PART I

QUALITY CONTROL

1

Introduction to Quality Control

1.1. INTRODUCTION

If we are to talk intelligently about the quality of thing or the quality of a product, we must have in mind a clear picture of what we mean by quality. Quality can be defined in various ways, depending on the perspective of the user. Quality is

- Conformance to applicable specifications and standards.
- Fitness for use.
- Satisfaction of customer wants, need and expectations at the competitive cost.

Conformance. Quality of conformance refers to the extent to which the product complies with the specifications, standards, and workmanship criteria imposed upon its manufacture. A product manufactured to specification and in conformance with the control limits of the production processes should satisfy the customer provided that the specifications have correctly translated the customer's requirements (and that pertinent reliability aspects were considered in design). The difference between quality of design and quality of conformance is illustrated by the following example : Two electrical freezers are made to the same design, specifications, procedures, and standards—they both have the same quality of design. One of them is unable to carry its cooling load as advertised ; it therefore does not conform to the specification, and the two units differ in their quality of conformance.

Fitness for use. All human institutions (industrial companies, schools, hospitals etc.) are engaged in providing products or services to human beings. This relationship is constructive only if the goods and services respond to the overall needs of the user in price, delivery date, and fitness for use. If the goods and services do respond to these overall needs, they are said to be possess

marketability. Among these overall needs, the extend to which the product successfully serves the purpose of the user, during usage, is called its "fitness for use". This concept of fitness for use, popularly called by such names as "Quality" is a universal concept, applicable to all goods and services. Fitness for use is determined by those features of the product which the user can recognize as beneficial to him, *e.g.* clear reception of T.V. programs, timeliness of bus service, life of shoes etc. Fitness for use is judged as seen by the user, not by the manufacturer.

Customer Satisfaction at the Competitive Price. Another definition says that product or service quality is the producer's ability to satisfy customer needs while still being able to realize a profit. This definition has both a customer and a manufacturer orientation. While the customer is the reason for the organization's existence, the product manufacturer and service producer must still make a profit.

This definition focuses on satisfying the customer at the competitive price. Many customers will not purchase a product or service unless it is reasonably priced.

1.2. QUALITY CONTROL

The top management of a company of course bears overall responsibility for that company's products and services, but factory managers, department managers, section managers, supervisors, and foremen are all responsible for the quality of the products and services produced by their respective factories, departments, sections, group and teams. Meanwhile, the duty of engineers and technical specialists is systematically and methodically to prepare, revise, and improve standards that will enable their companies to supply society with products as economically as possible.

Controlling quality does not simply mean studying statistics or preparing control charts. I believe that the aims of quality control should be first to strengthen a country's economic base by enabling it to export large volumes of high quality, reasonably priced products, and finally to secure a firm economic foundation for the future by establishing and actively exporting industrial technology. The ultimate aims of quality control should to enable companies to share their profits sensibly and fairly among consumers, employers and shareholders, to raise the country's standards of living, and to make life better for the world as a whole.

Quality control is the engineering and management activity by which we measure the quality characteristics of the product, compare them with specifications or requirements, and take appropriate remedial action whenever there is a difference between actual performance and the standard.

The objective of the quality-control department is not to eliminate all variability of the items produced—which would be an impossible task—but to constrain this variability to economically feasible limits. The basic quality control plan should provide for the control of the product throughout its development and production cycle.

Control is impossible unless objectives and targets are clearly defined, and it is also impossible if objectives and policies change with every passing whim. For example, we cannot control a design or process without setting quality standards, and we cannot control research and technology without setting quality targets. There are six steps to control the quality, which is shown in Fig. 1.1.

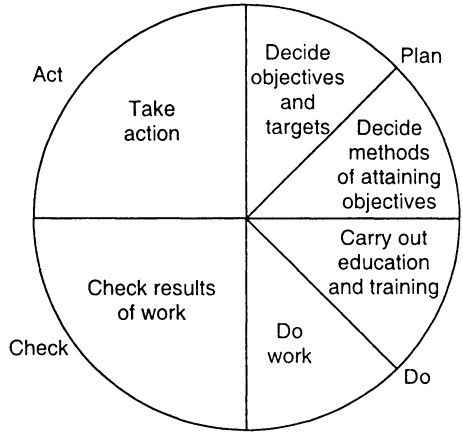

Fig. 1.1. The six control steps.

