QUALITY CONTROL

FIFTH EDITION

DALE H. BESTERFIELD

QUALITY CONTROL
FIFTH EDITION

Dale H. Besterfield, Ph.D., P.E.
Professor Emeritus
College of Engineering
Southern Illinois University
Principal
Besterfield & Associates

Prentice Hall
Upper Saddle River, New Jersey ■ Columbus, Ohio

Library of Congress Cataloging-in-Publication Data
Besterfield, Dale H.
Quality control / Dale H. Besterfield. — 5th ed.
p. cm.
Includes bibliographical references and index.
ISBN 0-13-632571-8
1. Quality control. I. Title
TS156.B47 1998
658.5′62—dc21

97-9443
CIP

Editor: Stephen Helba
Production Editor: Rex Davidson
Design Coordinator: Julia Zonneveld Van Hook
Cover Designer: Rod Harris
Production Manager: Patricia A. Tonneman
Marketing Manager: Debbie Yarnell

This book was set in Times Roman by Bi-Comp, Inc. and was printed and bound by R. R. Donnelley & Sons Company. The cover was printed by Phoenix Color Corp.

Printed in the United States of America

10 9 8 7 6 5 4 3 2

ISBN: 0-13-632571-8

Prentice-Hall International (UK) Limited, *London*
Prentice-Hall of Australia Pty. Limited, *Sydney*
Prentice-Hall of Canada, Inc., *Toronto*
Prentice-Hall Hispanoamericana, S. A., *Mexico*
Prentice-Hall of India Private Limited, *New Delhi*
Prentice-Hall of Japan, Inc., *Tokyo*
Simon & Schuster Asia Pte. Ltd., *Singapore*
Editora Prentice-Hall do Brasil, Ltda., *Rio de Janeiro*

PREFACE

This book provides a fundamental, yet comprehensive, coverage of quality control concepts. A practical state-of-the-art approach is stressed throughout. Sufficient theory is presented to ensure that the reader has a sound understanding of the basic principles of quality control. The use of probability and statistical techniques is reduced to simple mathematics or is developed in the form of tables and charts.

The book has served the instructional needs of technology students in technical institutes, community colleges, and universities. It has also been used by undergraduate and graduate business students. Professional organizations and industrial corporations have found the book an excellent training manual for instruction of manufacturing, quality, inspection, marketing, purchasing, and product design personnel.

Quality Control, Fifth Edition, begins with an introductory chapter about quality responsibility. This chapter is followed by quality improvement techniques, fundamentals of statistics, control charts for variables, additional SPC techniques for variables, fundamentals of probability, and control charts for attributes. A subsequent group of chapters describes acceptance sampling and standard sampling plans. The final chapters cover the topics of cost of poor quality, computer utilization, and total quality management.

This Fifth Edition includes a complete updating of all material. It also includes a new computer software diskette.

I am indebted to the publishers and authors who have given permission to reproduce their charts, graphs, and tables. I thank Dennis Lithgow of Southern Illinois University and Dr. Greg E. Maksi, State Technical Institute of Memphis, for reviewing the manuscript. Professors, practitioners, and students throughout the world have been most helpful in pointing out the need for further clarification and additional material in this Fifth Edition.

Dale H. Besterfield

CONTENTS

1 INTRODUCTION TO QUALITY

INTRODUCTION

Definitions

When the expression "quality" is used, we usually think in terms of an excellent product or service that fulfills or exceeds our expectations. These expectations are based on the intended use and the selling price. For example, a customer expects a different performance from a plain steel washer than from a chrome-plated steel washer because they are a different grade. When a product surpasses our expectations we consider that quality. Thus, it is somewhat of an intangible based on perception.

Quality can be quantified as follows:

$$Q = P/E$$

where Q = quality
P = performance
E = expectations

If Q is greater than 1.0, then the customer has a good feeling about the product or service. Of course, the determination of P and E will most likely be based on perception, with the organization determining performance and the customer determining expectations. Customer expectations are continually becoming more demanding.

Quality has nine different dimensions. Table 1-1 shows these nine dimensions of quality with their meanings and explanations in terms of a slide projector.

