6

QUALITY CONTROL

CHAPTER OUTLINE

6.1 INTRODUCTION

In any business organization, profit is the ultimate goal. To achieve this, there are several approaches. Profit may be maximized by cutting costs for the same selling price per unit. If it is a monopolistic business, without giving much of importance to the cost reduction programs, the price may be fixed suitably to earn sufficient profit. But, to survive in a competitive business environment, goods and services produced by a firm should have the minimum required quality. Extra quality means extra cost. So, the level of quality should be decided in relation to other factors such that the product is well absorbed in the market. In all these cases, to have repeated sales and thereby increased sales revenue, basic quality is considered to be one of the supportive factors. Quality is a measure of how closely a good or service conforms to specified standard.

Quality standards may be any one or a combination of attributes and variables of the product being manufactured. The attributes will include performance, reliability, appearance, commitment to delivery time, etc., variables may be some measurement variables like, length, width, height, diameter, surface finish, etc.

Most of the above characteristics are related to products. Similarly, some of the quality characteristics of services are meeting promised due dates, safety, comfort, security, less waiting time and so forth. So, the various dimensions of quality are performance, features, reliability, conformance, durability, serviceability, aesthetics, perceived quality, safety, comfort, security, commitment to due dates, less waiting time, etc.

6.2 QUALITY

Different meaning could be attached to the word quality under different circumstances. The word quality does not mean the quality of manufactured product only. It may refer to the quality of the process (*i.e*., men, material, and machines) and even that of management. Where the quality manufactured product referred as or defined as "Quality of product as the degree in which it fulfills the requirement of the customer. It is not absolute but it judged or realized by comparing it with some standards".

Quality begins with the design of a product in accordance with the customer specification further it involved the established measurement standards, the use of proper material, selection of suitable manufacturing process etc., quality is a relative term and it is generally used with reference to the end use of the product.

Crosby defined as "Quality is conformance to requirement or specifications".

Juran defined as "Quality is fitness for use". "The Quality of a product or service is the fitness of that product or service for meeting or exceeding its intended use as required by the customer."

6.2.1 Fundamental Factors Affecting Quality

The nine fundamental factors **(9 M's)**, which are affecting the quality of products and services, are: markets, money, management, men, motivation, materials, machines and mechanization. Modern information methods and mounting product requirements.

1. **Market:** Because of technology advancement, we could see many new products to satisfy customer wants. At the same time, the customer wants are also changing dynamically. So, it is the role of companies to identify needs and then meet it with existing technologies or by developing new technologies.

2. **Money:** The increased global competition necessitates huge outlays for new equipments and process. This should be rewarded by improved productivity. This is possible by minimizing quality costs associated with the maintenance and improvements of quality level.

3. **Management:** Because of the increased complex structure of business organization, the quality related responsibilities lie with persons at different levels in the organization.

4. **Men:** The rapid growth in technical knowledge leads to development of human resource with different specialization. This necessitates some groups like, system engineering group to integrate the idea of full specialization.

5. **Motivation:** If we fix the responsibility of achieving quality with each individual in the organization with proper motivation techniques, there will not be any problem in producing the designed quality products.

6. **Materials:** Selection of proper materials to meet the desired tolerance limit is also an important consideration. Quality attributes like, surface finish, strength, diameter etc., can be obtained by proper selection of material.

7. **Machines and mechanization:** In order to have quality products which will lead to higher productivity of any organization, we need to use advanced machines and mechanize various operations.

8. **Modern information methods:** The modern information methods help in storing and retrieving needed data for manufacturing, marketing and servicing.

9. **Mounting product requirements:** Product diversification to meet customers taste leads to intricacy in design, manufacturing and quality standards. Hence, companies should plan adequate system to tackle all these requirements.

6.3 CONTROL

The process through which the standards are established and met with standards is called control. This process consists of observing our activity performance, comparing the performance with some standard and then taking action if the observed performance is significantly too different from the standards.

The control process involves a universal sequence of steps as follows:

1. Choose the control object
2. Choose a unit of measure
3. Set the standard value
4. Choose a sensing device which can measure
5. Measure actual performance
6. Interpret the difference between actual and standard
7. Taking action.

6.3.1 Need for Controlling Quality

In the absence of quality, the following will result:

1. No yardstick for comparing the quality of goods/services.
2. Difficulty in maintaining consistency in quality.
3. Dissatisfied customers due to increased maintenance and operating costs of products/services.
4. Increased rework cost while manufacturing products/providing services.
5. Reduced life time of the products/services.
6. Reduced flexibility with respect to usage of standard spare parts.
7. Hence, controlling quality is an essential activity.

6.4 INSPECTION

Inspection is an important tool to achieve quality concept. It is necessary to assure confidence to manufacturer and aims satisfaction to customer. Inspection is an indispensable tool of modern manufacturing process. It helps to control quality, reduces manufacturing costs, eliminate scrap losses and assignable causes of defective work.

The inspection and test unit is responsible for appraising the quality of incoming raw materials and components as well as the quality of the manufactured product or service. It checks the components at various stages with reference to certain predetermined factors and detecting and sorting out the faulty or defective items. It also specified the types of inspection devices to use and the procedures to follow to measure the quality characteristics.

Inspection only measures the degree of conformance to a standard in the case of variables. In the case of attributes inspection merely separates the nonconforming from the conforming. Inspection does not show why the nonconforming units are being produced.

Inspection is the most common method of attaining standardization, uniformity and quality of workmanship. It is the cost art of controlling the production quality after comparison with the established standards and specifications. It is the function of quality control. If the said item does not fall within the zone of acceptability it will be rejected and corrective measure will be applied to see that the items in future conform to specified standards.

6.4.1 Objectives of Inspection

1. To detect and remove the faulty raw materials before it undergoes production.
2. To detect the faulty products in production whenever it is detected.
3. To bring facts to the notice of managers before they become serous to enable them discover weaknesses and over the problem.
4. To prevent the substandard reaching the customer and reducing complaints.
5. To promote reputation for quality and reliability of product.

6.4.2 Purpose of Inspection

1. To distinguish good lots from bad lots.
2. To distinguish good pieces from bad pieces.
3. To determine if the process is changing.
4. To determine if the process is approaching the specification limits.
5. To rate quality of product.
6. To rate accuracy of inspectors.
7. To measure the precision of the measuring instrument.
8. To secure products-design information.
9. To measure process capability.

6.4.3 Types of Inspection

Types of inspection are:

1. Floor inspection
2. Centralized inspection
3. Combined inspection
4. Functional inspection
5. First piece inspection
6. Pilot piece inspection
7. Final inspection

1. Floor Inspection

In this system, the inspection is performed at the place of production. It suggests the checking of materials in process at the machine or in the production time by patrolling inspectors. These inspectors move from machine to machine and from one to the other work centres. Inspectors have to be highly skilled. This method of inspection minimize the material handling, does not disrupt the line layout of machinery and quickly locate the defect and readily offers field and correction.

Advantages

1. Detection of errors of the source reduces scrap and rework.
2. Correction is done before it affects further production, resulting in saving cost of unnecessary work on defective parts.
3. Material handling time is reduced.
4. Job satisfaction to worker as he can't be held responsible for bad work at a later date.
5. Greater number of pieces can be checked than a sample size.
6. Does not delay in production.

Disadvantages

1. Delicate instruments can be employed.
2. Measuring or inspection equipment have to be recalibrated often as they are subjected to wear or dust.
3. High cost of inspection because of numerous sets of inspections and skilled inspectors.
4. Supervision of inspectors is difficult due to vibration.
5. Pressure on inspector.
6. Possibility of biased inspection because of worker.

Suitability

1. Heavy products are produced.
2. Different work centres are integrated in continuous line layout.

2. Centralised Inspection

Inspection is carried in a central place with all testing equipment, sensitive equipment is housed in air-conditioned area. Samples are brought to the inspection floor for checking. Centralised inspection may locate in one or more places in the manufacturing industry.

Advantages

1. Greater degree of inspection due to sensitive equipment.
2. Less number of inspectors and tools.
3. Equipment needs less frequency of recalibration.
4. Cost of inspection is reduced.
5. Unbiased inspection.
6. Supervision of inspectors made possible.
7. No distraction to the inspector.

Disadvantages

1. Defects of job are not revealed quickly for prevention.
2. Greater material handling.
3. High cost as products are subjected to production before they are prevented.
4. Greater delay in production.
5. Inspection of heavy work not possible.
6. Production control work is more complicated.
7. Greater scrap.

3. Combined Inspection

Combination of two methods whatever may be the method of inspection, whether floor or central. The main objective is to locate and prevent defect which may not repeat itself in subsequent operation to see whether any corrective measure is required and finally to maintain quality economically.

4. Functional Inspection

This system only checks for the main function, the product is expected to perform. Thus an electrical motor can be checked for the specified speed and load characteristics. It does not reveal the variation of individual parts but can assure combined satisfactory performance of all parts put together. Both manufacturers and purchasers can do this, if large number of articles are needed at regular intervals. This is also called assembly inspection.

5. First Piece or First-off Inspections

First piece of the shift or lot is inspected. This is particularly used where automatic machines are employed. Any discrepancy from the operator as machine tool can be checked to see that the product is within in control limits. Excepting for need for precautions for tool we are check and disturbance in machine set up, this yields good result if the operator is careful.

6. Pilot Piece Inspection

This is done immediately after new design or product is developed. Manufacturer of product is done either on regular shop floor if production is not disturbed. If production is affected to a large extent, the product is manufactured in a pilot plant. This is suitable for mass production and products involving large number of components such as automobiles aeroplanes etc., and modification are design or manufacturing process is done until satisfactory performance is assured or established.

7. FINAL INSPECTION

This is also similar to functional or assembly inspection. This inspection is done only after completion of work. This is widely employed in process industries where there is not possible such as, electroplating or anodizing products. This is done in conjunction with incoming material inspection.

6.4.4 Methods of Inspection

There are two methods of inspection. They are: 100% inspection and sampling inspection.

1. 100% INSPECTION

This type will involve careful inspection in detail of quality at each strategic point or stage of manufacture where the test is involved is non-destructive and every piece is separately inspected. It requires more number of inspectors and hence it is a costly method. There is no sampling error. This is subjected to inspection error arising out of fatigue, negligence, difficulty of supervision etc. Hence, completer accuracy of influence is seldom attained. It is suitable only when a small number of pieces are there or a very high degree of quality is required. Example: Jet engines, aircraft, medical and scientific equipment.

2. SAMPLING INSPECTION

In this method randomly selected samples are inspected. Samples taken from different patches of products are representatives. If the sample proves defective, the entire concerned is to be rejected or recovered. Sampling inspection is cheaper and quicker. It requires less number of Inspectors. It is subjected to sampling errors but the magnitude of sampling error can be estimated. In the case of destructive test, random or sampling inspection is desirable. This type of inspection governs wide currency due to the introduction of automatic machines or equipments which are less susceptible to chance variable and hence require less inspection, suitable for inspection of products which have less precision importance and are less costly. Example: Electrical bulbs, radio bulbs, washing machine etc.

