environment management system.

ISO 14001 : Environmental management system – Specification with guidance for use.

ISO 14004 : Environmental management system – General guidelines on principles, system and supporting techniques.

ISO 14010 : Guidelines for environmental auditing – General principles

**Quality Information System :** It is the perfect choice to manage production, satisfy auditors, and meet customer's quality – reporting requirements, and it can be implemented with limited staff time, budget, and IT resources.

**Documentation :** The documentation includes quality manual, quality procedures, work instructions and forms/records/ specifications/files, etc. There would be normally four hierarchical divisions of documentation : Policy – Procedures – Practices – Records or Proofs.

**Auditing :** A systematic and independent examination to determine whether quality activities comply with planned arrangements, whether these arrangements are implemented effectively and whether these are suitable to achieve the objectives.

### Questions-Answers

**Long Answer Type and Medium Answer Type Questions**

**Que 5.15. What is ISO 14000 ? Give its historical background and its elements.**

**Answer**

1. The International Organization for Standards (ISO) completed the quality management system (ISO 9000) in 1987.
2. Its worldwide success, along with increased emphasis on environmental issues, was instrumental in ISO's decision to develop environmental management standard.
3. In 1991, ISO formed the Strategic Advisory Group on the Environment (SAGE), which led to the formation of Technical Committee (TC) 207 in 1992.
4. The mission of TC 207 is to develop standard for an Environmental Management System (EMS) which was identified as ISO 14000.
5. The EMS is part of a comprehensive management system that addresses how the overall business activities, including its products and services, impact the environment.
6. The EMS maximizes company participation in environmental performance now and in the future.
7. The series is divided into two separate areas :

**A. Organizational Evaluation Standards :**

1. These standards as shown in Fig. 5.15.1 and consist of three categories : Environmental Management System (EMS), Environmental Auditing (EA), and Environmental Performance Evaluation (EPE).
2. ISO 14001, entitled, "Environmental Management System–Specifications with Guidance for Use," gives the elements that organizations are required to conform to if they seek registration.

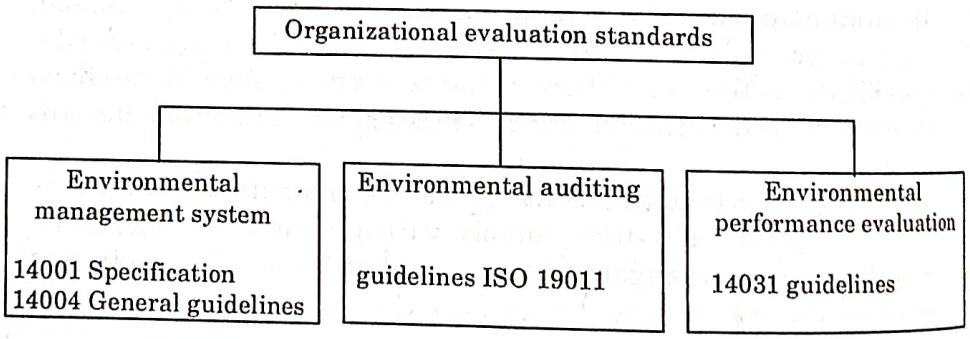


**Fig. 5.15.1.** Organizational evaluation standards.

**B. Product Evaluation Standards :**

1. These standards are under development and are shown in Fig. 5.15.2.
2. They consist of three categories :

Environmental Aspects in Product Standard (EAPS), Environment Labeling (EL), and Life-Cycle Assessment (LCA).

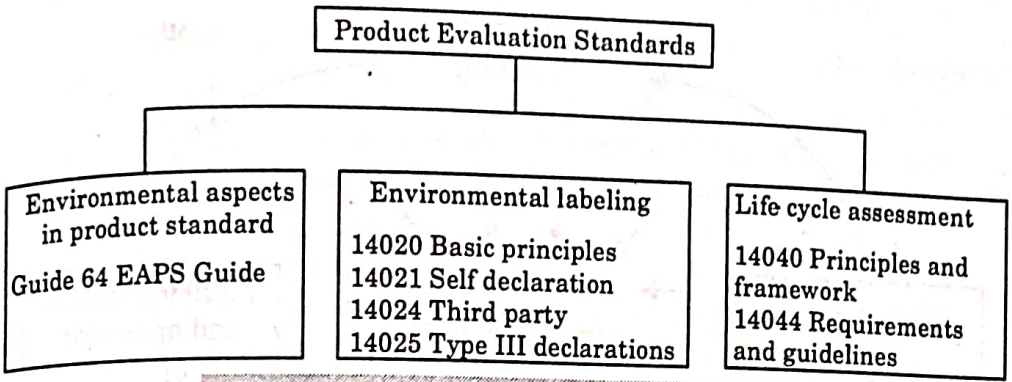


**Fig. 5.15.2.** Product evaluation standards

**Que 5.16. What are the concepts of ISO 14001 ?**

**Answer**

1. This standard provides organizations with the elements for an environmental management system (EMS), which can be integrated into other management systems to help to achieve environmental and economic goals.
2. It describes the requirements for registration and/or self-declaration of the organization's EMS.
3. Demonstration of successful implementation of the system can be used to assure other parties that an appropriate EMS is in place.
4. It was written to be applicable to all types and sizes of organizations and to accommodate diverse geographical, cultural and social conditions.
5. The basic approach to EMS is shown in Fig. 5.16.1.
6. It begins with the environmental policy, which is followed by planning, implementation and operation, checking and corrective action, and management review.
7. The approach follows the PDSA cycle.
8. There is a logical sequence of events to achieve continual improvement.
9. Many of the requirements may be developed concurrently or revisited at any time.
10. The overall aim is to support environmental protection and prevention of pollution in balance with socioeconomic needs.
11. There are four sections to the standard-scope, normative references, definitions, and EMS requirements and an informative annex.