Plan-do-check-act (PDCA) cycle is also known as Deming Cycle.

The above is the basic philosophy of control, and control only takes place when the loops shown in Fig. 1.2 are followed. If this is done with respect to clearly defined quality objectives, it is quality control. Also control can be exercised effectively if statistical methods are used skillfully at each of the above stages. This is statistical control. When exercised with respect to quality, it is statistical quality control (SQC).

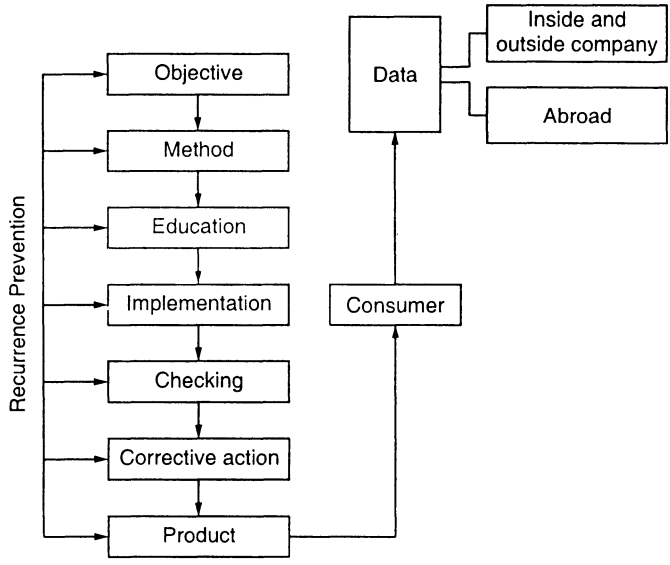

Fig. 1.2. Cycle of Quality Control.

Talk of making good-quality products is often misunderstood as making products of the best possible quality. However, when we talk about quality in quality control. We are talking about designing, manufacturing, and selling products of a quality that will actually satisfy the consumer in use. In other words, "good quality" means the best quality that a company can produce with in present production technology and process capability, and that will satisfy the consumers needs, in terms of factors such as cost and intended use.

We wish to produce good quality for the consumer, we must therefore decide in advance what quality of product to plan, produce, and sell. To do this, we must consider the following four aspects of quality, and plan, design and control it comprehensively.

(*i*) **Q (Quality).** quality characteristics in their narrow sense. Performance, purity, strength, dimensions, tolerances, appearance, reliability, lifetime, fraction defective, rework fraction, non-adjustment ratio, packing method, etc.

(*ii*) **C (Cost).** Characteristics related to cost and price (*i.e.* profit), cost control and profit control.

yield, unit cost, losses, productivity, raw materials, costs, production costs, fraction defective, defects, cost price, selling price, profit, etc.

(*iii*) **D (Delivery).** Characteristics related to qualities and bad times (quantity control).

Production volume, sales volume, changeover losses, inventory, consumption, bad times, changes in production plans, etc. Quality control is impossible without numerical data.

(*iv*) **S (Service).** Problem arising after products have been shipped; product characteristics requiring follow-up.

Safety and environmental characteristics, product liability, product liability prevention, compensation period, warranty period, before-sales and after-sales service, parts interchangeability, spare parts, ease of repair, instruction manuals, inspection and maintenance methods, packaging method, etc.

When products are accompanied by good after-sales service, are of reliable quality, and have a good compatibility and long life times with little dispersion, the consumer will probably buy them with confidence. Conversely, the consumer will be unsure about buying products with short life times and poor reliability with which something goes wrong a few days or a few months after purchase.

1.3. QUALITY ASSURANCE SYSTEM

This section discusses the basic elements of quality assurance system. The objective of such a system is to maintain the necessary standard of quality. Basic elements of the quality assurance system are as follows :

1. Configuration Management. Procedure used to specify describe, audit, and release the configuration of an item, as well as to control it during modifications or changes (configuration includes all of an items functional and physical characteristics as given in the documentation and as present in the hardware and/or software). Configuration management is one of the most important tools for quality assurance during the development phase. It is subdivided into configuration identification, auditing, control, and accounting. Auditing of a configuration is carried out through design review.