6.4.5 Drawbacks of Inspection

Following are the disadvantages of inspection:

1. Inspection adds to the cost of the product but not for its value.
2. It is partially subjective, often the inspector has to judge whether a products passes or not.
3. Fatigue and Monotony may affect any inspection judgment.
4. Inspection merely separates good and bad items. It is no way to prevent the production of bad items.

6.5 QUALITY CONTROL

Quality Control (QC) may be defined as a system that is used to maintain a desired level of quality in a product or service. It is a systematic control of various factors that affect the quality of the product. It depends on materials, tools, machines, type of labour, working conditions etc.

QC is a broad term, it involves inspection at particular stage but mere inspection does not mean QC. As opposed to inspection, in quality control activity emphasis is placed on the quality future production. Quality control aims at prevention of defects at the source, relies on effective feedback system and corrective action procedure. Quality control uses inspection as a valuable tool.

According to Juran "Quality control is the regulatory process through which we measure actual quality performance, compare it with standards, and act on the difference". Another definition of quality control is from ANSI/ASQC standard (1978) quality control is defined as "The operational techniques and the activities which sustain a quality of product or service that will satisfy given needs; also the use of such techniques and activities".

Alford and Beatty define QC as "In the broad sense, quality control is the mechanism by which products are made to measure up to specifications determined from customers, demands and transformed into sales engineering and manufacturing requirements, it is concerned with making things right rather than discovering and rejecting those made wrong".

6.5.1 Types of Quality Control

QC is not a function of any single department or a person. It is the primary responsibility of any supervisor to turn out work of acceptable quality. Quality control can be divided into three main sub-areas, those are:

1. Off-line quality control, 2. Statistical process control, and 3. Acceptance sampling plans.

1. **Off-line quality control:** Its procedure deal with measures to select and choose controllable product and process parameters in such a way that the deviation between the product or process output and the standard will be minimized. Much of this task is accomplished through product and process design.

Example: Taguchi method, principles of experimental design etc.

2. **Statistical process control:** SPC involves comparing the output of a process or a service with a standard and taking remedial actions in case of a discrepancy between the two. It also involves determining whether a process can produce a product that meets desired specification or requirements. On-line SPC means that information is gathered about the product, process, or service while it is functional. The corrective action is taken in that operational phase. This is real-time basis.

3. **Acceptance sampling plans:** A plan that determines the number of items to sample and the acceptance criteria of the lot, based on meeting certain stipulated conditions (such as the risk of rejecting a good lot or accepting a bad lot) is known as an acceptance sampling plan.

6.5.2 Steps in Quality Control

Following are the steps in quality control process:

1. Formulate quality policy.
2. Set the standards or specifications on the basis of customer's preference, cost and profit.
3. Select inspection plan and set up procedure for checking.
4. Detect deviations from set standards of specifications.
5. Take corrective actions or necessary changes to achieve standards.

6. Decide on salvage method *i.e*., to decide how the defective parts are disposed of, entire scrap or rework.
7. Coordination of quality problems.
8. Developing quality consciousness both within and outside the organization.
9. Developing procedures for good vendor-vendee relations.

6.5.3 Objectives of Quality Control

Following are the objectives of quality control:

1. To improve the companies income by making the production more acceptable to the customers, *i.e.*, by providing long life, greater usefulness, maintainability etc.
2. To reduce companies cost through reduction of losses due to defects.
3. To achieve interchangeability of manufacture in large scale production.
4. To produce optimal quality at reduced price.
5. To ensure satisfaction of customers with productions or services or high quality level, to build customer goodwill, confidence and reputation of manufacturer.
6. To make inspection prompt to ensure quality control.
7. To check the variation during manufacturing.

The broad areas of application of quality control are incoming material control, process control and product control.

6.5.4 Benefits of Quality Control

- Improving the quality of products and services.
- Increasing the productivity of manufacturing processes, commercial business, corporations.
- Reducing manufacturing and corporate costs.
- Determining and improving the marketability of products and services.
- Reducing consumer prices of products and services.
- Improving and/or assuring on time deliveries and availability.
- Assisting in the management of an enterprise.

6.5.5 Seven Tools for Quality Control

To make rational decisions using data obtained on the product, or process, or from the consumer, organizations use certain graphical tools. These methods help us learn about the characteristics of a process, its operating state of affairs and the kind of output we may expect from it. Graphical methods are easy to understand and provide comprehensive information; they are a viable tool for the analysis of product and process data. These tools are effect on quality improvement. The seven quality control tools are:

1. Pareto charts
2. Check sheets
3. Cause and effect diagram
4. Scatter diagrams
5. Histogram
6. Graphs or flow charts
7. Control charts

1. Pareto Charts

Pareto charts help prioritize by arranging them in decreasing order of importantce. In an environment of limited resources these diagrams help companies to decide on the order in which they should address problems. The Pareto analysis can be used to identify the problem in a number of forms.

(*a*) Analysis of losses by material (number or past number).

(*b*) Analysis of losses by process *i.e.*, classification of defects or lot rejections in terms of the process.

(*c*) Analysis of losses by product family.

(*d*) Analysis by supplier across the entire spectrum of purchases.

(*e*) Analysis by cost of the parts.

(*f*) Analysis by failure mode.

Example: The Fig. 6.1 shows a Pareto chart of reasons for poor quality. Poor design will be the major reason, as indicated by 64%. Thus, this is the problem that the manufacturing unit should address first.

A — Poor Design B — Defective Parts
C — Operator Error D — Wrong Dimensions
E — Surface Abrasion F — Machine Calibrations
G — Defective Material

2. Check Sheets

Check sheets facilitate systematic record keeping or data collection observations are recorded as they happen which reveals patterns or trends. Data collection through the use of a checklist is often the first step in analysis of quality problem. A checklist is a form used to record the frequency of occurrence of certain product or service characteristics related to quality. The characteristics may be measurable on a continuous scale such as weight, diameter, time or length.

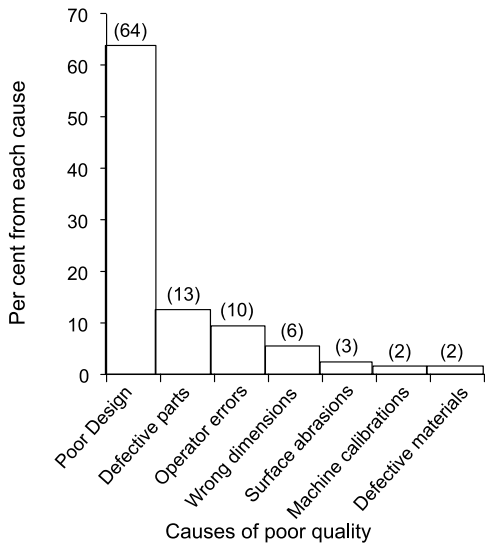


Fig. 6.1 *Pareto chart*

Example: The table is a check sheet for an organization's computer related problems.

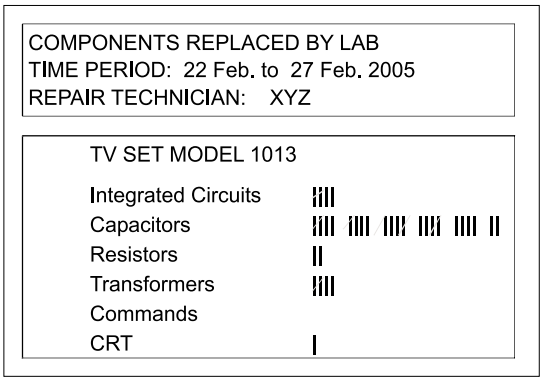


Fig. 6.2 *Checklist*

3. CAUSE AND EFFECT DIAGRAM

It is sometimes called as Fish-bone diagram. It is first developed by Kaorv Ishikawa in 1943 and is sometimes called as Ishikawa diagram. The diameter helps the management trace customer complaints directly to the operations involved. The main quality problem is referred to Fish-head; the major categories of potential cause structural bones and the likely specific causes to ribs. It explores possible causes of problems, with the intention being to discover the root causes. This diagram helps identify possible reasons for a process to go out of control as well as possible effects on the process.

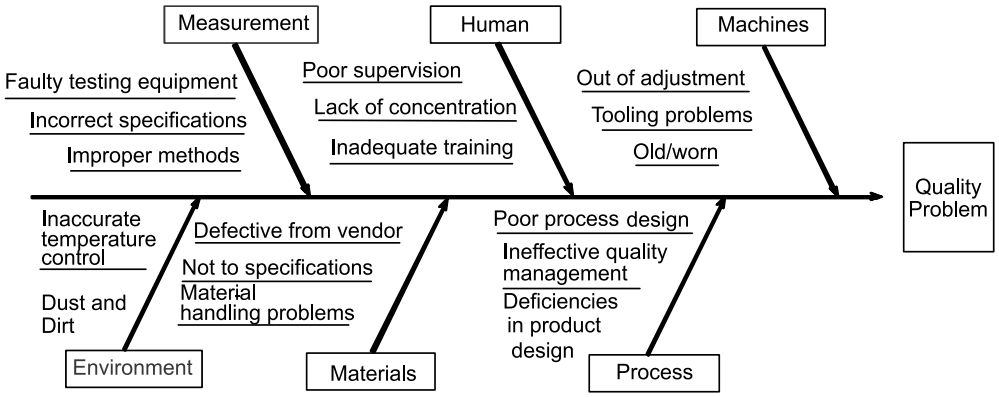


Fig. 6.3 *Fishbone diagram*

4. SCATTER DIAGRAM (SCATTER PLOTS)

It often indicates the relationship between two variables. They are often used as follow-ups to a cause and effect analysis to determine whether a stated cause truly does impact the quality characteristics.

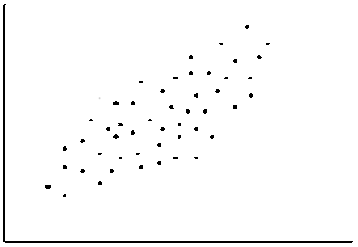


Fig. 6.4 *Scatter diagram*

Example: The above figure plots advertising expenditure against company sales and indicates a strong positive relationship between the two variables. As the level of advertising expenditure increases sales tend to increase.

5. Histogram (or) Bar Charts

It displays the large amounts of data that are difficult to interpret in their raw form. A histogram summarizes data measured on a continuous scale showing the frequency distribution of some quality characteristics (in statistical terms the central tendency and the dispersion of the data).

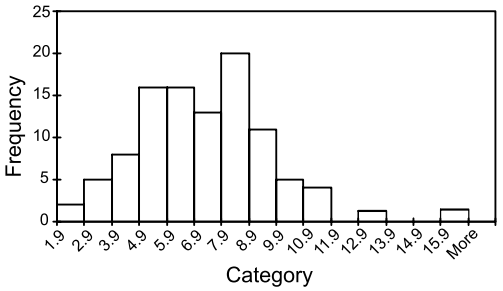


Fig. 6.5 *Histogram*

Often the mean of the data is indicated on the histogram. A bar chart is a series of bare representing the frequency of occurrence of data characteristics, the bar height indicates the number of times a particular quality characteristic was observed.