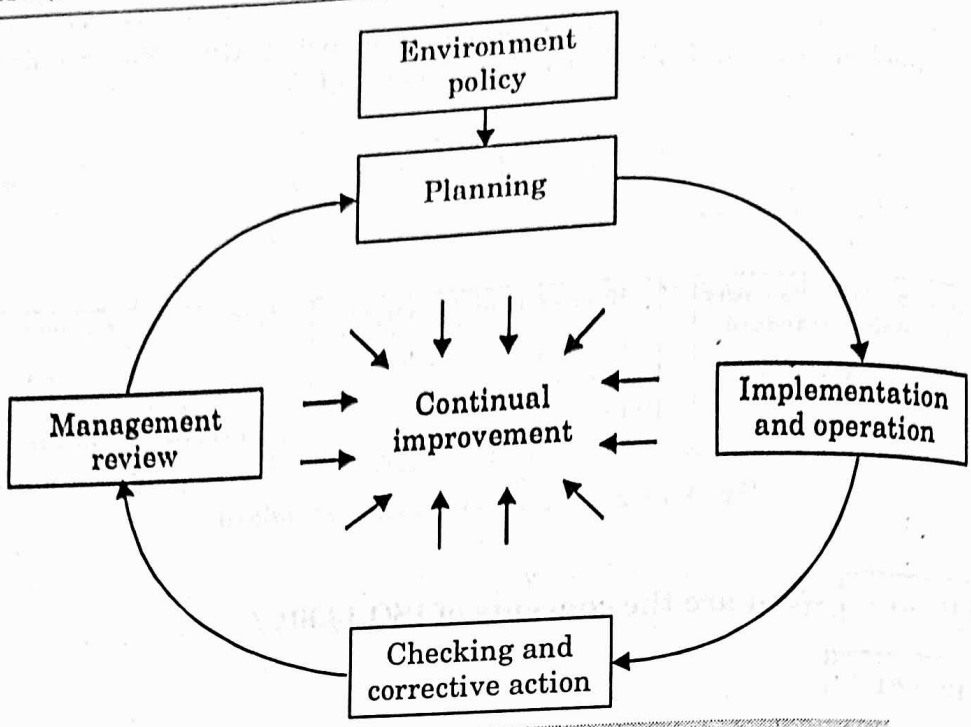


Fig. 5.16.1. Environmental management system model.

**Que 5.17. What are the requirements of ISO 14001 ?**

**Answer**

**A. General Requirements :**

1. The organizations shall establish, maintain and continually improve an environmental management system that includes policy, planning, implementation and operation, checking and corrective action, and management review.
2. These requirements are given in the rest of the standard.
3. The organization shall define and document the scope of its environment management system.

**B. Environmental Policy :**

1. The organization's policy statement should be based on its mission and values.
2. It should show management commitment, leadership, and direction for the environmental activities, management will ensure that the policy is implemental and carried out.
3. An initial environmental review is suggested which includes the following :
   a. Identification of legislative and regulatory requirements.
   b. Identification of environmental aspects of its activities, products, or services that can have significant impact and liabilities.
   c. Identification of existing activities with suppliers.

d. Identification of existing management policies and procedures.

e. Evaluation of past performance with regard to the above.

f. Feedback from investigation of previous incidents of noncompliance.

**C. Planning :**

1. This area contains four elements: environmental aspects, legal and other requirements, objectives and targets, and environmental management program(s).

**D. Environmental Aspects :**

1. The relationship among the environmental aspects, environmental impacts, and the standard is necessary for successful implementation of the standard.

2. It requires that environmental aspects of an organization's activities, product, and services that it can control and influence be identified within the defined scope in order to determine the environmental impact.

3. The organization shall take into account planning of new developments in new/modified activities, products and services.

**E. Legal and Other Requirements :**

1. The standard requires the organization to have a procedure to identify and have access to all legal and other requirements to which it subscribes.

2. In general, legal environmental requirements are those attributed to governmental legislative and regulatory action.

**F. Objectives and Targets :**

1. The organization shall establish and maintain these objectives and targets at each relevant function and level.

2. They shall be consistent with the policy statement especially in regard to the prevention of pollution and shall be measurable (wherever practical).

**G. Environmental Management Program(s) :**

1. The organization shall establish and maintain a program(s) for achieving the objectives and targets.

2. It shall include designation of the responsible function team or individual and a timeframe for achievement. This requirement can be achieved with the following terms :

   a. State the objective/target.

   b. State the purpose (How the objective/target will support the policy).

   c. Describe how the objective/target will be achieved.

   d. State the program (team) leader.

   e. Designate departments and individuals responsible for specific tasks.

   f. Establish the schedule for completion of the tasks.

   g. Establish the program review, which will include format, content, and review schedule.

**Que 5.18. What is quality information system ?**

**Answer**

1. It plays a very important role in implementation and operation of EMS and related standards.
2. It is the perfect choice to manage production, satisfy auditors, and meet customer's quality–reporting requirements.
3. It can be implemented with limited staff, time, budget and IT resources.
4. This area contains seven elements : structure and responsibility; training, awareness, and competency; communication; EMS documentation; document control; operational control; and emergency preparedness and response.

**A. Resources, Roles, Responsibility and Authority :**

1. Roles, responsibilities, and authorities shall be defined, documented, and communicated for all personal affecting the EMS.
2. They must be given the freedom and authority to take the necessary actions.
3. An organization chart is one method to show the flow of authority.
4. A management representative must be appointed and given the authority to ensure that this standard is being met and to periodically report to senior management the status of EMS with the aim of continued improvement.