2. Quality Tests. Tests to verify whenever an item conforms to specified requirements. Quality tests include incoming inspections as well as qualification tests, production tests, and acceptance tests. They also cover reliability, maintainability and safety aspects. To be cost effective, quality tests must be co-ordinated and, if possible integrated into a test and screening strategy.

3. Quality Control During Production. Control of the production processes and procedures in order to reach a stated quality of manufacturing.

4. Quality Data Reporting System. A system to collect, analyze, and correct all defects and failures (faults) occurring during the production and test of an item, as well as to evaluate and feedback the corresponding quality and reliability data. Such a system can be computer assisted. Analysis of failures and defects must be traced to the cause in order to determine the best corrective actions necessary to avoid repetition of the same problem. Ideally, a quality data reporting system should also remain active during the operating phase.

1.4. THE RESPONSIBILITY FOR QUALITY

Every manufacturing industry and many service industries have a formal quality assurance function. The responsibility of this organisation is to assist general management and manufacturing management in providing quality assurance for the companies products. The quality organization does not design, manufacture distribute, or service the product. This means that the responsibility for quality is spread throughout the entire organization. Some specific functional responsibilities are discussed below :

1. Product Planning, Marketing and Sales. These functions have responsibility for providing the market research activities that lead to a product description that best fulfills the customer's fitness-for-use objectives. They are also responsible for presenting product quality data to the consumer.

2. Development of Design and Specification of Product. These functions have responsibility for the original product design, determining specifications, selection of materials, tolerances and performance characteristics of the product.

3. Manufacturing Engineering. This function is responsible for the selection of manufacturing process, and selection of work methods.

4. Purchasing. This function is responsible for selecting vendors and interacting with those vendors regarding the quality of the materials and components that they supply.

5. Manufacturing Management. These managers are responsible for operator education, proper maintenance of manufacturing facilities, correct interpretation of drawings and

specifications, and for maintaining control of the product as it is manufactured.

6. Inspection and Test. This function is responsible for measuring the quality of incoming parts and materials, and for appraising the performance of a manufactured products to the specifications.

7. Packaging. This function is responsible for the packaging of the product. Proper packaging protects contents against damage due to vibration, shock, and heat etc.

8. Customer Service. This function is responsible for maintenance of the product, including all repair activities and installation of replacement part. The principal role of product service is to help the consumer realize the intended performance potential of the product over its useful life.

1.5. COMPANY-WIDE QUALITY MANAGEMENT

As the issue of quality becomes more prominent, Quality assurance is evolving into a company-wide quality management (CWQM) function. CWQM is also called the total quality management (TQM) or total quality control (TQC). The quality organization is the prime facilitator or consultant in this efforts. Corporate quality groups are small with more authority but less direct responsibility for quality. For example, the quality organisation has authority to stop defective material from leaving the manufacturing door, while the responsibility for the control of quality is pushed to the manufacturing department operator.

Implementing TQC requires the following :

1. All departments must participate, with the head of each department taking the lead. Each department must take the initiative in biasing with related departments.
2. Every employee must become involved ; in other words, all members of the company, from the chairman of the Board through the Chief Executive, senior officers, directors, department and section managers, and technical and administrative staff down to QC circle members (*i.e.* shop foreman, full time workers, sales staff, and part timers) must participate in implementing quality control.
3. QC must be implemented comprehensively. To produce products that consumers and society will buy happily,

quality (Q) must come first, but at the same time, costs (C) (*i.e.*, sales price and profit), delivery (D) (*i.e.* production volumes, sales volumes, and inventories) and safety (S) (including social and environmental factors) must be comprehensively controlled. This is why the term "total quality control" (TQC) is used.

TQC means improving the quality of everything, *i.e.* creating a high-quality company, high-quality executives and department manager, high-quality sales departments, personnel departments, factories and laboratories, high quality sales staff and supervisors, high-quality suppliers, high quality distributors, etc.