6. Flow Charts (or) Graphs

It shows the sequence of events in a process. They are used for manufacturing and service operations. Flow charts are often used to diagram operational procedures to simplify the system. They can identify bottlenecks, redundant steps and non-value added activities. A realistic flow chart can be constructed by using the knowledge of the person who are directly involved in the particular process. The flow chart can be identifies where delays can occur.

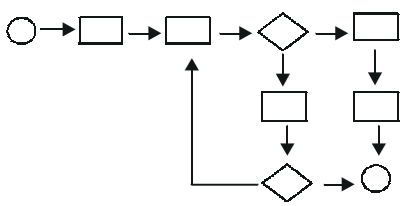


Fig. 6.6 *Flowchart*

7. Control Charts

It distinguish special causes of variations from common causes of variation. They are used to monitor and control process on an ongoing basis. A typical control chart plots a selected quality characteristic found from sub-group of observations as a function of sample number. Characteristics such as sample average, sample range and sample proportion of non-conforming units are plotted. The centre line on a control chart represents the average value of characteristics being plotted. Two limits know as the upper control limit (UCL) and lower control limit (LCL) are also shown on control charts. These limits are constructed so that if the process is operating under a stable system of chance causes, the problem of an observation falling outside these limits is quite small. Figure 6.7 shows a generalized representation of a control chart.

Control chart shows the performance of a process from two points of view. *First*, they show a snapshot of the process at the moment the data are collected. *Second*, they show the process trend as time progresses. Process trends are important because they help in identifying the out-of-control status if it actually exists. Also, they help to detect variations outside the normal operational limits, and to identify the cause of variations. Fig. 6.7 shows a generalised representation of a control chart.

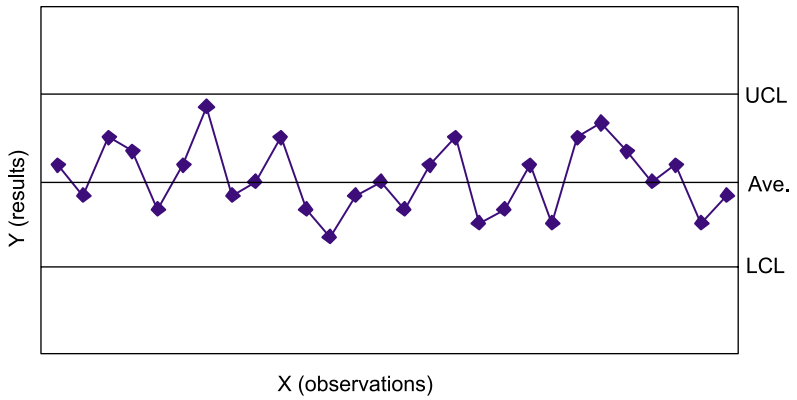


Fig. 6.7 *Control charts*

6.5.6 Causes of Variation in Quality

The variation in the quality of product in any manufacturing process is broadly classified as:

(*a*) Chance causes

(*b*) Assignable causes.

(a) Chance Causes

The chance causes are those causes which are inherit in manufacturing process by virtue of operational and constructional features of the equipments involved in a manufacturing process.

This is because of—

1. Machine vibrations
2. Voltage variations
3. Composition variation of material, etc.

They are difficult to trace and difficult to control, even under best condition of production. Even though, it is possible to trace out, it is not economical to eliminate. The chance causes results in only a minute amount of variation in process. Variation in chance causes is due to internal factors only the general pattern of variation under chance causes will follow a stable statistical distribution (normal distribution). Variation within the control limits means only random causes are present.

(B) ASSIGNABLE CAUSES

These are the causes which creates ordinary variation in the production quality.

Assignable cause's variation can always be traced to a specific quality. They occur due to—

1. Lack of skill in operation
2. Wrong maintenance practice
3. New vendors
4. Error in setting jigs and fixtures
5. Raw material defects

Variation due to these causes can be controlled before the defective items are produced. Any one assignable cause can result in a large amount of variation in process. If the assignable causes are present, the system will not follow a stable statistical distribution. When the actual variation exceeds the control limits, it is a signal that assignable causes extend the process and process should be investigated.

6.6 STATISTICAL PROCESS CONTROL

Statistical process control (SPC) is the application of statistical techniques to determine whether the output of a process conforms to the product or service design. It aims at achieving good quality during manufacture or service through prevention rather than detection. It is concerned with controlling the process that makes the product because if the process is good then the product will automatically be good.

6.6.1 Control Charts

SPC is implemented through control charts that are used to monitor the output of the process and indicate the presence of problems requiring further action. Control charts can be used to monitor processes where output is measured as either *variables* or *attributes*. There are two types of control charts: Variable control chart and attribute control chart.

1. **Variable control charts:** It is one by which it is possible to measures the quality characteristics of a product. The variable control charts are **X-BAR** chart, **R-BAR** chart, **SIGMA** chart.

2. **Attribute control chart:** It is one in which it is not possible to measures the quality characteristics of a product, *i.e.*, it is based on visual inspection only like good or bad, success or failure, accepted or rejected. The attribute control charts are **p-charts, np-charts, c-charts, u-charts.** It requires only a count of observations on characteristics *e.g.*, the number of non-conforming items in a sample.

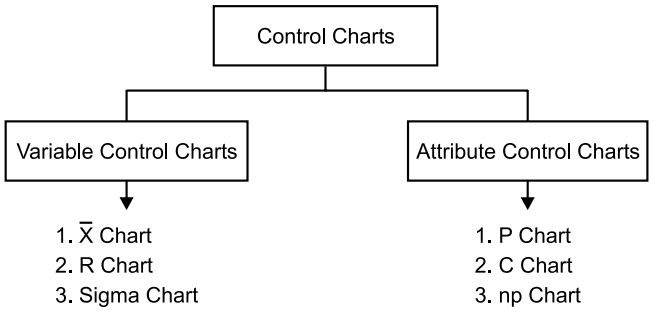


Fig. 6.8 *Control charts*

Characteristics of Control Charts

A control chart is a time-ordered diagram to monitor a quality characteristic, consisting of:

1. A nominal value, or centre line, the average of several past samples.
2. Two control limits used to judge whether action is required, an upper control limit (UCL) and a lower control limit (LCL).
3. Data points, each consisting of the average measurement calculated from a sample taken from the process, ordered overtime. By the Central Limit Theorem, regardless of the distribution of the underlying individual measurements, the distribution of the sample means will follow a normal distribution. The control limits are set based on the sampling distribution of the quality measurement.

Benefits of Using Control Charts

Following are the benefits of control charts:

1. A control chart indicates when something may be wrong, so that corrective action can be taken.
2. The patterns of the plot on a control chart diagnosis possible cause and hence indicate possible remedial actions.
3. It can estimate the process capability of process.
4. It provides useful information regarding actions to take for quality improvement.

Objectives of Control Charts

Following are the objectives of control charts:

1. To secure information to be used in establishing or changing specifications or in determining whether the process can meet specifications or not.
2. To secure information to be used on establishing or changing production procedures.
3. To secure information to be used on establishing or changing inspection procedures or acceptance procedures or both.
4. To provide a basis for current decision during production.

5. To provide a basis for current decisions on acceptance for rejection of manufacturing or purchased product.
6. To familiarize personnel with the use of control chart.

CONTROL CHARTS FOR VARIABLES

As the name indicates, these charts will use variable data of a process. X chart given an idea of the central tendency of the observations. These charts will reveal the variations between sample observations. R chart gives an idea about the spread (dispersion) of the observations. This chart shows the variations within the samples.

X-Chart and R-Chart: The formulas used to establish various control limits are as follows:

(a) Standard Deviation of the Process, σ, Unknown

R-Chart: To calculate the range of the data, subtract the smallest from the largest measurement in the sample.

The control limits are: $UCL_R = D_4 \bar{R}$ and $LCL_R = D_3 \bar{R}$

where $\bar{R}$ = average of several past *R* values and is the central line of the control chart, and

D_3, D_4 = constants that provide three standard deviation (three-sigma) limits for a given sample size

$\bar{X}$ *-Chart:* The control limits are:

$UCL_{\bar{X}} = \bar{\bar{X}} + A_2 \bar{R}$ and $LCL_{\bar{X}} = \bar{\bar{X}} - A_2 \bar{R}$

where $\bar{\bar{X}}$ = central line of the chart and the average of past sample mean's, and

A_2 = constant to provide three-sigma limits for the process mean.

(b) Standard Deviation of the Process, σ, Known

Control charts for variables (with the standard deviation of the process, σ, known) monitor the mean, $\bar{X}$, of the process distribution.

The control limits are:

$UCL = \bar{\bar{X}} + 2\sigma_{\bar{X}}$

and $LCL = \bar{\bar{X}} - 2\sigma_{\bar{X}}$

where $\bar{\bar{X}}$ = centre line of the chart and the average of several past sample means, Z is the standard normal deviate (number of standard deviations from the average),

$\sigma_{\bar{X}} = \sigma / \sqrt{n}$ and is the standard deviation of the distribution of sample means, and *n* is the sample size

Procedures to construct X-chart and R-chart

1. Identify the process to be controlled.

2. Select the variable of interest.
3. Decide a suitable sample size (n) and number of samples to be collected (k).
4. Collect the specified number of samples over a given time interval.
5. Find the measurement of interest for each piece within the sample.
6. Obtain mean (X) of each sample.
7. Establish control limits for X and R-charts.

CONTROL CHARTS FOR ATTRIBUTES

P-charts and C-charts are charts will used for attributes. This chart shows the quality characteristics rather than measurements.

P-CHART

A p-chart is a commonly used control chart for attributes, whereby the quality characteristic is counted, rather than measured, and the entire item or service can be declared good or defective.

The standard deviation of the proportion defective, p, is:

$\sigma_p = \sqrt{\bar{p}(1-\bar{p})/n}$, where n = sample size, and $\bar{p}$ = average of several past p values and central line on the chart.

Using the normal approximation to the binomial distribution, which is the actual distribution of p,

$$UCL_p = \bar{p} + Z\sigma_p$$

and

$$LCLp = \bar{p} - Z\sigma_p$$

where z is the normal deviate (number of standard deviations from the average).