**B. Training, Awareness, and Competency :**

1. Training needs should be evaluated on a regular basis, usually annually to ensure their effectiveness.
2. There are two types of training : general awareness and job competency requirements for any person(s) performing tasks for or on behalf of an organization shall be defined.
3. General awareness includes the importance of conformance to the EMS, the relationship of significant environmental impacts to the employees work activities, employee roles and responsibilities and potential consequences of failing to follow specific operating procedures.
4. At a minimum, this training should include :
   a. Record of training needs assessments.
   b. Task competency requirements.
   c. Training procedures.
   d. Training plans.
   e. Records of training delivered to specific employees.

**C. Communication :**

1. A key aspect of any management program is communication with all stakeholders.
2. The standard requires that procedures shall be established and maintained for internal communication among all employees.
3. The organization shall decide whether to communicate externally about its significant environmental aspects and shall also establish suitable mechanism for it.

**D. Environmental Management System Documentation :**

1. The organization shall establish and maintain information, in paper or electronic form, to describe the core elements of the system and their interaction and provide direction to applicable related documents.
2. ISO 14000 requires a documentation system very similar to ISO 9001, which makes integration of the two systems very easy.

**E. Operational Control :**

1. This element aligns operations and activities including subcontractors with the identified significant environmental aspects, environmental policy, and environmental objectives and targets.
2. Cover situations where their absence could lead to deviations from the policy and the objectives and targets.

**Emergency Preparedness and Response :**

Procedures are required to identify and respond to potential accidents and emergency situations.

In addition the procedures should prevent of mitigate the environmental impact of these accidents and emergency situations.

**Checking and Corrective Action :**

Effective decisions usually require quantifiable data.

The organization is required to monitor and measure the key characteristics of its objective and activities in order to assess its performance in meeting environmental operations and targets.

Procedures are required to define responsibility and authority for

Handling and investigating nonconformance,

Taking action to mitigate any impacts,

Initiating corrective and preventative action, and

Evaluating the need for action(*s*) to prevent non conformities.

**EMS Audit :**

The purpose of this audit is to ensure that the EMS conforms to plans and is being properly implemented and maintained.

Internal or self audit and external audit information should be distributed to senior management to assist in the management review process.

3. Audit procedures should cover the scope, frequency and methodologies, and responsibilities and requirements for conducting audits and reporting results.

**I. Management Review :**

1. Management review and revision, if applicable, is required to ensure the continuing suitability, adequacy, and effectiveness of the EMS.
2. The intent of this clause is to involve top management in the EMS continuous improvement process.

**Que 5.19. What do you understand by documentation ?**

**Answer**

**A. Documentation of Quality Systems :**

1. ISO 9000 is quite explicit in that the quality system should be documented, established and maintained.
2. The documentation includes :

**a. Quality Manual :**

1. Quality manual is the first level of documentation.
2. It should state the company's policy with respect to quality and identify the corresponding responsibilities and records.
3. This first level of documentation should be structured in line with the sections of ISO 9000.
4. It communicates the quality policy and objectives of an organization.
5. It should be circulated internally to ensure its recognition and externally to promote the organization in its business activities.

**b. Quality Procedures :**

1. Opinion is divided as to whether the quality procedures should reflect the requirements of the standards or the operations of the business.
2. Most companies employ hybrid approach whereby certain procedures relate specifically to the standard (for example, control of non conforming product) whereas other reflect the business process (for examples, preparation of quotations).
3. The procedure is a specified way to perform an activity.
4. This is designed to instruct the workforce in broad terms–how the policies and objectives expressed in the quality manual are being addressed and achieved.

**c. Work Instructions :**

1. The third level of documentation is normally company specific, giving details of how individual work processes (for examples, welding, soldering, testing, etc.) are carried out within a company.

2. Work instructions should also specify how the work should be done; who should undertake the work and what records are to be maintained.
3. Work instructions should be clear, concise and auditable.

**d. Forms and Records :**

1. This category of ISO 9000 documentation demonstrates that the product or service provided has been developed and produced in accordance with the specified requirements.
2. It also proves that the quality system is operating effectively.
3. Quality records are those documents which furnish objectives evidence of activities performed or results achieved.

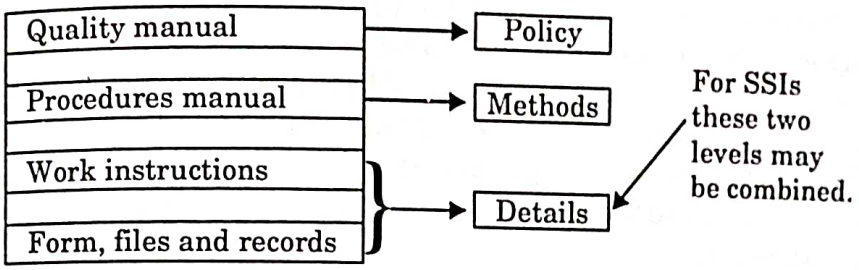


**Fig. 5.19.1.** Basic quality system structure.

**e. Documents Approval :**

1. It is required that approval and authorisation of all the documents be carried out.
2. This responsibility should be assigned to appropriate personnel within the organization (generally, the approving authority).
3. The standard requires that a control should be exercised to ensure that only pertinent documents are maintained at correct revision status wherever and whenever they are required by removing all obsolete documentation.

**B. Benefits of Documentation :**

1. Documentation formalises the way people carry out their day to day activities, providing on acceptable practices and feedback on action;
2. Documentation provides formats for standardizing practices and hence results in consistency in the managements decisions;
3. It provides reference for assessing degree of enforcement in practice;
4. Documentation provides a method for new entrants and on the job processes;
5. It also facilitates troubleshooting for tracing back on the processes;
6. It is necessary for demonstrating conformance to internationally acceptable practices in line with ISO 9000 and facilitating recognition by third party or customers.