1.6. THE BENEFITS OF COMPANYWIDE QUALITY CONTROL

When a company implements quality control is earnest throughout its organization. The following benefits are obtained :

1. Quality (in its narrow sense) is raised, and the number of defective products decreases.
2. Quality becomes more uniform and the number of complaints decreases.
3. Reliability increases, confidence in the products improves, and customers' trust is obtained.
4. Products can be sold at higher prices.
5. A quality assurance system is established, and the trust of consumers and customers is obtained.
6. Complaints are dealt with more quickly, and effective action is taken to prevent their recurrence.
7. Technology is established, engineers can be employed in their true capacity, and technology improves.
8. Relationships and the flow of information within the company organization become smoother.
9. Human relations improve, and barriers between departments are broken down.
10. The whole of the company organisation can be rationalized and department managers, section managers, supervisors, and foremen become able to work more effectively.

1.7. QUALITY PROBLEM SOLVING

The system approach is a logical, systematic method for solving many types of quality problems. The value of this method lies in its ability to define a problem and to arrive at a solution through a logical processes. The goal of the system approach is not only to eliminate the symptom, put also to identify the root cause and to eliminate it as well. The system approach follows the systematic methodology illustrated in Fig. 1.3 and described in the following paragraphs.

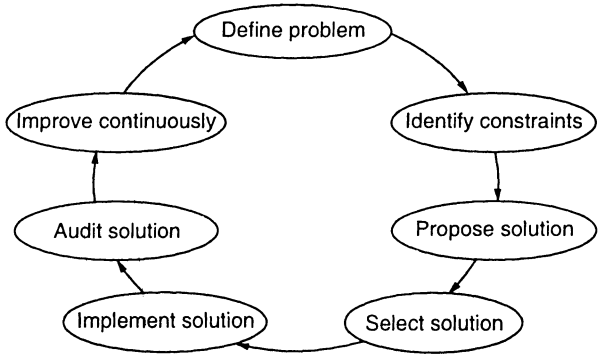

Fig. 1.3. Systems approach.

Define Problem. The problem and its scope are first outlined. The problem is defined to ensure it is solvable. It is not solvable with available organizational resources, including knowledge personnel, financial and political, additional resources are requisitioned. Sometimes, even with additional resources a problem cannot be solved.

It is important that a problem be defined to determine whether it is solvable within the required time period and with available resources. A problem might become a major and costly project that taxes corporate resources and does not return the initial investment. In such case, the entire CWQM program and any subsequent improvement projects might be jeopardized.

Modern industrial or service problems are complex. Usually one person does not have the skills or knowledge to solve them. So interdisciplinary teams are created to solve these problems. These teams consist of representative from the area where the problem is located as well as experts from peripheral areas who can supply information. For example, if a vendor is supplying a defective product, a team composed of personnel from purchasing,

engineering, and manufacturing is formed to work with the vendor to improve product quality.

Identity Constraints. Constraints to solving the problem or implementing solutions are identified. Constraints are factors that might have to be anticipated and eliminated as problems arise. Common constraints are cost, time, size, regulations, environments, permits and culture.

With a quality related decision, cost is always a major constraints. Any product or service has to be cost-effective. However good a product or service, it will only be purchased if it is priced competitively.

Propose Solutions. The team brainstorms and proposes possible solutions. In the nonthreatening atmosphere of a brainstorming session, the people are less constrained and are free to offer unconventional and novel ideas for problems that previously were thought to be unsolvable. Sometimes the most bizarre proposal turns out to be the most innovative solutions.

Select Solutions. Each proposed solution is evaluated in terms of its ability to overcome the constraints discussed and to achieve corporate objectives depending on selection criteria. Proposals are ranked and qualified based on corporate requirements. The solution that is most cost-effective, easiest to implement generates the most revenue, or save the most money is selected.

If the problem is a defective product or a deficient machine, the selected solution should attack the root cause of the problem. For example, if the identified cause of failed pump is a defective seal, then replacing the seal would get the pump operating, but not prevent premature pump failure. The seal is not the root cause solution. A properly designed and implemented preventive maintenance program could have extended the life of the seal.

Implement Solution. Next the solution is implemented, so that problems do not recur. People in the area where the problem is located are responsible for its implementation. These people have a personnel interest in its implementation and the elimination of the problem. These people also monitor implementation over time, so that the problem does not recur. Schedules are established, and project milestones are identified and tracked.

Audit Solution. The solution is finally monitored for effectiveness, cost and reliability. If the solution does not solve the problem, further corrective action may be warranted. In corrective

action, the team goes back to identifying the problem and repeating the whole cycles, always keeping in mind the goal is continuously improvement. This forms a feedback loop, so that a solution is optimized and the problem does not occur.