ILLUSTRATIONS ON X BAR CHART AND R BAR CHART

(*i*) *Standard Deviation of the Process, Σ, Unknown*

ILLUSTRATION 1: *Several samples of size n = 8 have been taken from today's production of fence posts. The average post was 3 yards in length and the average sample range was 0.015 yard. Find the 99.73% upper and lower control limits.*

SOLUTION:

$\bar{\bar{X}}$ = 3 yds

$\bar{R}$ = 0.015 yds

A_2 = 0.37 from Statistical Table

$UCL = \bar{\bar{X}} + A_2\bar{R} = 3 + 0.37(0.015) = 3.006$ yds

$LCL = \bar{\bar{X}} - A_2\bar{R} = 3 - 0.37(0.015) = 2.996$ yds

ILLUSTRATION 2 (*Problem on $\bar{X}$ and R Chart*): *The results of inspection of 10 samples with its average and range are tabulated in the following table. Compute the control limit for the $\bar{\bar{X}}$ and R-chart and draw the control chart for the data.*

Sample No. (*Sample Size 5*)	$\overline{\overline{X}}$ (*Mean*)	*R* (*Range*)
1	7.0	2
2	7.5	3
3	8.0	2
4	10.0	2
5	9.5	3
6	11.0	4
7	11.5	3
8	4.0	2
9	3.5	3
10	4.0	2
	$\Sigma \overline{\overline{X}} = 76$	$\Sigma R = 26$

SOLUTION: $\overline{\overline{X}} = \Sigma \overline{\overline{X}}$/No. of samples

$\overline{R} = \Sigma R$/No. of samples

Therefore, $\overline{\overline{X}} = \frac{76}{10} = \mathbf{7.6}$

$\overline{R} = \frac{26}{10} = \mathbf{2.6}$

For $\overline{X}$ chart

Upper Control Limit (UCL) $= \overline{\overline{X}} + A_2 \overline{R}$

Lower Control Limit (LCL) $= \overline{\overline{X}} - A_2 \overline{R}$

For $\overline{R}$ chart

Upper Control Limit (UCL) $= D_4 \overline{R}$

Lower Control Limit (LCL) $= D_3 \overline{R}$

The values of various factors (like A_2, D_4 and D_3) based on normal distribution can be found from the following table:

$A_2 = 0.58$, $D_3 = 0$ and $D_4 = 2.11$

Thus, for $\overline{\overline{X}}$ chart

UCL $= 7.6 + (0.58 \times 2.6)$

$= 7.6 + 1.51 = \mathbf{9.11}$

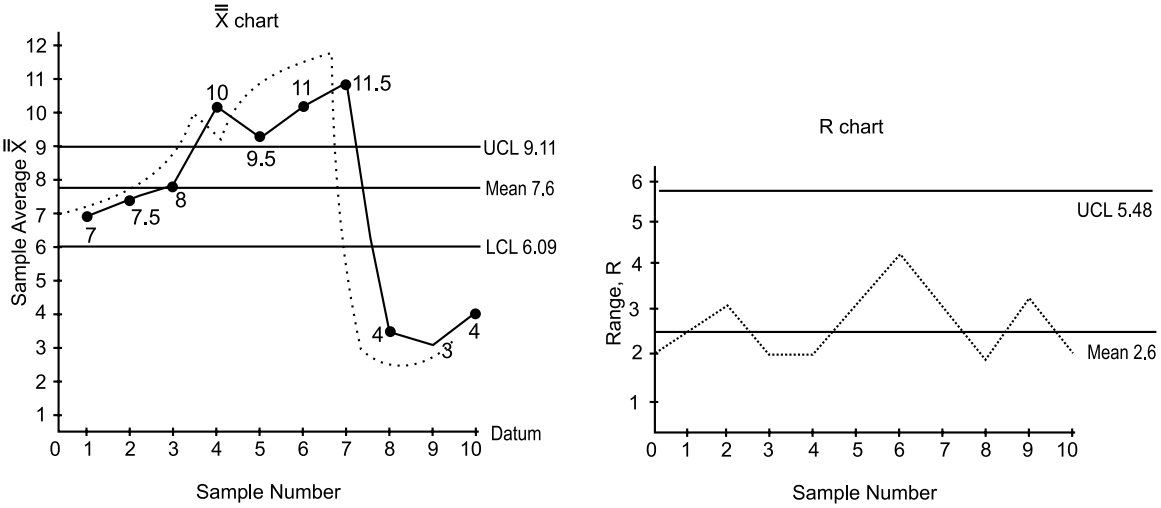
$\text{LCL} = 7.6 - (0.58 \times 2.6) = \mathbf{6.09}$

For R chart $\text{UCL} = 2.11 \times 2.6 = \mathbf{5.48}$

$\text{LCL} = D_3 \times \bar{R} = 0 \times \bar{R} = \mathbf{0}$

These control limits are marked on the graph paper on either side of the mean value (line). $\bar{\bar{X}}$ and R values are plotted on the graph and jointed, thus resulting the control chart.

From the $\bar{\bar{X}}$ chart, it appears that the process became completely out of control for 4th sample over labels.



(ii) Standard Deviation of the Process, σ, known

ILLUSTRATION 3: *Twenty-five engine mounts are sampled each day and found to have an average width of 2 inches, with a standard deviation of 0.1 inche. What are the control limits that include 99.73% of the sample means (z = 3)?*

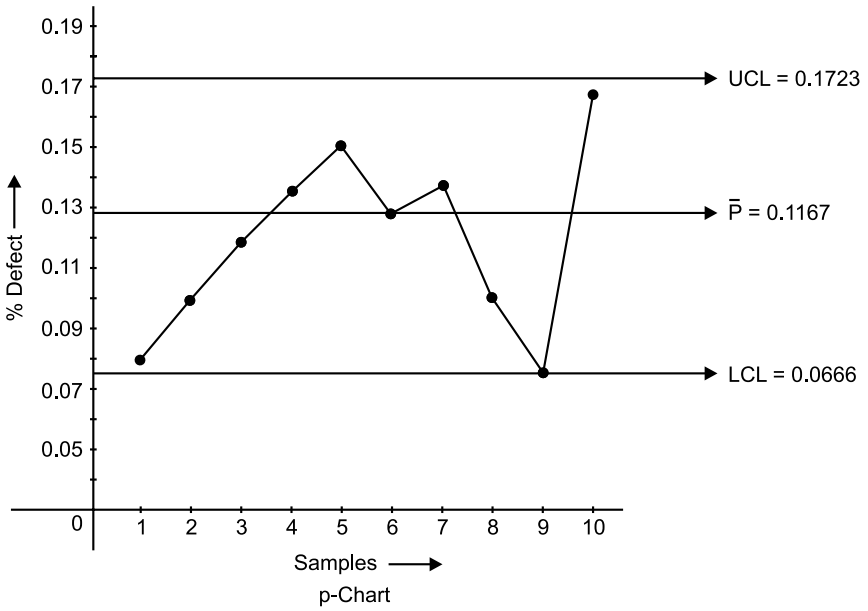
SOLUTION: $\text{UCL}_{\bar{X}} = \bar{\bar{X}} + Z\sigma_{\bar{X}} = 2 + 3\left(0.1/\sqrt{25}\right) = 2 + 0.06 = 2.06$ inches

$\text{LCL}_{\bar{X}} = \bar{\bar{X}} - Z\sigma_{\bar{X}} = 2 - 3\left(0.1/\sqrt{25}\right) = 2 - 0.06 = 1.94$ inches

ILLUSTRATION 4 ***(Problem on p-Chart)*****:** *The following are the inspection results of 10 lots, each lot being 300 items. Number defectives in each lot is 25, 30, 35, 40, 45, 35, 40, 30, 20 and 50. Calculate the average fraction defective and three sigma limit for P-chart and state whether the process is in control.*

SOLUTION:

Date	*Number of pieces inspected* (*a*)	*Number of defective pieces found* (*b*)	*Fraction defective* $p = (b)/(a)$	*% Defective loop*
November 4	300	25	0.0834	8.34
November 5	300	30	0.1000	10.00
November 6	300	35	0.1167	11.67
November 7	300	40	0.1333	13.33
November 8	300	45	0.1500	15.00
November 10	300	35	0.1167	11.67
November 11	300	40	0.1333	13.33
November 12	300	30	0.1000	10.00
November 13	300	20	0.0666	6.66
November 14	300	50	0.1666	16.66
Total Number = 10	3000	350		



Upper Control Limit, UCL $= \bar{p} + 3\sqrt{\dfrac{\bar{P}\left(1-\bar{P}\right)}{n}}$

$$\text{Lower Control Limit, LCL} = \bar{p} - 3\sqrt{\frac{\bar{P}\left(1-\bar{P}\right)}{n}}$$

where $$\bar{p} = \frac{\text{Total number of defective pieces found}}{\text{Total number of pieces inspected}}$$

$$\bar{p} = \frac{350}{3000} = \mathbf{0.1167}$$

and n = number of pieces inspected every day
= 300

Therefore, $$\sqrt{\frac{\bar{p}\left(1-\bar{p}\right)}{n}} = \sqrt{\frac{0.1167 \times \left(1-0.1167\right)}{300}}$$

$$= \sqrt{\frac{0.1167 \times 0.8333}{300}} = \mathbf{0.01852}$$

and $$3.\sqrt{\frac{\bar{p}\left(1-\bar{p}\right)}{n}} = 0.01852 \times 3 = \mathbf{0.05556}$$

Thus, UCL = 0.1167 + 0.05556 = 0.17226 = 0.1723 (Approx.)
LCL = 0.1167 – 0.05566 = 0.06114 = 0.0611 (Approx.)

Conclusion: All the samples are within the control limit and we can say process is under control.

Types of Sampling Errors

There are two types of errors. They are type-I and type-II that can occur when making inferences from control chart.

Type-I: Error or α-error or Level of Significance

Reject the hypothesis when it is true.

This results from inferring that a process is out of control when it is actually in control. The probability of type-I error is denoted by α, suppose a process is in control. If a point on the control chart falls outside the control limits, we assume that, the process is out of control. However, since the control limits are a finite distance (3σ) from the mean. There is a small chance about 0.0026 of a sample falling outside the control limits. In such instances, inferring the process is out of control is wrong conclusion.

The control limits could be placed sufficiently far apart say 4 or 5σ stand deviations on each side of the central lines to reduce the probability of type-I error.

Type-II: Error or β-error

Accept the hypothesis when it is false.

This results from inferring that a process is in control when it is really out of control. If no observations for outside the control limits we conclude that the process is in control while in reality it is out control. For example, the process mean has changed.

The process could out of control because process variability has changed (due to presence of new operator). As the control limits are placed further apart the probability of type-II error increases. To reduce the probability of type-II error it tends to have the control limits placed closer to each other. This increases the probability of type-I error. Thus, the two types of errors are inversely related to each other as the control limits change. Increasing the sample size can reduce both α and β.

6.6.2 Acceptance Sampling

The objective of acceptance sampling is to take decision whether to accept or reject a lot based on sample's characteristics. The lot may be incoming raw materials or finished parts.

An accurate method to check the quality of lots is to do 100% inspection. But, 100% inspection will have the following limitations:

- The cost of inspection is high.
- Destructive methods of testing will result in 100% spoilage of the parts.
- Time taken for inspection will be too long.
- When the population is large or infinite, it would be impossible or impracticable to inspect each unit.

Hence, acceptance-sampling procedure has lot of scope in practical application. Acceptance sampling can be used for attributes as well as variables.

