

STATISTICAL QUALITY CONTROL

E. L. GRANT

INDUSTRIAL ORGANIZATION AND MANAGEMENT SERIES

STATISTICAL QUALITY CONTROL

EUGENE L. GRANT

PROFESSOR OF ECONOMICS OF ENGINEERING
STANFORD UNIVERSITY

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STATISTICAL QUALITY CONTROL

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McGRAW-HILL INDUSTRIAL ORGANIZATION
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L. C. MORROW, *Consulting Editor*

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To
JOHN CHARLES LOUNSBURY FISH

PREFACE TO THE SECOND EDITION

The most important changes from the first edition of ~~this book~~ are as follows:

1. The chapters dealing with acceptance sampling by attributes have been considerably expanded and largely rewritten. In part, this rewriting has been aimed at including developments in this field since the writing of the first edition, particularly those in multiple and sequential sampling. In part, the rewriting has been aimed at up-to-date coverage of the attributes sampling procedures used by the military services. In part, also, the objective has been to improve the presentation of fundamental principles.

2. The chapter dealing with acceptance sampling by variables has been entirely rewritten. Many recent developments in this field are described, including the Shainin Lot Plot and the variables tables and procedures developed by the Applied Mathematics and Statistics Laboratory of Stanford University under the direction of Dr. A. H. Bowker.

3. The treatment of the cost aspects of quality decisions has been considerably expanded.

4. Less extensive changes have been made in the remainder of the book, chiefly to introduce new material.

5. The number of problems has been more than doubled. Answers are now given to about 30% of the problems with the thought that this may be helpful to those persons who use the book for home study.

6. The master tables from "Military Standard 105A—Sampling Procedures and Tables for Inspection by Attributes" have been included in an appendix. Two tables for use in variables sampling have also been included. One gives representative factors from the Bowker-Goode volume "Sampling Inspection by Variables." The other gives factors recently developed under Dr. Bowker's direction that make it possible to determine the approximate operating characteristics of a wide range of unknown-sigma plans for one-sided specifications.

Much expansion of the use of the techniques of statistical quality control has occurred since the first edition of this book was published in 1946. In hundreds of industrial companies that had made little or no use of these techniques, their use is now accepted as a routine and commonplace cost-saving matter. In procurement by all of the armed services of the United States, the use of statistical sampling tables is standard. It has become evident that many of these statistical techniques originally developed for use in manufacturing can be applied successfully to clerical work and

other nonmanufacturing activities. From small beginnings in 1946, the American Society for Quality Control has grown rapidly to become an active and important organization with an excellent technical journal. The literature of statistical quality control has expanded rapidly.

Nevertheless, from the viewpoint of the over-all contribution of these techniques to industry, persons most competent to judge seem to agree that the surface has only been scratched. Not only do these techniques appear to be destined for a permanent spot in industry; it is evident that throughout the years they can be expected to make an increasing contribution to the industrial objective of better quality at lower cost.

The thanks of the author are due to a number of users of the first edition who have pointed out errors and made suggestions for improvement. His thanks are also due to his Stanford University colleagues, L. F. Bell, A. H. Bowker, H. P. Goode, C. D. Henderson, and W. G. Ireson, who have made suggestions regarding the manuscript of this second edition. Special acknowledgment and thanks are due to Harold F. Dodge of Bell Telephone Laboratories for many helpful comments and suggestions. However, as in all technical books, the final responsibility for the selection and treatment of material must fall on the shoulders of the author, and he should receive the blame for any deficiencies.

EUGENE L. GRANT

STANFORD, CALIF.
April, 1952

PREFACE TO THE FIRST EDITION

This is a working manual. Its object is to explain simple but powerful statistical techniques that can be widely used in industry to reduce costs and improve product quality. The most effective use of these techniques depends upon their being understood by production and inspection supervisors, by engineers, and by management.

The object has been to write a book that might be immediately useful to all of these groups. No attempt has been made to write for the professional statistician or the mathematician. The aim has been to give just enough theory to supply practical working rules that will enable one to recognize the limitations of the methods as well as their many uses.