These dimensions are somewhat independent; therefore, a product can be excellent in one dimension and average or poor in another. Very few, if any, products excel in all nine dimensions. For example, the Japanese were cited for high-quality cars in the 1970s based only on the dimensions of reliability, conformance, and aesthetics. Therefore, quality products can be determined by using a few of the dimensions of quality.

Marketing has the responsibility of identifying the relative importance of each dimension of quality. These dimensions are then translated into the requirements for the development of a new product or the improvement of an existing one.

Quality control is the use of techniques and activities to achieve, sustain, and improve the quality of a product or service. It involves integrating the following related techniques and activities:

TABLE 1-1 The Dimensions of Quality.

DIMENSION	MEANING AND EXAMPLE
Performance	Primary product characteristics, such as the brightness of the picture
Features	Secondary characteristics, added features, such as remote control
Conformance	Meeting specifications or industry standards, workmanship
Reliability	Consistency of performance over time, average time for the unit to fail
Durability	Useful life, includes repair
Service	Resolution of problems and complaints, ease of repair
Response	Human-to-human interface, such as the courtesy of the dealer
Aesthetics	Sensory characteristics, such as exterior finish
Reputation	Past performance and other intangibles, such as being ranked first

Adapted from David A. Garvin *Managing Quality: The Strategic and Competitive Edge* (New York: Free Press, 1988).

1. *Specifications* of what is needed
2. *Design* of the product or service to meet the specifications
3. *Production* or *installation* to meet the full intent of the specifications
4. *Inspection* to determine conformance to specifications
5. *Review of usage* to provide information for the revision of specifications if needed

Utilization of these activities provides the customer with the best product or service at the lowest cost. The aim should be continued quality improvement.

Statistical quality control (SQC) is a branch of quality control. It is the collection, analysis, and interpretation of data for use in quality control activities. While much of this book emphasizes the statistical approach to quality control, this is only a part of the total picture. *Statistical process control* (SPC) and *acceptance sampling* are the two major parts of SQC.

All the planned or systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality is called *quality assurance*. It involves making sure that quality is what it should be. This includes a continuing evaluation of adequacy and effectiveness with a view to having timely corrective measures and feedback initiated where necessary.

Total Quality Management (TQM) is defined as both a philosophy and a set of guiding principles that represent the foundation of a continuously improving organization. It is the application of quantitative methods and human resources to improve all the processes within an organization and exceed customer needs now and in the future. TQM integrates fundamental management techniques, existing improvement efforts, and technical tools under a disciplined approach.

A *process* is a set of interrelated activities that use specific inputs to produce specific outputs. The output of one process is usually the input to another. Process refers to both business and production activities. *Customer* refers to both internal and external customers, and *supplier* refers to both internal and external suppliers.

Historical Review

The history of quality control is undoubtedly as old as industry itself. During the Middle Ages, quality was to a large extent controlled by the long periods of training required by the guilds. This training instilled pride in workers for quality of a product.

The concept of specialization of labor was introduced during the Industrial Revolution. As a result, a worker no longer made the entire product, only a portion. This change brought about a decline in workmanship. Because most products manufactured during that early period were not complicated, quality was not greatly affected. In fact because productivity improved there was a decrease in cost, which resulted in lower customer expectations. As products became more complicated and jobs more specialized, it became necessary to inspect products after manufacture.

In 1924, W. A. Shewhart of Bell Telephone Laboratories developed a statistical chart for the control of product variables. This chart is considered to be the beginning of statistical quality control. Later in the same decade, H. F. Dodge and H. G. Romig, both of Bell Telephone Laboratories, developed the area of acceptance sampling as a substitute for 100% inspection. Recognition of the value of statistical quality control became apparent by 1942. Unfortunately, U.S. managers failed to recognize its value.

In 1946, the American Society for Quality Control was formed. This organization, through its publications, conferences, and training sessions, has promoted the use of quality control for all types of production and service.