Acceptance sampling deals with accept or reject situation of the incoming raw materials and finished goods. Let the size of the incoming lot be N and the size of the sample drawn be *n*. The probability of getting a given number of defective goods parts out a sample consisting of *n* pieces will follow binomial distribution. If the lot size is infinite or very large, such that when a sample is drawn from it and not replaced, then the usage of binomial distribution is justified. Otherwise, we will have to use hyper-geometric distribution.

Specifications of a single sampling plan will contain a sample size (*n*) and an acceptance number C. As an example, if we assume the sample size as 50 and the acceptance number as 3, the interpretation of the plan is explained as follows: Select a sample of size 50 from a lot and obtain the number of defective pieces in the sample. If the number of defective pieces is less than or equal to 3, then accept the whole lot from which the sample is drawn. Otherwise, reject the whole lot. This is called single sampling plan. There are several variations of this plan.

In this process, one will commit two types of errors, *viz*., type-I error and type-II error. If the lot is really good, but based on the sample information, it is rejected, then the supplier/ producer will be penalized. This is called producer's risk or type-I error. The notation for this error is α. On the other hand, if the lot is really bad, but it is accepted based on the sample information, then the customer will be at loss. This is called consumer's risk or type-II error. The notation for this error is β. So, both parties should jointly decide about the levels of producer's risk (α) and consumer's risk (β) based on mutual agreement.

OPERATING CHARACTERISTIC CURVE (O.C. CURVE)

The concepts of the two types of risk are well explained using an operating characteristic curve. This curve will provide a basis for selecting alternate sample plans. For a given value of sample size (*n*), acceptance number (C), the O.C. curve is shown in Fig. 6.8.

In Fig. 6.9, per cent defective is shown on *x*-axis. The probability of accepting the lot for given per cent defective is shown on *y*-axis. The value for per cent defective indicates the quality level of the lot inspected. AQL means acceptable quality level and LTPD indicates lot tolerance per cent defectives. These represent quality levels of the lot submitted for inspection. If the quality level of the lot inspected is at AQL or less than AQL, then the customers are satisfied with the quality of the lot. The corresponding probability of acceptance is called $1 - \alpha$. On the other hand, if the quality level is more than or equal to LTPD, the quality of the lot is considered to be inferior from consumer's viewpoint. The corresponding probability of acceptance of the lot is called β. The quality levelling between AQL and LTPD is called indifferent zone.

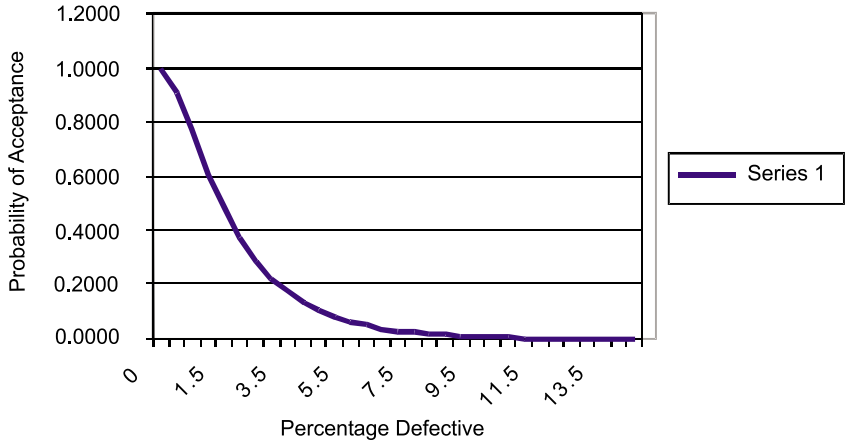


Fig. 6.9 *Operating characteristic curve*

So, we require α, β, AQL and LTPD to design a sample plan. Based on these, one can determine n and C for the implementation purpose of the plan.

Fig. 6.10 shows a various O.C. curves for different combinations of *n* and C.

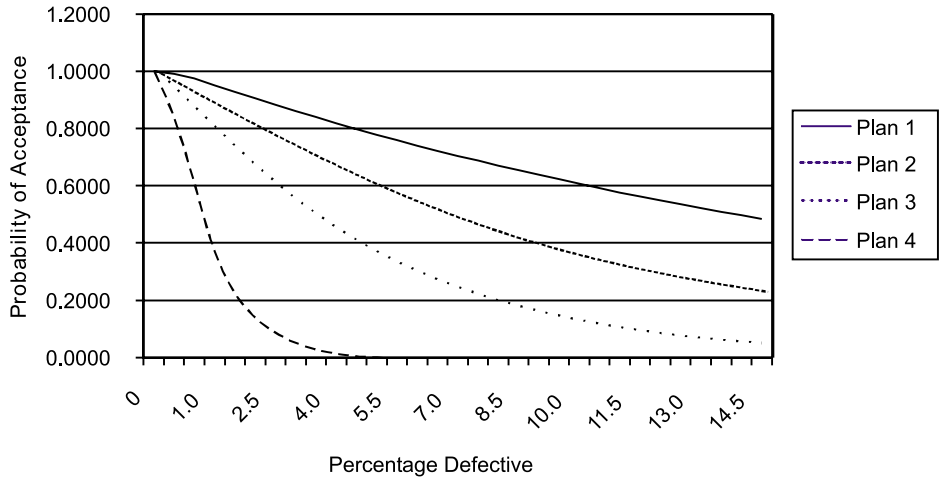


Fig. 6.10 *Operation characteristic curve for different samples.*

SINGLE SAMPLING PLAN

The design of single sampling plan with a specified producer's risk and consumer's risk is demonstrated in this section. The required data for designing such plan are as follows:

(*a*) Producer's Risk (α)

(*b*) Consumer's Risk (b)

(*c*) Acceptable Quality Level (AQL)

(*d*) Lot Tolerance Per cent Defectives (LPTD)

The objective of this design is to find out the values for the sample size (*n*) and acceptance number (C). The values for *n* and C are to be selected such that the O.C. curve passes through the following two coordinates:

- Coordinate with respect to the given α and AQL.
- Coordinate with respect to the given β and LTPD.

But, the values of *n* and C should be integers. So, it will be very difficult to find *n* and C exactly for the given parameters of the design. Hence, we will have to look for approximate integer values for *n* and C such that the O.C. curve more or less passes through the above two coordinates.

6.7 QUALITY CIRCLES

The quality circles begun in Japan in 1960s. The concept of quality circles is based on the participating style of management. It assumes that productivity will improve through an uplift of morale and motivations which are in turn achieved through consultation and discussion in informal groups. One organizational mechanism for worker participation in quality is the quality circle. It is typically an informal group of people that consists of operators, supervisors, managers and so on who get together to improve ways to make the product or deliver the service.

According to Juran, quality circle defined as "a group of work force level people, usually from within one department, who volunteer to meet weekly (on company time) to address quality problems that occur within their department."

Quality circle members select the problems and are given training is problem-solving techniques. A quality circle can be an effective productivity improvement tool because it generates new ideas and implements them. Where the introduction of quality circle is capably planned and where the company environment is supporting they are highly successful.

The benefits fall into two categories: those are measurable saving and improvement in the attitudes and behaviour of people. Quality circles pursue two types of problems, those concerned with the personal well being of the worker and those concerned with the well being of company.

6.7.1 Benefits of QC

The most important benefit of quality circles is their effect on people's attitudes fall into three categories:

1. Quality Circles Effect on Individual Characteristics

(*a*) Quality circles enable the individual to improve personal capabilities—group participation and learning specific problem-solving tools.

(*b*) Quality circles increase the individual's self-respect.

(*c*) Quality circles help worker change certain personality characteristics—shy person become as active.

2. Quality Circles Effect on Individuals Relations with Other

(*a*) Quality circles increase the respect of the supervisor for the worker.

(*b*) Quality circles increase workers understanding of the difficulties faced by supervisors—problem selection, solving and implementations.

(*c*) Quality circle increase management's respect for worker.

3. Quality Circles Effect on Workers and Their Attributes

(*a*) Quality circles change some workers negative attitudes.

(*b*) Quality circle reduces conflict stemming from the working environment.

(*c*) Quality circles help workers to understand better the reasons while many problems solved quickly.

Quality circles, as a **management tool**, are based on the following basic principles of people:

(*a*) People want to do a good job.

(*b*) People want to be recognized as intelligent, interested employees and to participate in decisions affecting their work.

(*c*) People want information to better understand goals and problems of their organization and make informed decisions.

(*d*) Employees want recognition and responsibility and a feeling of self-esteem.

Motivational methods are not enough for successful quality circle programs. Management support, technical knowledge, and statistical procedures are essential.

6.8 TOTAL QUALITY MANAGEMENT

Now-a-days, customers demand products/services with greater durability and reliability at the most economic price. This forces producers to strictly follow quality procedures right from design till shipment and installation of the products. So that goal of any competitive industry is to provide a product or service at the most economical costs, ensuring full customer satisfaction. This can be achieved through Total Quality Management (TQM), because, quality is not a technical function, but a systemic process extending throughout all phases of the business, *e.g.*, marketing, design, development, engineering, purchasing, production/operations.

As per Feigebaum, "*Total Quality Management* is an effective system of integrating the quality development, quality maintenance and quality improvement efforts of various groups in an organization so as to enable marketing, engineering, production and service at the most economical levels which allow for full customer satisfaction".

6.8.1 Benefits of TQM

The benefits of TQM can be classified into the following two categories:

1. Customer satisfaction oriented benefits.
2. Economic improvements oriented benefits.

1. **Customer satisfaction oriented benefits:** The benefits under this category are listed below:

(*a*) Improvement in product quality.
(*b*) Improvement in product design.
(*c*) Improvement in production flow.
(*d*) Improvement in employee morale and quality consciousness.
(*e*) Improvement of product service.
(*f*) Improvement in market place acceptance.

2. **Economic improvements oriented benefits:** The benefits under this category are as follows:

(*a*) Reductions in operating costs.
(*b*) Reductions in operating losses.
(*c*) Reductions in field service costs.
(*d*) Reductions in liability exposure.

6.9 ISO 9000 SERIES

ISO stands for International Organization for Standardization. It is an international body, which consists of representatives from more than 90 countries. The national standard bodies of these countries are the members of this organization. Bureau of Indian Standards (BIS) are the Indian representative to ISO, ISO and International Electro Technical Commission (IEC)) operate jointly as a single system. These are non-governmental organizations, which exist to provide common standards on international trade of goods and services.

ISO 9000 standards expect firms to have a quality manual that meets ISO guidelines, documents, quality procedures and job instructions, and verification of compliance by third-party auditors. ISO 9000 series has five international standards on quality managements. They are:

1. ISO 9000 — Quality management and Quality assurance standards
2. ISO 9001 — Quality systems: Quality in design
3. ISO 9002 — Quality systems: Production and Installation
4. ISO 9003 — Quality systems: Final inspection and test
5. ISO 9004 — Quality management and systems

6.9.1 Objectives of ISO 9000 Series

The objectives of ISO 9000 series is listed in Table 6.1.