**Que 5.20. Explain quality system audit ?**

**Answer**

**A. Quality System Audit :**

1. A quality system audit is defined as "a systematic and independent examination to determine whether quality activities comply with planned arrangements, whether these arrangement are implemented effectively and whether these are suitable to achieve objectives".
2. Quality system audit is one of the key management tools for achieving the objectives set out in the quality policy.
3. Audits should be carried out in order to verify whether a quality system is effective and suitable.
4. It also provides for the need for reduction, elimination and, most importantly, prevention of non conformities.
5. The results of these audits can be used by the management for improving the overall performance of the organization.
6. The main stages of an audit are as follow :
   a. Planning–40 %
   b. Performing–40 %
   c. Reporting–10 %
   d. Follow-up–10 %

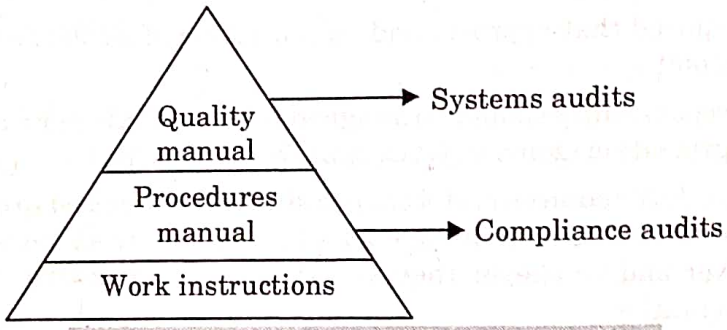


**Fig. 5.20.1.** Depth of quality system audits.

7. In terms of the organization carrying out the audit, the following distinctions can also be made.
   a. Internal audits are carried out by a company on its own quality systems.
   b. External audits are carried out by a company to evaluate supplier's quality systems.
   c. Extrinsic or second/third party audits are carried out on the company by a customer or a third party organization.
8. Based upon the above definitions the most common forms of audits are :
   a. Internal company audits : These are internal or compliance audits;
   b. Assessment of suppliers : These are external systems audits; and
   c. Accreditation assessment : These are extrinsic system audits.
9. These audits may be routine or may be prompted by significant changes in the organization's quality system, process, product or service quality.

10. Audits may be prompted by a need to follow up on corrective actions emanating from a previous audit.

**B. Objectives of Quality Audits :**

**a. The General Objectives are :**

1. To determine the conformity or non conformity of the quality system elements with specified requirements,
2. To determine the effectiveness of the implemented quality system in meeting the laid down quality objectives,
3. To afford an opportunity to improve the quality system, and
4. To permit the listing of the audited organisation's quality system in a register for third party certification.

**b. The Specific Objectives are :**

1. To evaluate a supplier before establishing a relationship, within the framework of a contractual relationship.
2. To verify that the supplier's quality system continues to meet the specified requirements and is being implemented effectively.
3. To evaluate an organization's own quality system against a quality system standard.

**Que 5.21. What are the benefits of EMS-ISO 14000 ?**

**Answer**

1. EMS benefits can be categorized as global and organizational.

**A. Global :**

1. Facilitate trade and remove trade barriers,
2. Improve environmental performance of planet Earth, and
3. Build consensus that there is a need for environmental management and a common terminology for EMS.

**B. Organizational :**

1. Assuring customers of a commitment to environmental management.
2. Meeting customer requirements, the primary reason for organizations to become certified.
3. Maintaining a good public/community relations image.
4. Satisfying investor criteria and improving access to capital.
5. Obtaining insurance at reasonable cost.
6. Increasing market share that results from a competitive advantage.
7. Reducing accidents that result in liability.
8. Improving defense posture in litigation.
9. Conserving input materials and energy.
10. Facilitating the attainment of permits and authorization.
11. Improving industry and government relations.

1 UNIT

# Quality Concepts Control on Purchased Product and Manufacturing Quality (2 Marks Questions)

## Memory Based Questions

**1.1. What is quality and quality characteristics ?**

**UPTU 2015-16, Marks 02**

**Ans.** Quality is defined as the degree of excellence provided by a product or service.

**Quality Characteristics :** The quality of a product consists of a number of elements and each constituents (element) has a specific task. These elements, such as shape, size, physical or chemical properties are the building blocks of product quality and are called the quality characteristics.

**1.2. What are the benefits of quality efforts ?**

**Ans.** The major benefits of good quality efforts are :

a. Higher productivity,
b. Lower costs,
c. Higher profit, and
d. Increased customer satisfaction.

**1.3. Define TQM.**

**Ans.** Total quality management (TQM) is defined as both, philosophy and a set of guiding principles that represent the foundation of a continuously improving organization.

**1.4. Write down the four steps of evolution of quality control.**

**Ans.** The evolution of quality control are as follows :

a. Craftsmanship,
b. Supervisor's control,
c. Inspection, and
d. Statistical quality control.

**1.5. What are the different factors affecting quality ?**

**Ans.** Factors affecting the quality are :

a. Types of customer in the market,
b. Profit consideration,
c. Environmental conditions, and
d. Special requirements of the product.

**1.6. What do you mean by capacity verification ?**

**Ans.** Capacity verification of prospective suppliers is one of the important functions of quality control organization, which is essential for practicing control over the quality of the purchased product.

**1.7. What is inspection ? Discuss its different aspects.**

**UPTU 2015-16, Marks 02**

**Ans.** Inspection is defined as the process of checking and measuring each sampled product at its finished form during the production process and rejecting or accepting the whole lot of goods on the basis of results of sampled goods measurements.