In 1950, W. Edwards Deming, who learned statistical quality control from Shewhart, gave a series of lectures on statistical methods to Japanese engineers and on quality responsibility to the CEOs of the largest organizations in Japan. Joseph M. Juran made his first trip to Japan in 1954 and further emphasized management's responsibility to achieve quality. Using these concepts the Japanese set the quality standards for the rest of the world to follow.

In 1960, the first quality control circles were formed for the purpose of quality improvement. Simple statistical techniques were learned and applied by Japanese workers.

By the late 1970s and early 1980s, U.S. managers were making frequent trips to Japan to learn about the Japanese miracle. These trips were really not necessary—they could have read the writings of Deming and Juran. Nevertheless, a quality renaissance began to occur in U.S. products and services, and by the middle of 1980 the concepts of TQM were being publicized.

In the late 1980s the automotive industry began to emphasize statistical process control (SPC). Suppliers and their suppliers were required to use these techniques. Other industries and the Department of Defense also implemented SPC. The Malcolm Baldrige National Quality Award was established and became the means to measure TQM. Genechi Taguchi introduced his concepts of parameter and tolerance design and brought about a resurgence of design of experiments (DOE) as a valuable quality improvement tool.

Emphasis on quality continued in the auto industry in the 1990s when the Saturn automobile ranked third in customer satisfaction behind the two most expensive Japanese automobiles. In addition, ISO 9000 became the worldwide model for a quality system. The automotive industry modified ISO 9000 to place greater emphasis on customer satisfaction and added elements on production part approval process, continuous improvement, and manufacturing capabilities. ISO 14000 was approved as the worldwide model for environmental management systems.

Metric System

In 1960, the International Committee of Weights and Measures revised the metric system. This revision is the International System of Units (SI),[1] which has the following base units:

Length—meter (m)
Mass—kilogram (kg)
Time—second (s)
Electrical current—ampere (A)
Thermodynamic temperature—kelvin (K)
Amount of matter—mole (mol)
Luminous intensity—candela (cd)

This book uses the metric system of units with U.S. units given in parentheses. Commonly used conversion factors are given in Table E of the appendix.

RESPONSIBILITY FOR QUALITY

Areas Responsible

Quality is not the responsibility of any one person or functional area; it is everyone's job. It includes the assembly-line worker, the typist, the purchasing agent, and the president of the company. The responsibility for quality begins when marketing determines the customer's quality requirements and continues until the product is received by a satisfied customer.

The responsibility for quality is delegated to the various areas with the authority to make quality decisions. In addition, a method of accountability, such as cost, error rate, or nonconforming units, is included with that responsibility and authority. The areas responsible for quality control are shown in Figure 1-1. They are marketing, design engineering, procurement, process

[1] Copies may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402. (Order by SD Catalog No. C13.10: 330/3.)

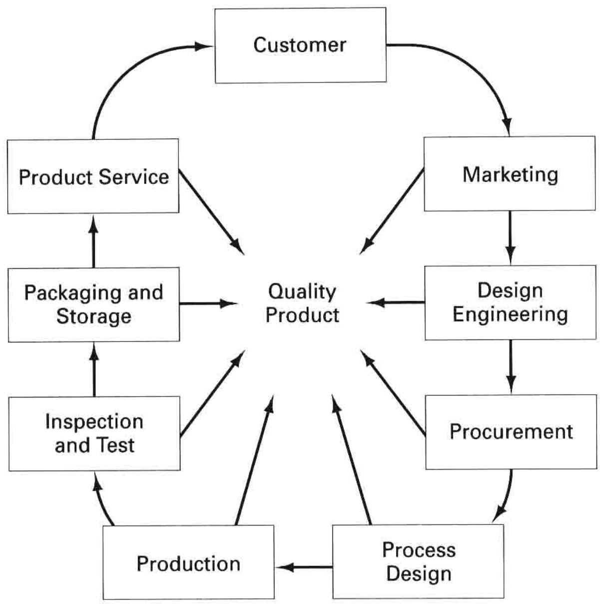

FIGURE 1-1 Areas responsible for quality.

design, production, inspection and test, packaging and storage, product service, and the customer. Figure 1-1 is a closed loop with the customer at the top and the areas in the proper sequence in the loop. Since quality assurance does not have direct responsibility for quality, it is not included in the closed loop of the figure.