TABLE 6.1: ISO 9000 series

Standard	*Objectives/Tasks*
ISO 9000	This provides guidelines on selection and use of quality management and quality assurance standards.
ISO 9001	It has 20 elements covering design, development, production, installation and servicing.
ISO 9002	It has 18 elements covering production and installation. It is same as ISO 9001 without the first two tasks, *viz*., design and development. This is applicable for the units excluding R & D functions.
ISO 9003	It has 12 elements covering final inspection and testing for laboratories and warehouses etc.
ISO 9004	This provides guidelines to interpret the quality management and quality assurance. This also has suggestions which are not mandatory.

6.9.2 Benefits of ISO 9000 Series

ISO 9000 series provides several tangible and intangible benefits which are listed below:

1. This gives competitive advantage in the global market.
2. Consistency in quality, since ISO helps in detecting non-conformity early which makes it possible to take corrective action.
3. Documentation of quality procedures adds clarity to quality system.
4. ISO 9000 ensures adequate and regular quality training for all members of the organization.
5. ISO helps the customers to have cost effective purchase procedure.
6. The customers while making purchases from companies with ISO certificate need not spend much on inspection and testing. This will reduce the quality cost and lead-time.
7. This will help in increasing productivity.
8. This will aid to improved morale and involvement of workers.
9. The level of job satisfaction would be more.

6.9.3 Steps in ISO 9000 Registration

1. Selection of appropriate standard from ISO 9001, ISO 9002 and ISO 9003 using the guidelines given in ISO 9000.
2. Preparation of quality manual to cover all the elements in the selected model.
3. Preparation of procedures and shop floor instructions which are used at the time of implementing the system. Also document these items.
4. Self-auditing to check compliance of the selected model.
5. Selection of a registrar and making application to obtain certificate for the selected model.

A registrar is an independent body with knowledge and experience to evaluate any one of the three models of the company's quality system (ISO 9002). Registrars are approved and certified by acridities.

The registrar, on successful verification and assessment will register the company. Before selecting a registrar, one should know the following:

1. Accreditors of the registrar.
2. Background and credibility of the registrar.
3. Cost of registration through the proposed registrar.
4. Expected harmony between the company and the potential registrar while working towards implementing ISO model in the company.

6.10 APPLICATION ISO 9000: ISO 14000 SERIES

OVERVIEW

The ISO 14000 series of environmental management standards are intended to assist organizations manage the environmental effect of their business practices. The ISO 14000 series is similar to the ISO 9000 series published in 1987. The purpose of the ISO 9000 series is to encourage organizations to institute quality assurance management programs. Although ISO 9000 deals with the overall management of an organization and ISO 14000 deals with the management of the environmental effects of an organization, both standards are concerned with processes, and there is talk of combining the two series into one.

Both series of standards were published by ISO, the International Organization for Standardization. The purpose of ISO is to facilitate international trade and cooperation in commercial, intellectual, scientific and economic endeavors by developing international standards. ISO originally focused on industrial and mechanical engineering standards. Now, it has ventured into setting standards for an organization's processes, policies, and practices.

The environmental standards of ISO 14000 deal with how a company manages the environment inside its facilities and the immediate outside environment. However, the standards also call for analysis of the entire life cycle of a product, from raw material to eventual disposal. These standards do not mandate a particular level of pollution or performance, but focus on awareness of the processes and procedures that can effect the environment. It should be noted that adherence to the ISO 14000 standards does not in anyway release a company from any national or local regulations regarding specific performance issues regarding the environment.

Some of the standards in the ISO 14000 series are:

- ISO 14001—Specification of Environmental Management Systems
- ISO 14004—Guideline Standard
- ISO 14010 through ISO 14015—Environmental Auditing and Related Activities
- ISO 14020 through ISO 14024—Environmental Labelling
- ISO 14031 through ISO 14032—Environmental Performance Evaluation
- ISO 14040 through ISO 14043—Life Cycle Assessment
- ISO 14050—Terms and Definitions

Although the ISO 14000 standards are similar to the ISO 9000 standards, the nature of the environmental standards creates a need for people who are technical environment professionals in addition to those required to maintain the documentation necessary for certification.

6.10.1 The Benefits of ISO 14000 Certification

The benefits of acquiring ISO certification go beyond the satisfaction of doing a good deed. Adhering to the standard may result in better conformance to environmental regulations, greater marketability, better use of resources, higher quality goods and services, increased levels of safety, improved image and increased profits.

- The environmental awareness and the documentation that are required by the ISO 14000 standards assist a company in conforming to environmental regulations. This means that a company, by diligently adhering to the standard, is less likely to violate environmental regulations and is always ready for inspection by a regulatory agency. In addition, the certification and documentation may aid a company in acquiring capital, in defending itself during environmental litigation and in receiving insurance or permits.
- A wider market for a company's goods and services may result from certification. Many corporations and governments will be looking for suppliers that are ISO 14000 certified in order to maintain their own certification and environment-friendly image.
- Producers of consumer goods may find that many consumers not only try to purchase goods from environment-friendly companies, but will spend a little more if they feel they are helping the environment. In order to reap this benefit, a company must make their environmental efforts known through advertising and labelling.
- The process analyses that go along with ISO 14000 certification may result in streamlining processes and more efficient use of resources and raw materials and subsequently reduce a company's costs.
- Reducing the amount of potentially dangerous substances in an end product may result in less use of dangerous chemicals in a plant. This leads to a safer internal environment for employees and the possibility of reduced insurance premiums. Improved employee morale may result when employees feel that the workplace is safer and they are contributing to the environmental effort.

ANNEXURE–I

List of Certifying Bodies

The list of certification bodies with Quality Management System and Environmental Management System for 9000 series is listed in the following tables:

List of Certification Bodies for Quality Management Systems:

Accrn. No.	Name	Address	Website & Phone
QM001	Det Norske Veritas AS (Certification Services, India)	203, Savitri Sadan 1, 11, Preet Vihar Community Centre, New Delhi-110 092 India	www.dnv.com Tel +91 11 2202 3242 Fax +91 11 2202 3244
QM002	TUV India Pvt. Ltd.	801, Raheja Plaza - I, L.B.S Marg, Ghatkopar (West), Mumbai - 400 086	www.tuvindia.co.in Tel + 91 22 6647 7000 Fax + 91 22 6647 7009
QM003	Bureau Veritas Certification (India) Pvt. Ltd.	Marwah Centre, 6th Floor, Opposite Ansa Industrial Estate, Kishanlal Marwah Marg, Off Sakivihar Road, Andheri, East, Mumbai–400 072	www.certification.bureauveritas.co.in Tel +91 22 6695 6330 Fax +91 22 6695 6302
QM004	Intal Quality Certification Pvt. Ltd.	Platinum City, G / 13 / 03, Site No. 02, Next to CMTI, HMT Road, Yeshwantpur Post Bangalore - 560 022	www.i-quality.net Tel +91 80 4117 2752 Fax +91 80 4128 0347
QM006	Indian Register Quality Systems (IRQS) Dept. of Indian Register of Shipping	161 A, Maker Towers 'E' (16th Floor), Cuffe Parade, Mumbai - 400 005	www.irclass.org Tel +91 22 2215 3871 / 2215 4162 / 2215 4164 Fax +91 22 2215 4250
QM007	ICRS Management Systems Private Ltd.	808, Suneja Tower - II, District Centre, Janakpuri, New Delhi 110058	www.icrsms.com Tel +91 11 3290 6779 Fax +91 11 2554 2745
QM008	British Standards Institution (BSI Management Systems India Pvt. Ltd.)	The Mira Corporate Suites (A-2), Plot 1&2, Ishwar Nagar, Mathura Road, New Delhi - 110 065	www.bsi-global.com Tel +91 11 2692 9000 (eight lines) Fax +91 11 2692 9001
QM010	TUV Rheinland (India) Private Limited	504-506, Prestige Centre Point Cunningham Road Bangalore - 560 002	www.ind.tuv.com +91 80 22282489 / 90
QM011	TUV South Asia Private Limited	321, Solitaire Corporate Park, Chakala, Andheri (East) Mumbai - 400 093	www.tuv-sud.in www.tuvsouthasia.com Tel +91 22 6692 3415 Fax +91 22 6692 3418
QM012	NVT Quality Certification Pvt. Ltd.	CAP-1, EOIZ, Export Promotion Industrial Park, Near ITPL, Whitefield, Bangalore - 560 066, India	www.nvtqualitygroup.org Tel +91-80-5534 3536/ 37 Fax +91-80-2841 6767
QM014	American Quality Assessors (India) Private Limited	"Victory Vihar", 4th Floor, Himayatnagar, Hyderabad - 500 029 (India)	www.aqa.in Tel +91 040 2322 2894/895, 2322 1228 Fax +91 040 2322 3023

QM015	Bureau of Indian Standards	Bureau of Indian Standards 9, Bahadur Shah Zafar Marg New Delhi - 110 002 (India)	www.bis.org.in Telefax: +91 11 2323 1842
QM016	URS Certification Ltd.	B-8, Dayanand Colony, Lajpat Nagar - IV New Delhi - 110 024	www.ursindia.com Tel + 91 11 2622 3444 Fax + 91 11 2622 6974
QM018	Transpacific Certifications Ltd.	59/10, Old Rajinder Nagar, New Delhi 110060	www.tclcertifications.com Tel / Fax +91 11 235 25107/ 08/12
QM019	Knowledge Partner QR Pvt. Ltd.	Address B-1, Nutech Narayana 48, Tirumalai Road, T. Nagar Chennai 600017 India	www.kpqr.com Tel + 91 44 4202 4230 Fax + 91 44 2834 2041
QM020	QMS Certification Services Pvt. Ltd.	207, Durga Towers, RDC, Raj Nagar Ghaziabad (U.P.) 210002	www.qmscertification.com Tel +91 120 282 4369, 652 6369, 647 1796 Fax +91 120 282 4369
QM021	Lloyd's Register Quality Assurance Ltd. (India Branch)	Solitaire Corporate Park, Building No. 1, 5th Floor, 151 M. Vasanji Road Chakala, Andheri East, Mumbai 400 093	Tel + 91 22 2825 8601/ 02 Fax + 91 22 2825 8618
QM022	Vexil Business Process Services Pvt. Ltd.	208A/4 Savitri Nagar, New Delhi 110017, India	www.vexilbps.com Tel + 91 11 3245 3661 Fax + 91 11 2601 8001
QM023	NQA Certification Pvt. Ltd.	# 15/1, 9th Main, Hampi Nagar (RPC Layout), Near Govt. Central Library, Vijayanagar II Stage, Bangalore - 560 040. India	www.nqaindia.com Tel + 91 80 3272 2698, 2314 2208, 2314 2407 Fax + 91 80 4117 8952.
QM024	QSS, Quality Management Services	'Sai Shraddha', 'C' Wing, Station Road, Vikhroli (East), Mumbai 400083, India	Tel + 91 22 2574 9499/3501 Mobile 0 98210 56619 Fax + 91 22 2574 6200
QM025	QSI (India) Certifications Pvt. Ltd.	557, Sector - 1, Vidyadhar Nagar, Jaipur - 302 023 (India)	www.qsi-india.com Tel +91 0141 2236 895 Fax +91 0141 2236 133 Mobile +91 98290 17133
QM026	RINA India Pvt. Ltd.	B Wing 607/608, Everest Chambers, Marol Naka, Andheri-Kurla Road, Andheri (E), Mumbai-400 059, India	www.rina.org Tel +91 022 2851 5862/63 Fax +91 022 2852 5139
QM027	SGS India Pvt. Ltd.	SGS House, 9-1-127/2, 43, Sarojini Devi Road, Secunderabad - 500 003, India	www.sgs.com Mobile 0 98488 14239