Improve Continuously. Continuous improvement in a product or service has become a necessary element of an organization's survival in a global economy. In times past, if a firm had a quality or low priced product, the firm probably dominated the marked. There were several reasons for this. The number of firms producing the product was limited. There were also barriers for firms trying to enter the market such as traffic, cultural restrictions, cost, technical knowledge, or management skills.

Now there is no such things as long-term ownership of a market. In a global economy, many of these constraints are gone, and if a market for a product or service evolves, an organization somewhere will emulate or improve on the existing product.

1.8. QUALITY COST CATEGORIES

The first step toward quantifying quality cost is to agree on what is meant by "quality costs". This is done by identifying and defining those categories of costs which are associated with making, finding, repairing, or avoiding (preventing) defects. Many manufacturing companies have gone through this process, resulting in a rather standardized set of core categories. The core categories and their typical definitions area as follows :

1.8.1. Internal Failure Cost

These are costs which would disappear if no defects existed in the product prior to shipment to the customer. They include :

Scrap. The net loss in labor and material resulting from defectives which can not economically be repaired or used.

Rework. The cost of correcting defectives to make them fit for use. Sometimes this category is broadened to include extra operations created to solve an epidemic of defects, or special piece rates provided for a similar purpose.

Retest. The cost of reinspection and retest of products which have undergone rework or other revision.

Downtime. The cost of ideal facilities resulting from defects (*e.g.* printing press down due to paper breaks, aircraft ideal due to unreliability). In some industries this category is very large and hence is quantified. In most companies, this is ignored.

Yield losses. The cost of process yields lower than might be attainable by improved controls. Includes "overfill" of constraints (going to customers) due to variability in filling and measuring equipment.

Disposition. The effert required to determine whether nonconforming products are usable and to make final disposition. Includes the time of individuals and material review boards, no matter what the department of origin of the workers involved, e.g. a designer preparing a deviation authorization.

1.8.2. External Failure Costs

These costs also would disappear if there were no defects. They are distinguished from the internal failure costs by the fact that the defects are found after shipment to the customer. They include :

Complaint adjustment. All costs of investigation and adjustment of justified complaints attributable to defective product or installation.

Returned material. All costs associated with receipt and replacement of defective product returned from the field.

Warranty charges. All costs involved in service to customers under warranty contracts.

Allowances. Cost of concessions made to customers due to substandard products being accepted by the customers as is. Includes loss is income due to downgrading products for sale as seconds.

1.8.3. Appraisal Costs

These are the costs incurred to discover the condition of the product mainly during the "first time through". The cost include :

Incoming material inspection. The cost of determining the quality of vendor made products, whether by inspection or receipt, by inspection at the source or by surveillance methods.

Inspection and test. The cost of checking the conformance of the product throughout its progression in the factory, including final acceptance, and check of packing and shipping. Includes life, environmental and reliability tests. Also includes testing done at the customer's premises prior to turning the product over to the customer. (It is usual to keep separate subaccounts for inspection, laboratory testing, and field testing). In collecting these costs, what is decisive is the kind of work done and not the department name (*i.e.* the work may be done by chemists in a technical department

laboratory, by sorters in the Production Department, by testers in the Inspection Department, or by outsider services engaged for the purpose of testing).

Maintaining accuracy of test equipment. Includes the cost of operating the system that keeps the measuring instruments and equipment in calibration.

Materials and Services Consumed. Includes the costs of products consumed through destructive tests, materials consumed (*e.g.* X-ray film), and services (e.g. electric power) where significant.

Evaluation of Stocks. Includes the costs of testing products in field storage or in stock to evaluate degradation.

1.8.4. Prevention Costs

These costs are incurred to keep failure and appraisal costs to a minimum. The usual categories are as follows :

Quality Planning. This includes the broad array of activities which collectively create the overall quality plan, the inspection plan, the reliability plan, the data system, and the numerous specialized plans. It includes also preparation of manuals and procedures needed to communicate these plans to all concerned.

As in the case of inspection and test, some of this work may be done by personnel who are not on the pay roll of a department called Quality Control. The decisive criterion is again the type of work, not the name of the department performing the work.