**Aspects :**

a. Stage inspection, and
b. Final inspection.

**1.8. What is spot check ?**

**Ans.** Spot check is a simple technique, where rather than checking every piece, a few pieces are checked occasionally to ensure that the product conforms to the specified quality.

**1.9. What do you mean by stage inspection ?**

**Ans.** Stage inspection involves the inspection of the product after every operation or group of operations where important quality characteristics are developed.

**1.10. What do you mean by guarantee of quality ?**

**Ans.** The guarantee of quality is primarily meant to protect the customer, should the product purchased by him turn out to be defective.

**1.11. What are the main factors influence purchasing decisions ?**

**Ans.** The two main factors influence the purchasing decisions are :

a. Price, and
b. Quality of product.

**1.12. What information should present on the guarantee card ?**

**Ans.** A guarantee card should include the following information :

a. Period of validity,
b. Liability of the manufacturers,
c. Procedure of submitting guarantee claims, and

d. Conditions which make the guarantee invalid.

**1.13. Which department is responsible for adjustment of guarantee claims ?**

**Ans.** The adjustment of guarantee claims is generally the responsibility of the sales department.

**1.14. What are the important elements in after-sales services ?**

**Ans.** Important elements in after-sales services are :

a. Education of the customer,
b. Maintenance and repairs where required, and
c. Looking into customer complaints.

**1.15. What are the requirements of efficient maintenance and repair ?**

**Ans.** The efficient maintenance and repair will require the following :

a. Creation of a service organisation,
b. Setting up of repair facilities, and
c. Feedback on repair problems.

**1.16. What will happen if the process going out of control ?**

**Ans.** If a process going out of control it may result in the production of a large number of defective pieces before it is detected, which may result in considerable loss.

**1.17. What are the general consideration for a good design ?**

**Ans.** Following are the consideration for a good design :

a. Appearance,
b. Safety,
c. Reliability, and
d. Maintainability.

**1.18. Differentiate between quality of conformance and quality of performance.**

**Ans.**

| S. No. | Quality of Conformance | Quality of Performance |
|---|---|---|
| 1. | It is concerned with how well the manufactured product conforms to the quality of design. | It is concerned with how well the manufactured product gives its performance. |

2 UNIT

# Quality Management and Human Factor in Quality (2 Marks Questions)

## Memory Based Questions

**2.1. What is organisation ?**

**Ans.** Organisation is defined as the process of identifying and grouping the work to be performed, defining and delegating authority and establishing relationships for the purpose of enabling people to work most effectively together in accomplishing objectives.

**2.2. What are the advantages of organisation ?**

**Ans.** The advantages of organisation are :

a. It provides for the optimum use of resources.
b. It aids in the correct evaluation of individual contributions.
c. It stimulates creativity by removing routine burdens from those who are supposed to do creative thinking.

**2.3. What are different types of business ?**

**Ans.** Business can be broadly categorised into two parts :

a. Traditional business, and
b. Diversified business.

**2.4. Write down the basic steps for design of an organisation.**

**Ans.** Design of an organisation essentially consists of three basic steps :

a. Identification and grouping of jobs,
b. Allocation of authority and responsibility, and
c. Establishment of co-operative relationships.

**2.5. Give the classification of quality functions.**

**Ans.** The quality functions can be classified into two groups :

a. Quality engineering, and
b. Quality control.

**2.6. Differentiate between quality engineering and quality control.**

**Ans.**

| S. No. | Quality Engineering | Quality Control |
|---|---|---|
| 1. | This comprises of specialist staff functions as well as activities connected with the development defining, and planning of quality during preproduction stage. | It is concerned with the interpretation and implementation of quality plans. |

**2.7. Write one advantage and one disadvantage of decentralisation of quality functions.**

**Ans.** **Advantage :**
The main benefit is the smooth flow of production and less interdepartment friction.

**Disadvantage :**
The longer feedback loop results in slower reactions.

**2.8. Name the different types of organisational structures.**

**Ans.** Following are the organisational structures :
a. Single product line at the one location,
b. Multiproduct company at one location,
c. Single product-multiplant situation,
d. Large divisionalised corporation,
e. A jobbing company, and
f. Cottage industry.

**2.9. What is the main characteristic of a jobbing company ?**

**Ans.** The main characteristic of a jobbing company is that it has no specific line of production.

**2.10. What do you mean by quality of conformance ?**

**Ans.** Quality of conformance is an index of the extent to which the product conforms to the design.

**2.11. Give the classification of quality costs.**

**Ans.** Quality costs can be divided into three parts :
a. Failure costs,
b. Appraisal costs, and
c. Cost of prevention.

**2.12. Define the quality cost.**

**Ans.** In quality control practice, any cost which is incurred to ensure that the outgoing product is of requisite quality is termed as quality cost.

**2.13. What is the effect of quality of conformance on appraisal costs ?**

**Ans.** Appraisal costs are relatively high, when the quality of conformance is low.

**2.14. How is operator responsible for the quality of a product ?**

**Ans.** The operator is responsible for the quality of a product in following ways :

a. The operator must know what he is supposed to do.
b. He must have means by which he can know the results of his action.
c. He must be able to regulate the process, should the results be unsatisfactory.

**2.15. What is the responsibility of management for operator's performance ?**

**Ans.** It is the management's responsibility to provide the operator with the necessary means by which he can exercise effective control over the process.

**2.16. What are the causes of operator's errors ?**

**Ans.** Following are the causes of operator's errors :

a. Incompetence,
b. Lack of awareness, and
c. Carelessness and lack of interest.

**2.17. What should corrective measures be taken to reduce the operator's error ?**

**Ans.** Following corrective measures should be taken to reduce the operator's error :

a. Motivation of workers,
b. Education of workers, and
c. Financial incentives.