QM028	Global Certification Services	"Sathya Manor", W- 27/3, 1st Street, Anna Nagar, Chennai 600 040, India	www.global-certification.com Tel 044 2621 3360 Fax 044 2622 4657
QM029	NQAQSR Certification Pvt. Ltd.	107/55, Madhuban Building, Nehru Place, New Delhi-110019	www.nqacertification.com Tel 011 - 4654 2669 - 76 Fax +91 11 4163 6292/2921 7475
QM030	BSC International Certifications Co.	Office No. 124, Dwarka Complex, SCO 102-103, Sector 16, Faridabad Pin 121002, Haryana, India	www.bsc-icc.com Telefax: +91 129 3290068 / 98108 82505 / 93134 82505
QM031	Swiso (India) Pvt. Ltd.	507 Pragati Tower, 26 Rajendra Place New Delhi 110008	www.swisoindia.com Tel +91 11 41539720 Fax +91 11 41539721
QM032	KBS Certification Services Pvt. Ltd.	343, Om Shubham Tower Neelam - Bata Road N.I.T. Faridabad - 121 001 (Haryana)	Tel +91 129 4034513, 4054513 Fax +91 0129 4034513 Mobile +91 98107 12926
QM033	Intertek Systems Certification (a division of Intertek Testing Services India Pvt. Ltd.)	501 Everest House, 4th Floor 6 Suren Road Andheri (East) Mumbai - 400093	Tel +91 22 6703 8686 Fax +91 22 6703 8688
QM034	STQC Certification Services	Ministry of Communication & IT STQC Directorate, Electronic Niketan 6, CGO Complex, Lodhi Road New Delhi 110003	Tel +91 11 2436 3107/2430 1817 Fax +91 11 2436 3083

ANNEXURE–II

List of Certification Bodies for Environmental Management Systems for 14000 Series:

Accrn. No.	Name	Address	Website & Phone
EM001	Det Norske Veritas AS (Certification Services, India)	203, Savitri Sadan 1, 11, Preet Vihar Community Centre, New Delhi–110 092 India	www.dnv.com Tel +91 11 2202 3242 Fax +91 11 2202 3244
EM002	TUV India Pvt. Ltd.	801, Raheja Plaza–I, L.B.S Marg, Ghatkopar (West), Mumbai–400 086	www.tuvindia.co.in Tel + 91 22 6647 7000 Fax + 91 22 6647 7009
EM003	International Certification Services Pvt. Ltd.	22/23, Goodwill Premises, Swastik Estate, 178, CST Road, Kalina, Santacruz (East) Mumbai–400 098 (Maharashtra)	www.icsasian.com Tel + 91 22 2650 7777-82 Fax + 91 22 2650 7777-82 extension–333

EM004	Bureau Veritas Certification (India) Pvt. Ltd.	Marwah Centre, 6th Floor, Opposite Ansa Industrial Estate, Kishanlal Marwah Marg, Off Sakivihar Road, Andheri East, Mumbai - 400 072	www.certification.bureauveritas.co.in Tel +91 22 6695 6330 Fax +91 22 6695 6302
EM005	Indian Register Quality Systems (IRQS) Dept. of Indian Register of Shipping	161 A, Maker Towers 'E' (16th Floor), Cuffe Parade, Mumbai - 400 005	www.irclass.org Tel +91 22 2215 3871/ 2215 4162 / 2215 4164 Fax +91 22 2215 4250
EM006	NVT Quality Certification Pvt. Ltd.	CAP-1, EOIZ, Export Promotion Industrial Park, Near ITPL, Whitefield, Bangalore–560 066, India	www.nvtqualitygroup.org Tel +91-80-5534 3536/ 37 Fax +91-80-2841 6767
EM007	Lloyd's Register Quality Assurance Ltd. (India Branch)	Solitaire Corporate Park, Building No. 1, 5th Floor, 151 M. Vasanji Road Chakala, Andheri East, Mumbai 400 093	Tel + 91 22 2825 8601/ 02 Fax + 91 22 2825 8618
EM008	Vexil Business Process Services Pvt. Ltd.	208A/4 Savitri Nagar, New Delhi 110017, India	www.vexilbps.com Tel + 91 11 3245 3661 Fax + 91 11 2601 8001
EM009	TUV South Asia Private Limited	321, Solitaire Corporate Park, Chakala, Andheri (East) Mumbai - 400 093	www.tuv-sud.in www.tuvsouthasia.com Tel +91 22 6692 3415 Fax +91 22 6692 3418
EM010	AQSR India Private Limited	3rd Floor, 7 Community Center East of Kailash New Delhi–110 065 (India)	www.aqsr.com Tel +91 11 4160 1242, 3294 2268 Fax +91 11 4160 1243
EM011	NQAQSR Certification Pvt. Ltd.	107/55, Madhuban Building, Nehru Place, New Delhi-110019	www.nqacertification.com Tel 011 - 4654 2669–76 Fax +91 11 4163 6292/2921 7475

EXERCISES

Section A

1. Define quality.
2. What do you mean by inspection?
3. Mention the objectives of inspection.
4. Mention any four drawbacks of inspection.
5. What do you mean by 'control'?
6. Mention the control process.
7. Define 'quality control'.

8. Mention different types of quality control.
9. What is statistical process control?
10. What is QC?
11. Mention two types of control charts.
12. Mention the characteristics of control charts.
13. What is P-chart?
14. What do you mean by 'quality circles'?
15. What do you mean by TQM?
16. Mention the five international standards of ISO 9000 series.
17. What is ISO?

Section B

1. What is inspection? Explain the purpose of inspection.
2. Explain the different methods of inspection.
3. Explain the steps in quality control process.
4. Explain the objectives of quality control.
5. Explain the cause of variation in quality.
6. What are the benefits of using control charts.
7. Explain the objectives of control charts.
8. Explain the benefits of TQM.
9. What are the benefits of ISO 9000 series?
10. What are the steps in ISO 9000 registration?

Section C

1. Discuss the different types of inspection.
2. Discuss the seven tools for quality control.
3. Discuss the fundamental factors affecting quality.
4. Discuss the '9 M' 's of quality of product or service.

Skill Development

FAST FOOD RESTAURANT VISIT: Get the information for the following questions:

1. Quality control technique adopted for raw material.
2. Maintenance of quality in the process of manufacture.
3. Method of quality control technique (i.e. inspection or sampling technique).
4. Quality control tools used (i.e. Pareto chart, Scatter diagram etc.)
5. Application of control charts (i.e. control charts for variable i.e. thickness and size of pizza, and for attributes i.e. number of defects in process of manufacturing)
6. Types of errors in accepting or rejecting samples (i.e. accepting bad one and rejecting good one or vice versa).

7. Total quality Management approach for continual improvement of quality.
8. Quality standard certification obtained if any.

CASELET

The Roots of Quality Control in Japan: An Interview with W. Edwards Deming Dr. Deming, you said it will take about thirty years for the United States to catch up with Japan. This is a somewhat pessimistic view of the United States. Would you elaborate on this point?

I don't really know how long it will take. I think it will take thirty years; it should take all of thirty years. I don't think America will catch up with Japan because, so far as I can see, the Japanese system has the advantage over the American system. For example, consider the principle of constancy of purpose, which is absolutely vital and is number one in my Fourteen Points. It refers to planning for the future with constancy of purpose.

Now in America some companies certainly do have constancy of purpose, but most do not. Most have a president who was brought in to improve the quarterly dividend. That's his job; you can't blame him for doing it. He'll be there a while, and then go on to some other place to raise the quarterly dividend there. For instance, someone told me that there were five candidates for president of one of the biggest and most famous of America's companies. When one of them was selected, the other four resigned from the company. Such a thing could not happen in Japan. So you see, the American system is so set up that it cannot use the talents of its people. That's very serious.

People cannot work for the company. They only get out their quota. You can't blame a person for doing the job that is cut out for him since he has to pay his rent and take care of his family. You can't blame him, but you can blame management for a situation in which people cannot work for the company. An employee cannot remain on the job to find out for sure what the job is. The foreman does not have time to help him. As a matter of fact, the foreman may decide a particular person cannot do the job at all and perhaps should be let go. People report equipment out of order and nothing happens. If someone reports equipment out of order more than three or four times, that person is considered a troublemaker. If he tries to find out more about the job from the-foreman, he is considered a troublemaker. People find out that it is impossible to do what is best for the company or do their best work for the company. They just have to carryon as best they can, given the handicaps.

In addition, people have to use materials that are not suited to the job, and this creates a sense of desperation. There isn't much they can do about it-if they report, or try to do something, they are labeled troublemakers. This situation does not exist in Japan. There, everyone is willing to help everyone else.

Dr. Deming, as you've mentioned, one of the Fourteen Points emphasizes constancy of purpose. Personally, I learned a great deal from that. Could you elaborate a little more on that point?

A good way to assess a company's constancy of purpose is to evaluate the source of ultimate authority in that company. To whom does the president of the company answer? Does anybody own the company? Do the owners answer to the stockholders? The stockholders, thousands of them, who want dividends-to whom do they answer? Do they answer to their

consciences? Do they answer to a built-in institution? Do they answer to a constitution of the company? Is there a constitution for the company?

Some companies have a constitution. In medical service, for example, you have some constancy of purpose. Not all, but some nursing homes or other medical institutions are under the governance of a religious board, and they're very exact about service. The head of the organization answers to constancy of purpose. There is a constitution with an aim of going beyond the making of dividends.

You have to pay to keep such institutions going, but their job is service. The reason why the public school systems fail in America is because the schools don't answer to anybody. There is no constitution. What is their aim? Is it to teach, or to produce? Is it to help youngsters that have ability to develop that ability, or is it something else? I don't know. The aim is not stated, so the schools are failing.

We hear that American companies are now changing and adopting such things as quality control. Do you think American companies are heeding your message?

Many companies are forming QC circles in America without understanding what they're doing. QC circles cannot be effective in the absence of quality control, which means management actively adopting my Fourteen Points. Many companies are forming QC circles because management wants a lazy way to avoid the job of improving quality and productivity. These circles will make a worthwhile contribution if they are given a chance, but QC circles alone are not quality control. Once it becomes obvious that management is working on the Fourteen Points and is trying to do something to make people more effective in their work, then the workers will be creative.

