Introduction to

Statistical Quality Control

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Preface

This book is about the modern practice of statistical quality control. It provides comprehensive coverage from basic principles to state-of-the-art concepts and applications. The objective is to give the reader a sound understanding of the principles and the basis for applying those principles in a wide variety of product and nonproduct environments. While statistical techniques are used throughout, the book has a strong engineering orientation, and extensive knowledge of statistics is not a necessary prerequisite. Readers whose background includes a basic course in statistical methods will find the book easily accessible.

This book is an outgrowth of 15 years of teaching, research, and consulting in the assurance sciences. It is designed as a textbook for students in engineering, management, and technology in colleges and universities who are taking a first course in quality control. Such courses are often taught at the junior or senior level. I have also used the text materials extensively in training programs for professional practitioners, including manufacturing and development engineers, managers, procurement specialists, marketing personnel, technicians and laboratory analysts, inspectors, and operators. Many professionals have also used the material for self-study.

Chapter 1 is an introduction to quality assurance in the modern business and manufacturing environment. It deals with the facts that quality has become a major business strategy and that organizations with successful quality-assurance programs can increase their productivity, enhance their market penetration, and achieve greater profitability and a strong competitive advantage.

Following the introductory chapter, the book is divided into three parts. Part I presents a description of statistical methods useful in quality assurance. Topics covered include sampling and descriptive statistics, the basic notions of probability and probability distributions, point and interval estimation of parameters, and statistical hypothesis testing. These topics are usually covered in a basic course in statistical methods; however, their presentation in this text is from the quality-assurance viewpoint. My experience has been that even readers with a strong statistical background will find the approach to this material somewhat different than that of the usual statistics textbook.

Part II contains six chapters on statistical process control. The primary process-control technique advocated is the control chart. While the concept of control charts is not new, its use in modern-day industry is of tremendous value. As sensing and measurement technology develops, along with the widespread availability of powerful microcomputers, the implementation of statistical process controls at the work center is becoming a commonplace activity in many businesses. Statistical process controls will play an even greater role in U.S. industry over the next 20 years than it has in the last 50.

Part III contains three chapters dealing with acceptance sampling. The focus is on lot-by-lot acceptance sampling, although there is some discussion of continuous sampling and MIL STD 1235B in Chapter 12. Other sampling topics presented include details of the design of acceptance-sampling plans; a discussion of MIL STD 105D, MIL STD 414, and their civilian counterparts, ANSI/ASQC Z1.4 and ANSI/ASQC Z1.9; and other important techniques useful in a near-zero defects manufacturing environment, such as chain sampling and skip-lot sampling. Throughout Parts II and III guidelines are given for selecting the proper type of process-control and sampling technique to use in a wide variety of product and nonproduct situations.

Many people have generously contributed their time and knowledge of the assurance sciences to the completion of this book. A complete list of colleagues with whom I have interacted in various teaching, research, or consulting projects over the years would be too extensive to include here. However, some of the major contributors and their professional affiliations are as follows: Dr. William W. Hines, Dr. Lynwood A. Johnson, Dr. Russell G. Heikes, Dr. David E. Fyffe, and Dr. H. M. Wadsworth, Jr., Georgia Institute of Technology; Dr. Joseph J. Moder, University of Miami; Dr. Erwin M. Saniga, University of Delaware; Dr. John S. Ramberg, University of Arizona; Dr. Frank B. Alt, University of Maryland; Dr. Kenneth E. Case, Oklahoma State University; Mr. John A. Butora, Mr. Leon V. Mason, Mr. Lloyd K. Collins, Mr. Dana D. Lesher, Mr. Roy E. Dent, Mr. Mark Fazey, Ms. Kathy Schuster, Mr. Dan Fritze, Mr. Jay Gardiner, Mr. Ariel Rosentrater, Mr. Lally Marwah, Mr. Ed Schleicher, Mr. Armin Weiner, and Ms. Elaine Baechtle, IBM; Mr. Larry Newton and Mr. C. T. Howlett, Georgia-Pacific Corporation; Mr. Robert V. Baxley, Monsanto Chemicals; Dr. Craig Fox, Dr. Thomas L. Sadosky, Mr. James F. Walker, and Mr. John Blevins, The Coca-Cola Company; and Mr. Seymour M. Selig, Office of Naval Research. All of these individuals and many others have contributed to my knowledge and understanding of quality assurance. I am in their debt.

I would also like to thank my editor, Mr. William Stenquist, and his assistant, Ms. Jane Kenneally, for exhibiting considerable patience and understanding throughout the lengthy completion of this project. They have tolerated the peculiarities of authorship far better than any other editorial team with whom I have worked. I also thank the various professional societies and publishers who have given permission to reproduce their materials. Credit for this permission is acknowledged at appropriate places in the text. In addition I am indebted to the Office of Naval Research, which has sponsored my research activities in the assurance sciences for a number of years: It has provided an open and stimulating environment for conducting research and has generated many opportunities to work with navy fleet and support personnel on a wide range of quality and reliability engineering problems. I also thank Ms. Joene Owen for carefully preparing the final version of this manuscript, and Ms. Lisa Allen for help in proofreading.