New-products review. Includes preparation of bid proposals, evaluation of new design, preparation of test and experimental programs, and other quality activities associated with the launching of new designs.

Training. The costs of preparing training programs for attaining and improving quality performance, no matter which department is to be the recipient of the training. Includes the cost of conducting formal training programs as well.

Process Control. Includes the part of process control which is conducted to achieve fitness for use, as distinguished from achieving productivity, safety etc. (separating these is often difficult).

Quality data acquisition and analysis. This is the work of running the quality data system to acquire continuing data on quality performance. It includes analysis of these data of identify the quality troubles, to sound the alarms, stimulate study, etc.

Quality reporting. Includes the work of summarizing and publishing quality information to the middle and upper management.

Improvement Projects. Includes the work of structuring and carrying out progress for breakthrough to new levels of performance, *i.e.* defect prevention programs, motivation programs etc.

1.9. THE MEANING OF QUALITY IN SOFTWARE

There is nothing particularly new in the ideas of software quality. It has evolved from inspection methods and procedures into systems of control and is characterised by the requirement for conformance to formal procedures. It is, however, rooted in the manufacturing activities which have dominated hardware production for several decades. Hardware quality is achieved by bringing together conforming parts and materials by mean of proven processes.

The design of software, on the other hand, has no equivalent model. Simple conformance of individual program modules to some specification is certainly no guarantee of system quality and, in any case, it is rarely possible of test for total conformance until all the system modules are brought together as a whole. In other words, although it is possible to validate each module of code without reference to the system, the inter-relationship of coded modules is far more subtle than is the case with hardware pieceparts.

Currently quality systems concentrate on establishing the existenance of standards and controls and seek, by means of audit, to verify that they are applied. They operate by specifying various areas for control and requiring that suitable audits take place to verify that they are being applied.

The role of quality management, in these systems, is to monitor conformance with procedures and standards by means of :

- Establishing quality plans
- Quality management reporting
- Review meetings
- Quality audits

In some cases the software quality function is set up as a separate activity from the existing hardware quality. Due to the slightly different skills involved, or perhaps to the craft approach which still pervades the production of software, the activity often

evolves as a separate responsibility. This can lead to a blinkered approach to the resolution of problems due to the polarisation of failures into 'hardware problems' and 'software problems'. When, more often than not, a solution can be found in a compromise involving both. The principles of quality are common to both and there should be a focal responsibility for this function within any organisation.

There has to be an identifiable organisation responsibility for software quality. The important thing is that the actual function can be identified—actual titles are not very important. In a small organisation individuals often carry out a number of different tasks and the quality activities may well be adequately carried out by someone who contributes them with other duties.

There should be quality mannual for the organisation and a quality plan together with specific documents for each project. Whereas the quality manual describes the tools and procedures available, the quality plan consists of specific methods drawn from the manual, for that project. These should be produced by the design team but controlled independently of the design activity. They may not have these fancy titles but what is important is the intent. Quality plans must be used effectively and not just left on the shelf.

Specialist quality staff are essential to ensure that customer requirements are adequately planned at the precontract stage. During the project the quality engineer will review progress with the project manager and others.

The quality plan must embrace :

— How, when, and by whom reviews are to be carried out.
— What standards, procedures and codes of practice will be applied.
— The extent of quality control of subcontractors.
— Method of failure reporting.
— Test strategy and the control of testing.
— Extent of customer involvement in project quality.

The basic quality attribute for software is that the final product performs all functions in the manner intended under all required conditions. To achieve this level of quality, the final software design must contain a minimum of mistakes in implementing these intentions as well as being void of misconceptions. In the long run, high quality software save time and money, especially when the system is later maintained or enhanced.

REVIEW QUESTIONS

1.1. Define quality control, and explain what is importance of customer in quality control ?

1.2. What are the important elements of the quality assurance system ?

1.3. What are functional responsibilities of quality ?

1.4. What is difference between quality control and total quality control ?

1.5. Write the benefits of companywide quality control.

1.6. How to solve quality problem ?

1.7. Describe quality cost categories.

1.8. What is difference between internal failure cost and external failure cost ?

1.9. What is role of quality planning in preventive cost ?

1.10. What is meaning of quality in software ?