**2.18. What is QFD ?**

**Ans.** Quality function deployment (QFD) is a planning tool used to fulfill customer expectations.

**2.19. What do you mean by quality loss function ?**

**Ans.** Quality loss function of a product is defined as the loss imparted by the product to the society from the time a product is shipped to the customer.

**2.20. What are the benefits of QFD ?**

**Ans.** Following are the benefits of QFD :

a. Improves customer satisfaction,
b. Reduces implementation time,

c. Promotes teamwork, and
d. Provides documentation.

**2.21. What is the driving force behind QFD ?**

**Ans.** The driving force behind QFD is that the customer dictates the attributes of a product.

**2.22. How excellence can be achieved by an organisation ?**

**Ans.** Excellence can be achieved by an organisation with the help of following steps :

a. Set goals and establish policies and procedures.
b. Organise, motivate and control people.

**2.23. What is failure cost ?**

**Ans.** Failure cost is quality control cost that is associated with products or services that have been found not to conform to requirements. These are further divided into internal costs and external costs.

3 UNIT

# Control Charts (2 Marks Questions)

## Memory Based Questions

**3.1. Explain SPC.** **UPTU 2015-16, Marks 02**

**Ans.** Statistical process control (SPC) is a statistical procedure using control charts and other tools to see if any part of a production process is not functioning properly and could cause poor quality. There is unusual or undesirable variability, the process is corrected so that defects will not occur.

**3.2. What is control chart ?**

**Ans.** The control chart is a graph used to study how a process changes over time. Data are plotted in time order. A control chart always has a central line for the average, an upper for the upper control limit and lower line for the lower control unit.

**3.3. What is acceptance sampling ?**

**Ans.** The inspection of materials to determine their acceptability, whether they are in raw material, semi-finished or completed state is called acceptance sampling.

**3.4. What is the aim of acceptance sampling ?**

**Ans.** The aim of acceptance sampling is to evaluate a definite lot of material that is already in existence and about whose quality decision must be made.

**3.5. What are the different kinds of variations ?**

**Ans.** There are two kinds of variations :

a. Variations due to assignable causes, and
b. Variations due to chance causes.

**3.6. What are assignable variations ?**

**Ans.** The assignable variations are those variations that may be attributed to special non-random causes.

**3.6. What is chance variation ?**

**Ans.** The chance variation is one which results from many minor causes that behave in a random manner and produce slight differences in product characteristics.

**3.8. What are *R*-charts ?**

**Ans.** Range control charts (normally called *R*-charts) are used to control the range or dispersion of the process.

**3.9. In which condition the process is out of control ?**

**Ans.** If a point falls outside the limit lines it can be taken as an indication that the process is out of control.

**3.10. Why is $\bar{X}$ control chart used ?**

**Ans.** An $\bar{X}$ control chart is used to control the central tendency of the process. It is also known as mean chart.

**3.11. Give all the formulae related to R-chart and $\bar{X}$ chart.**

**UPTU 2015-16, Marks 02**

**Ans.** **$\bar{X}$ chart :** Used to control central tendency of the process.

$$UCL = \bar{\bar{X}} + 3\sigma_{\bar{x}} = \bar{\bar{X}} + A_2\bar{R}$$

$$LCL = \bar{\bar{X}} - 3\sigma_{\bar{x}} = \bar{\bar{X}} - A_2\bar{R}$$

**R-chart :** Used to control the dispersion of the process.

$$UCL = D_4\bar{R}$$

$$LCR = D_3\bar{R}$$

**3.12. Define process capability.**

**Ans.** Process capability is the quality performance capability of a process under controlled conditions.

**3.13. Name the different methods for calculating process capability.**

**Ans.** Methods for calculating process capability are :

a. Standard deviation method,
b. The average range method, and
c. Single range method.

**3.14. Define capability index.**

**Ans.** Capability index is defined as the combination of process capability and the tolerance.

$$C_p = \frac{USL - LSL}{6\sigma}$$

**3.15. Define the term defect.**

**Ans.** The term defect refers to the failure of a quality characteristic to meet the specified standard.

**3.16. What do you mean by defective ?**

**Ans.** The term defective designates an item which has one or more defects.

**3.17. What are *P*-charts ?**

**Ans.** Percent defective charts (*P*-charts) are the control charts for attribute inspection data. It is also known as fraction defective charts.

**3.18. What is the utility of *P*-chart ?**

**Ans.** The main utility of the *P*-chart is that, it indicates the magnitude of the quality problem and highlights the areas of weakness.

**3.19. What is the drawback of basic *C*-chart ?**

**Ans.** The main drawback of the basic *C*-chart is that it treats all defects alike, certain defects may be of a minor nature requiring only a slight adjustment which could be carried out in a few minutes.

**3.20. What is the use of pre-control technique ?**

**Ans.** The pre-control technique does not require any calculations and charting, yet it gives quick indication, when the process is going to be out of control.

**3.21. What is the value of lower control limit, if there is no value of percent defective less than zero ?**

**Ans.** If there cannot be any value of percent defective less than zero, lower control limit in such cases is taken as zero.

**3.22. Which basic information is required for construction of control charts ?**

**Ans.** The basic information required for construction of control charts is the central tendency or the process mean, and the sample range.

**3.23. What is the use of *C*-chart ?**

**Ans.** *C*-chart is used to record the number of defects found in a given sample size.

**3.24. Explain CL, UCL and LCL ?**

**Ans.** **Central Line (CL) :** It passes through the middle of the chart and is parallel to the base.
**Upper Control Limit (UCL) :** It is a line that passes through the chart above and parallel to the central line.
**Lower Control Limit (LCL) :** It is a line that passes through the chart below and parallel to the central line.