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Chapter 1
Quality Assurance in the Modern Business Environment

1-1 THE MEANING OF QUALITY

This book is about quality assurance for the products used by our society. Products consist of manufactured goods, such as automobiles, computers, and clothing, as well as services, such as electrical energy, public transportation, and health care. Quality-assurance principles apply to both manufactured goods and services. Our purpose is to present the technical tools necessary to achieve quality assurance in manufacturing and service organizations.

It is essential that products meet the requirements of those who use them. Therefore, our definition of quality is that quality means *fitness for use*. The term *consumer* applies to many different types of users. A purchaser of a product that is used as a raw material in its manufacturing operations is a consumer, and to this manufacturer fitness for use implies the ability to process this raw material with low cost and minimal scrap or rework. A retailer purchases finished goods with the expectation that they are properly packaged, labeled, and arranged for easy storage, handling, and display. You and I may purchase automobiles that we expect to be free of initial manufacturing defects or *nonconformities*, and which should provide reliable and economical transportation over time.

There are two general aspects of quality: quality of design and quality of conformance. All goods and services are produced in various grades or levels of quality. These variations in grades or levels of quality are intentional, and, consequently, the appropriate technical term is *quality of design*. For example, all automobiles have as their basic objective providing safe transportation for the consumer. However, automobiles differ with respect to size, appointments, appearance, and performance. These differences are the result of intentional design differences between the types of automobiles. These design differences include the types of materials used in construction, tolerances in manufacturing, reliability obtained through engineering development of engines and drive trains, and other accessories or equipment.

The *quality of conformance* is how well the product conforms to the specifications and tolerances required by the design. Quality of conformance is influenced by a number of factors, including the choice of manufacturing processes, the training and supervision of the work force, the type of quality-assurance system (process controls, tests, inspection activities, etc.) used, the extent to which these quality-assurance procedures are followed, and the motivation of the work force to achieve quality.

There is considerable confusion in our society about quality. The term is often used without making clear whether it is quality of design or quality of conformance about which we are speaking. To achieve quality of design requires conscious decisions during the product or process design stage to ensure that certain functional requirements will be satisfactorily met. For example, the designer of an office copier machine may design a circuit component with a redundant element, because he knows that this will enhance the reliability of the product in the field and will increase the mean time between failures. This in turn will result in fewer service calls to keep the copier running, and the consumer will be far more satisfied with the performance of the product. Designing quality into the product in this fashion often results in a higher product cost. However, such cost increases are actually *prevention costs*, as they are intended to prevent quality problems at later stages in the life cycle of the product. We discuss other aspects of quality costs in Section 1-3.

Improvements in quality of conformance are often made by changing certain aspects of the quality-assurance system, such as the use of statistical process-control procedures, changing the type of inspection procedures used, and so forth. Thus higher quality of conformance is often achieved with a reduction in total costs, because it leads to reduced scrap, rework, and a smaller fraction of nonconforming products and services.

Every product possesses a number of elements that jointly describe its fitness for use. These parameters are often called *quality characteristics*. Quality characteristics may be of several types:

1. **Physical.** Length, weight, voltage, viscosity.
2. **Sensory.** Taste, appearance, color.
3. **Time Orientation.** Reliability, maintainability, serviceability.

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.

1-2 QUALITY ASSURANCE, TECHNOLOGY, AND PRODUCTIVITY

Quality is becoming the basic consumer decision factor in many products and services. This phenomenon is widespread, regardless of whether the consumer is an individual, an industrial corporation, a military defense program, or a retail store. Consequently, quality is a key factor leading to business success, growth, and enhanced competitive position. There is a substantial return on investment from an effective quality-assurance program that provides increased profitability to firms that effectively employ quality as a business strategy. Consumers feel that the products of certain companies are substantially better in quality than those of their competition, and make purchasing decisions accordingly. Effective quality-assurance programs can result in increased market penetration, higher productivity, and lower overall costs of manufacturing and service. Consequently, firms with such programs can enjoy significant competitive advantages.

Achieving quality in the modern business and manufacturing environment is not easy. A significant problem is the rapid evolution of technology. The last 20 years have seen an explosion of technology in such diverse fields as electronics, metallurgy, ceramics, composite materials, and the chemical and pharmaceutical sciences. This has resulted in many new products and services. For example, in the electronics field, the development of the integrated circuit has revolutionized the design and manufacture of computers and many electronic office products. Basic integrated circuit technology has been surplanted by large-scale integration (LSI) and very large-scale integration (VLSI) technology, with corresponding developments in semiconductor design and manufacturing. When technological advances occur rapidly, and when the new technologies are used quickly to exploit competitive advantages, the problems of manufacturing products with adequate levels of quality of design and quality of conformance are greatly complicated.

The basic problem in many industries is that of manufacturing a product in adequate volumes. Often, too little attention is paid to achieving economy, efficiency, productivity, and quality in production. An effective quality-assurance program can be instrumental in increasing productivity and reducing cost. As an example, consider the manufacturer of a mechanical component used in a copier machine. The parts are manufactured in a machining process at a rate of approximately 100 parts per day. For various reasons, the process is operating at a yield of about 75% (that is, about 75% of the process output conforms to specifications, and about 25% of the output is nonconforming). About 60% of the fallout (the 25% nonconforming) can be reworked into acceptable product, and the rest must be scrapped. The direct manufacturing