The information in this section pertains to a manufactured item; however, the concepts can be adapted to a service.

Marketing

Marketing helps to evaluate the level of product quality that the customer wants, needs, and is willing to pay for. In addition, marketing provides the product-quality data and helps to determine quality requirements.

A certain amount of marketing information is readily available to perform this function. Information concerning customer dissatisfaction is provided by customer complaints, sales representative reports, product service, and product liability cases. The comparison of sales volume with the economy as a whole is a good predictor of customer opinion of product quality. A detailed analysis of spare-part sales can locate potential quality problems. Useful market quality information is also provided by government reports on consumer product safety and independent laboratory reports on quality.

When information is not readily available, there are four methods that can be developed to obtain the desired product quality data:

1. Visit or observe the customer to determine the conditions of product use and the problems of the user.
2. Establish a realistic testing laboratory such as an automotive test track.
3. Conduct a controlled market test.
4. Organize a dealer advisory or focus group.

Marketing evaluates all the data and determines the quality requirements for the product. An information-monitoring and feedback system on a continuing basis is essential to collect data in an effective manner.

Marketing provides the company with the product brief, which translates customer requirements into a preliminary set of specifications. Among the product brief elements are

1. Performance characteristics, such as environmental, usage, and reliability considerations,
2. Sensory characteristics, such as style, color, taste, and smell,
3. Installation, configuration, or fit,
4. Applicable standards and statutory regulations,
5. Packaging, and
6. Quality verification.

Marketing is the liaison with the customer and as such is a vital link to the development of a product that surpasses customer expectations.

Design Engineering

Design engineering translates the customer's quality requirements into operating characteristics, exact specifications, and appropriate tolerances for a new product or revision of an established product. The simplest and least costly design that will meet the customer's requirements is the best design. As the complexity of the product increases, the quality and reliability decrease. Early involvement of marketing, production, quality, procurement, and the customer is essential to prevent problems before they occur. This type of involvement is called concurrent engineering.

Whenever possible, design engineering should utilize proven designs and standard components. In this regard, industry and government standards are used when applicable.

Tolerance is the permissible variation in the size of the quality characteristic, and the selection of tolerances has a dual effect on quality. As tolerances are tightened, a better product usually results; however, production and quality costs may increase. Ideally, tolerances should be determined scientifically by balancing the precision desired with the cost to achieve that precision. Since there are too many quality characteristics for scientific determination, many tolerances are set using standard dimensioning and tolerancing systems. Designed experiments are a very effective technique for determining which process and product characteristics are critical as well as their tolerances. Critical tolerances should be established in conjunction with the process capability.

The designer determines the materials to be used in the product. Material quality is based on written specifications, which include physical characteristics, reliability, acceptance criteria, and packaging.

In addition to the functional aspect, a quality product is one that can be used safely. It is also one that can be repaired or maintained easily.

Design reviews are conducted at appropriate phases in the development of the product. These reviews should identify and anticipate problem areas and inadequacies, and initiate corrective action to ensure that the final design and supporting data meet customer requirements. After the design review team approves the product for production, the final quality requirements are distributed. Quality is designed into the product before it is released to manufacturing.

No design is perfect over time; therefore, provision must be made for design-change control. Also there should be a periodic reevaluation of the product in order to ensure that the design is still valid.

Procurement

Using the quality requirements established by design engineering, procurement has the responsibility of procuring quality materials and components. Purchases fall into four categories: standard materials, such as coiled steel and angle iron; standard hardware, such as fasteners and fittings; minor components, such as gears and diodes; and major components, which perform one of the primary functions of the product. The quality requirements will vary depending on the category of the purchase.

A particular raw material or component part may have a single supplier or multiple suppliers. A single supplier as a source is usually able to provide better quality at a lower price with better service. The concept of a single supplier has been applied quite effectively in breweries, wherein the can or bottle manufacturer was located adjacent to the brewery. Multidivisional companies use the single-supplier technique and can control quality in a manner similar to the control between areas within a plant. The disadvantage