**3.25. What do you mean by AQL ?**

**Ans.** Acceptable quality level (AQL) is a statistical measurement of the maximum number of defective goods considered acceptable in a particular sample size.

**3.26. What are process control tools ? Enlist them.**

**Ans.** Most of the TQM systems use process tools to evaluate the control of the process or the system. The tools identify the problems and study the effects of the corrective actions taken. There are seven basic techniques : Pareto diagram, Process flow diagram, Cause-and-Effect diagram, Check sheets, Histogram, Control charts, and Scatter diagrams.

**3.27. What is Pareto diagram ?**

**Ans.** A Pareto diagram is a graph that ranks data classifications in descending order from left to right. Pareto diagrams are used to identify the most important problems. Usually, 75 % of the total results from 25 % of the items.

**3.28. Describe Histogram ?**

**Ans.** The first statistical SPC technique is the histogram. It describes the variation in the process. The histogram graphically estimates the process capability and, if desired, the relationship to the specifications and the target.

**3.29. What is meant by Scatter diagram ?**

**Ans.** It is the simplest way to determine if a cause-and-effect relationship exists between two variables or not.

**3.30. How control charts are useful in any industry ?**

**UPTU 2015-16, Marks 02**

**Ans.** a. Control charts are used to reduce the number of defectives by specifying the upper and lower control line its.
b. By reduction in defectives customer satisfaction can be achieved, which results in terms of increase in profit.

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4 UNIT

# Defects Diagnosis and Prevention (2 Marks Questions)

## Memory Based Questions

**4.1. Give the classification of defects.**

**Ans.** Defects may be broadly classified into two groups :

a. Sporadic, and
b. Chronic.

**4.2. Why should every defect not be investigated ?**

**Ans.** Defect studies cost money in the form of the time of engineers and technicians, test facilities and the products destroyed in testing. Therefore, unless the expected benefits from the prevention of defects are likely to exceed the cost of the defect study, it will not be economically justifiable.

**4.3. Write the methods to control the defects.**

**Ans.** Following methods are used to control the defects :

a. Management approval,
b. Defining responsibility, and
c. Conduct of defect study.

**4.4. What does sporadic defect signify ?**

**Ans.** A sporadic defect signifies that some new factor has entered into the process, and unless this factor is identified and eliminated, the process will remain out of control.

**4.5. What are the chronic defects ?**

**Ans.** Chronic defects are the various types of defects which have been occurring in a certain percentage of the product due to unknown causes.

**4.6. What is reliability ?** **UPTU 2015-16, Marks 02**

**Ans.** The reliability of a system or product is the probability that it will give satisfactory performance for a specified period of time under specified conditions.

**4.7. What are the factors affecting reliability ?**

**Ans.** Following are the factors affecting reliability :

a. Complexity of a product,
b. Component reliability,
c. Manufacturing process,
d. Environmental conditions, and
e. Operation and maintenance.

**4.8. Define mean time to failure (MTTF).**

**Ans.** MTTF is the average time that an item or equipment may be expected to function before failure.

**4.9. Write down the formula for reliability of parts in series and in parallel.**

**Ans.** Reliability of parts in series :

$$R_S(t) = R_1(t) \times R_2(t) \times R_3(t) \times \ldots\ldots .$$

Reliability of parts in parallel :

$$R_P(t) = 1 - (1 - R_1(t)) \times (1 - R_2(t)) \times (1 - R_3(t)) \ldots\ldots .$$

**4.10. If 3 elements are in parallel and each has a reliability of 0.60, then calculate the reliability of combined unit.**

**Ans.** The reliability of combined unit is given by,

$$\begin{aligned} R_p &= 1 - (1 - 0.6) \times (1 - 0.6) \times (1 - 0.6) \\ &= 1 - 0.4 \times 0.4 \times 0.4 \\ &= 1 - 0.064 \\ &= 0.936 \end{aligned}$$

**4.11. Give one example of active redundancy.**

**Ans.** Automatic emergency lights are an example of active redundancy.

**4.12. Define maintainability.**

**Ans.** Maintainability is defined as the probability that a device will be restored to its operational effectiveness within given period, if the specified maintenance is carried out.

**4.13. Define mean time between failures.**

**Ans.** Mean time between failures (MTBF) is the mean time between successive failures of a product.

$$\text{MTBF} = \frac{\text{Total test time}}{\text{Number of failure during test}}$$

**4.14. Define MTTR.**

**Ans.** Mean time to repair (MTTR) is the arithmetic mean of the time required to perform maintenance action.

$$\text{MTTR} = \frac{\text{Total maintenance time}}{\text{Number of maintenance action}}$$

**4.15. Which factors do affect the maintainability most ?**

**Ans.** The main factors which affect the maintainability are ease of fault location and ease of repair.

**4.16. What are the different types of FMECA ?**

**Ans.** Following are the different types of FMECA :

a. Design FMECA,
b. Process FMECA,
c. Equipment FMECA,
d. Maintenance FMECA, and
e. Service FMECA.

**4.17. What is zero defect ?** **UPTU 2015-16, Marks 02**

**Ans.** According to its originator James F. Halpin, zero defects is a concept which promotes a constant, conscious desire to do job right at the first time.

**4.18. What is quality circle ?**

**Ans.** Quality circle is a small group of members working together to meet each other voluntarily with a view to analyzing and resolving work related problems.

**4.19. Write down the elements of quality circle.**

**Ans.** The quality circle has following elements :

a. Top management,
b. Steering committee,
c. Coordinator,
d. Facilitators, and
e. Leaders.