Can you imagine people in a QC circle being effective when half of them will be turned out on the streets when business slacks off? Can you imagine an effective QC circle when half or even fewer of the people involved were rehired after being laid off during a slump? People have to feel secure. That means, according to the word's derivation, "without concern," from the Latin se for "without" and cure meaning "care" or "concern." Security means being able to speak, ask each other questions, and, help one another. There is nothing to hide and no one to please. Most people who work are only trying to please somebody because otherwise they might not have a job.

The lack of constancy of purpose in America is very serious. For example, I received a letter from a man who asked what he could do that would have a lasting benefit for his company. The problem is, the man will probably be where he is for only two more years. At the end of two years, he will either be promoted or he will look for a job with another company. He asked what fire he could start that would continue to burn after he leaves his job, whether he is promoted at the same company or goes elsewhere. It's a very serious question. I don't know if there is an answer.

There is another serious matter in this country: the supposition that quality control consists of a bag of techniques. Quality control is more than just a set of techniques. But you cannot have quality control without physical techniques. One of my Fourteen Points is to remove fear within a company, to make people secure. I don't know of any physical techniques to bring this about. But it is through physical techniques that I discovered the existence of fear. Fear is costing

companies a great deal of money and causing a lot of waste in out-of-order machines and rework. Fear causes wasted human effort and wasted materials. It arises because people do not understand their jobs, and have no place to go for help. I don't know of any statistical technique by which to establish constancy of purpose and eliminate fear.

Statistical techniques are certainly necessary for purchasing and selling materials, since without them you cannot measure or understand the quality of what you are buying. American industry and American government, especially the military, are being rooked by the practice of purchasing from the lowest bidder. They are forcing everyone to conform to the lowest price. That is wrong because there is no such thing as price without a measure of quality. Purchasing departments are not prepared to measure quality; they only know arithmetic. They understand that thirteen cents less per thousand pieces translates into so many thousands of dollars per year. But they don't understand that the quality of these pieces may be so bad that it will cause a great deal of trouble.

You already referred to American management's lack of understanding of quality control for production processes. Could we go back to that?

Most American managers 'have no idea how deep the trouble is, and those who do have no idea of what can be done. There is no way for them to learn what to do that I know of.

In the United States, I have been intrigued by the notion of the trade-off between quality and price and the trade-off between productivity and quality. Here these are seen as different things, and yet your message, which you say the Japanese have accepted, is not to treat quality and price, and productivity and quality, as trade-off. Why has this been so difficult for Americans to understand?

Americans simply have no idea of what quality is. Ask almost any plant manager in this country and he'll say it is a trade-off, that you have one or the other. He does not know that you can have both, and that once you have quality, then you can have productivity, lower costs, and a better market position. Here, people don't know this, but they know it in Japan. In 1950 in Japan, 1 was able to get top management together for conferences to explain what they had to do. No such gathering has ever been held in America and I don't know if anybody has any way of organizing one. In Japan, Mr. Ishikawa of JUSE organized conferences with top management in July 1950, again in August, then six months later, and so on. Top management understood from the beginning what they must do, and that as they improved quality, productivity would increase. They had some examples within six months, and more within a year. News of these examples spread throughout the country, and everyone learned about them because Japanese management was careful to disseminate the information.

The supposition of so many Americans that better quality means more gold plating or polishing, more time spent to do better work, is just not true. Quality improvement means improving the process so it produces quality without rework, quickly and directly. In other words, quality means making it right the first time so you don't have to rework it. By improving the process, you decrease wasted human effort, wasted machine time and materials, and you get a better product. If you decrease rework by six percent, you increase the productivity of a production line by six percent; and increase its capacity by the same amount. Therefore, in many cases, increased capacity could be achieved in this country simply by reducing wasted human

effort, machine time, and materials. In this country, better use of existing machinery-not new machinery or automation-is the answer.

How do you respond to American management's idea that mechanization and automation are cost-saving devices rather than quality-improvement devices? In Japan mechanization and automation are seen as quality improvement, obviously with cost-saving benefits on the side. But in Japan they're working toward mechanization, automation, and the use of robots as quality-improvement devices.

New machinery and automation very often bring higher costs, not lower ones. They also bring headaches and troubles, which a company is unprepared to handle. The result is that they decrease production, increase costs, lower quality, and create problems the company never had before. The best thing to do is learn to use what you have efficiently. Once you learn that, then there's a possibility you may learn to use more sophisticated equipment. I'm afraid that time is a long way off for this country.

In Japan, now that they're using present equipment successfully and efficiently and cannot extract any more capacity, the only way to increase production is with new automated machinery, because there are no more people to employ. There are no employment agencies in Japan where you can find people to work in plants. In the United States, on the other hand, there are seven million unemployed, maybe half of whom are actually able and willing to work, and are good workers.

Back in the 1950s, you made a prophetic statement when you told the Japanese that if they pursued this quality-first approach, Japan would dominate the world market and everyone, including the United States, would demand protection from Japanese imports. Did you make that prediction because you were convinced that American industries were not pursuing the proper course of action in this field?

No, I saw, through the conferences with the top management in Japan, that Japan could do a better job with quality control than America had ever done. Americans had not done well with quality control because they thought of it as a bag of techniques. As a group, management in America never knew anything about quality control. What you had in America, from the intensive statistical courses I started at Stanford University, were brilliant fires and applications all over the country. But when a person changed jobs, the fire burned out and there was nobody in management to keep it going.

We held the first course at Stanford in July 1942, and seventeen people came. Two months later, Stanford University gave another course, and later other universities gave courses. I taught twenty-three of them myself. By that time, they would be attended by fifty or sixty or seventy people. The War Department also gave courses at defense suppliers' factories. Quality control became a big fire. As a matter of fact, courses were given to a total of ten thousand people from eight hundred companies, but nothing happened.

Brilliant applications burned, sputtered, fizzled, and died out. What people did was solve individual problems; they did not create a structure at the management level to carry out their obligations. There was not sufficient appreciation at the management level to spread the methods to other parts of the company.

The man who saw these things first was Dr. Holbrook working at Stanford. He knew the job that management must carry out. He saw it first. We tried, but our efforts were feeble, and

the results were zero. We did not know how to do it. In our eight-day courses, we would ask companies to send their top people, but top people did not come. Some came for one afternoon. You don't learn this in one afternoon. So quality control died out in America.

Let me put it this way: more and more, quality control in America became merely statistical methods-the more applications, the better. Instead of finding many problems, we need to find the big problem. Where are the problems? Let's find the big problems first. What methods will help? Maybe no methods will help. Let's be careful-so many things that happen are just carelessness. We don't need control charts for them. We just need some action from management to cut that carelessness. Wrong design? That's management's fault. Recall of automobiles? Management's fault, not the workers' fault.

People started control charts everywhere. The Ford Company had charts all over their assembly plants across the country, one chart on top of another. Quality control "experts" sat and made more and more charts. One man told me his job was to count the number of points out of control every day. But what happened was nothing. Quality control drifted into so-called quality control departments that made charts. They would look at the charts and perhaps tell somebody if something was out of control. The only people who could do anything never saw the charts and never learned anything. That included everybody. Top management never heard or learned anything; people on the production lines did not learn anything. That was totally wrong, because the first step is for management to take on my Fourteen Points, namely, to gain purpose. The Japanese had already accomplished this task. The Japanese were all ready to work on training. JUSE was ready. But in 1950, quality control had practically died out in America. When I went to Japan in 1950, I said to myself, "Why repeat in Japan the mistakes that were made in America? I must get hold of top management and explain to them what their job is, because unless they do their part, these wonderful engineers will accomplish nothing. They will make business applications and then the fire will burn out."

It was at that time I was fortunate enough to meet Mr. Ichiro Ishikawa, who, after three conferences, sent telegrams to forty-five men in top management telling them to come and hear me. Well, I did a very poor job, but I explained what management must do, what quality control is from a management standpoint. For example, I told them to improve incoming materials, which means working with vendors as if they were members of your family, and teaching them. I told them they must learn statistical control of quality. It's a big job.

Incoming materials were wretched, deplorable, and nobody seemed to care. They just thought that industry consisted of taking what you got and doing the best you could. But I explained that that won't do because now you must compete. The consumer you never thought of-to whom you must now export-is in America, Canada, and Europe. Improve agriculture, yes, but the better way-the quicker way, the most effective way-is to export quality. They thought it could not be done. They said they had never done it, that they had a bad reputation. I told them, you can do it-you have to do it, you must. You must learn statistical methods. These methods of quality control must be a part of everybody's job.

At that time, consumer research was unknown in Japan, but the aim of making products was to help somebody. I think they had never thought of the consumer as the most important end of the production line. I told them they must study the needs of the consumer. They must look ahead

one year, three years, eight years, to be ahead in new services and new products. As they learned, they must teach everyone else. Well, that was the natural Japanese way. I did not know how much, but I gave them that advice.

How did you develop your own views, not only of statistical control methods, but also your central message that quality determines productivity?

By simple arithmetic, if you have material coming in that is difficult to use -and there was plenty of it coming to Japan in 1950-you will produce a lot of wasted human effort, machine time, and materials. There will be a lot of rework, with people occupying time trying to overcome the deficiencies of defective incoming material. So if you have better material coming in, you eliminate waste; production, quality, and productivity go up; costs go down; and your market position is improved.

Well I think that I have put some principles on paper that everybody knew but that, in a sense, nobody knew. They had never been put down on paper. I stated those principles in Japan in the summer of 1950, some for the first time. They're obvious, perhaps, as Newton's laws of motion are obvious. But like Newton's laws, they're not obvious to everyone.

Is there a company in the United States that has heeded your message? Are there some isolated cases?

The Nashua Corporation in Nashua, New Hampshire, under the direction of its former president, William E. Conway, was off to a good start. Mr. Conway himself was doing a great deal, not only for his corporation, but for American industry. Almost every day, visiting teams of ten to fifteen people from other companies came to Mr. Conway's offices and plants to hear about what he was doing. He was getting a very good start. The entire company was meant for quality.

Why is he so different from other American managers?

I don't know. There are other good companies. Some of them have started lately and they are pushing along one of the great problems is finding competent statistical consultants. There are very few that can give competent training. One company I work with must train fifty thousand people to discover problems how long do you think it will take the purchasing department to learn to take quality into consideration along with price? It will take five years or more, and at the end of five years a lot of people will be gone. They will have other jobs. It's going to take a long time. There is no quick road.

Discussion Questions

(*a*) Dr. Deming seems to put more emphasis on corporate culture than on quality control methodology. What is necessary to change a corporate culture to be as quality conscious as Deming feels is necessary to compete in global markets?

(*b*) What are the relationships between quality and productivity?

(*c*) If automation continues to be installed in both Japanese and U.S. industry, will the quality problem be solved by technology?

(*d*) What are the prospects for making the quality of U.S. manufactured products companies? How can such a goal be achieved, given the current Japanese lead?

[**Source:** *These edited interviews were given by Dr. Deming to the Pacific Basin Center Foundation on September 8, 1981, and July 28,1984*]