**4.20. Write down any two objectives of quality circles.**

**Ans.** Objectives of quality circles are :

a. To improve quality and productivity of the products.
b. To improve employee motivation.

5 UNIT

# ISO-9000 and Its Concept of Quality Management (2 Marks Questions)

## Memory Based Questions

**5.1. What is standardization ?**

**Ans.** Standardization is temporary crystallization of the best acceptable solution to a recurring problem, formulated in a scientific and systematic fashion by pooling the knowledge of all those who are concerned with the problem and is subjected to review and revision by common consent.

**5.2. What is the primary reason for employing ISO standards ?**

**Ans.** The primary reason for employing ISO standards is that customers or marketing are suggesting or demanding compliance to a quality system.

**5.3. What is ISO ? Give its concept.** **UPTU 2015-16, Marks 02**

**Ans.** ISO is a worldwide federation of national standards bodies from some 100 countries with one standards body representing each member country.

Example : BIS represents the Indian organisations collaborate in the development and promotion of international standards.

**5.4. Write some ISO standards used for standardization.**

**Ans.** These are the some ISO standards used for standardization :

a. ISO : 9000
b. ISO : 9001
c. ISO : 9002
d. ISO : 9003
e. ISO : 9004

**5.5. What are the different types of standardization systems ?**

**Ans.** Following are the different types of standardization systems :

a. Multi-tier standardization system,
b. Company / In-plant standards,
c. National standards,
d. International standards, and
e. Regional standards.

**5.6. How is Taguchi defined quality ?**

**Ans.** Taguchi is defined quality as the loss imparted to society from the time a product is shipped.

**5.7. Write down the procedure to determine the appropriate orthogonal array.**

**Ans.** To determine the appropriate orthogonal array, we use the following procedure :

a. Define the number of factors and their levels.
b. Determine the degrees of freedom.
c. Select an orthogonal array.
d. Consider any interactions.

**5.8. What are the uses of orthogonal arrays ?**

**Ans.** Orthogonal arrays are used in parameter design to obtain optimal factors / levels for robustness and cost in order to improve product and process performance.

**5.9. What is tolerance design ?**

**Ans.** Tolerance design is the process of determining the statistical tolerance around the target.

**5.10. Define JIT production.**

**Ans.** JIT production is defined as a philosophy that focuses attention on eliminating waste by purchasing or manufacturing just enough of the right items just in time.

**5.11. What is the objective of JIT ?**

**Ans.** The objective of JIT is to increase the inventory turnover and at the same time reduce the inventory holding cost.

**5.12. What are the 3 MUs avoided in JIT ?**

**Ans.** Following are the 3 MUs avoided in JIT :

a. Muri means excess,
b. Muda means waste, and
c. Mura means unevenness.

**5.13. What is the use of Kanban card ?**

**Ans.** The Kanban card is used for communicating the need for the parts from a preceding production stage.

**5.14. What are the advantages of JIT ?**

**Ans.** Advantages of JIT are :

a. Reduced inventory levels and manufacturing lead times.
b. Overall better quality of whatever is produced.

**5.15. Write some demerits of JIT.**

**Ans.** Demerits of JIT are :

a. Not able to meet any unforeseen demand.
b. Needs continuous and close evaluation and follow up of the whole process.

**5.16. What is ISO 14000 ?**

**Ans.** After the ISO 9000 series was completed, a new model for managing the environmental issues has been evolved known as ISO 14000 series of standards.

**5.17. Write some ISO standards used for Environmental management ?**

**Ans.** These are some ISO standards used for environmental management :

a. ISO 14001
b. ISO 14004
c. ISO 14010
d. ISO 14011
e. ISO 14012

**5.18. Define Quality information system.**

**Ans.** It is an attempt to manage production, satisfy auditors and meet customer's quality-reporting requirements all at the same time.

**5.19. What is Documentation ?**

**Ans.** ISO 9000 is quite explicit in that the quality system should be documented, established and maintained. The documentation includes quality manual, quality procedures, work instructions and forms / records.

**5.20. What is Quality System Audit ?** **UPTU 2015-16, Marks 02**

**Ans.** It is defined as a systematic and independent examination to determine whether quality activities comply with planned arrangements, whether these arrangements are implemented effectively and whether these are suitable to achieve objectives.

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1. This includes the "market survey" for consuming habits of people, prices they are willing to pay, the choice of design of the product.
2. But for capital goods, the decision is usually governed by such considerations as intended life, environmental conditions, reliability, maintainability etc.

**b. Profit Consideration :**

1. From company's point of view, profit is more important.
2. It is not necessary that the company should manufacture 100 % quality products.
3. Profit can be maximized by producing products in different grades to suit different types of customers.

**c. Environmental Conditions :**

1. This also plays an important role in deciding quality of design. *e.g.,* a car radiator designed for use in equatorial regions should be designed for increased ambient temperature.
2. A well designed bus body known for its good performance abroad, has failed to withstand both, road conditions and loading pattern in our country.

**d. Special Requirements of the Product :**

1. Generally, greater for strength, fatigue resistance, life, interchangeability of manufactured items closer tolerance should be given for better quality goods.

**Que 1.8. Explain the significance of review of design and what are the advantages of doing it ?** **UPTU 2013-14, Marks 04**

**Answer**

1. Before the preliminary design has progressed further it should be subjected to a critical review by all those who are connected with the product such as quality and production engineers, and sales personnel.
2. The design engineer could explain the salient features of the design with the help of mock-up model.
3. During this, each functional representative should be allowed to comment on the design.
4. The quality engineer for instance, could highlight the quality problems which were faced in the similar previous products during manufacture.
5. The production man may define the difficulties faced during production as non availability of tool or machine.
6. To avoid capital investment on new one, he suggests for some modifications in design.