The spectacular savings in man power and materials that resulted from certain wartime applications of statistical quality control have often generated much enthusiasm. Nevertheless, the remark of one enthusiast that statistical quality control is the most important event in manufacturing since the development of interchangeable manufacture is undoubtedly an exaggeration. Statistical quality control should be viewed as a useful tool for the solution of many manufacturing problems that cannot be solved so well by any other known method. The many applications developed in war industry have demonstrated its possibilities in a great diversity of situations. However, like any other tool, its limitations should be recognized.

It seems inevitable that at some future date the techniques of statistical quality control will become well-known basic tools for use in nearly all types of manufacturing. It also seems inevitable that there will be many headaches incident to the transition to this future situation from the present condition of full application in a few manufacturing plants, limited experimental application in many others, and no application at all in the great majority. This book has been written with the hope that it may help to ease some of these headaches and possibly prevent others.

From the viewpoint of the best possible service of these techniques to industry, it is important that their possible misuse should not retard the expansion of their application. Sometimes the sponsors of new methods do not realize the length of time required to work out effective applications. Moreover, some people undoubtedly will use the publicity given to successful applications of statistical quality control as a means of promoting as statistical quality control ideas that are really quite different. Because such hazards could conceivably result in temporarily discrediting

these methods in some organizations, this book emphasizes the limitations as well as the uses of statistical quality control.

In part this book has developed from a course in engineering applications of statistical methods that the author has given at Stanford University during the past 17 years. More particularly, it developed from short full-time courses given for key personnel of West Coast war industries in the summer of 1942 and thereafter. These courses were given by Stanford University as part of the Engineering, Science, and Management War Training program sponsored by the U. S. Office of Education. Practically all the West Coast developments in statistical quality control have been made by persons who were first introduced to these techniques in the Stanford courses or by others who were subsequently trained by these persons. The Stanford full-time courses with their subsequent follow-up seminars later became the pattern for a nationwide program of similar courses sponsored by the Office of Production Research and Development of the War Production Board in cooperation with ESMWT.

Before 1942, most statistical quality control applications were made in certain plants in the electrical manufacturing industry, in the textile industry, and in the production of munitions in certain government arsenals. When in 1942 and thereafter the suggestion was made that the methods be applied in other industries, the first reaction of inspection, production, engineering, and management personnel nearly always was, "But our business is different!" This was the reaction in the aircraft industry, in the chemical industry, in the milling industry, in the food canning and preserving industry, and in the container industry, in plants where many successful applications later were made. In fact, it was a common reaction in plants in those very industries where successful applications had already been made elsewhere. Sometimes even successful applications in adjoining departments of a plant did not prevent department heads from raising this objection.

Observation of the introduction of these methods in a great diversity of manufacturing plants convinces the author that no manufacturing business is really so different as to be unable to make some effective use of these techniques. Variation in product quality is inevitable; wherever variation exists, statistical quality control may be expected to be helpful. However, imagination and ingenuity as well as a knowledge of the basic principles of statistical quality control are likely to be required for each successful application.

In the preparation of this book, the author has been primarily influenced by the pioneers in the field of statistical quality control—both by their writings and by personal conversations relative to the general philosophy of the subject and to the treatment of specific problems. In this connection, special acknowledgment is due to A. G. Asheroft, W. E.

Deming, H. F. Dodge, G. D. Edwards, G. R. Gause, W. A. Shewhart, L. E. Simon, and R. E. Wareham. The book has been particularly influenced by the general point of view of Dr. Deming.

Much help on specific problems has come from friends on the Pacific Coast, in many of whose plants the author has had opportunity to see the evolution of applications of statistical quality control from the first tentative beginnings to routine use of the techniques as a standard tool. Special mention should be made of the help received from E. E. Bates, J. R. Crawford, George Dundas, P. C. Hammer, J. M. Howell, George Lebedeff, W. H. Lewis, Frederick MacKenzie, D. D. Pettit, and W. B. Rice. The entire manuscript has been read by Prof. Paul T. Norton, Jr., of Virginia Polytechnic Institute, former Chief of the Industrial Processes Branch of the Office of Production Research and Development, and by Profs. Henry Goode and Clarkson H. Oglesby of Stanford University. All three have made many helpful suggestions. Prof. Holbrook Working of Stanford University, former Chief of the O.P.R.D. quality control program, has also supplied helpful ideas regarding parts of the manuscript.

Specific acknowledgments of quotations and of some of the examples have been made at the appropriate places in the text. Data for many of the problems and examples have come from sources that may not be disclosed. In such cases the data have sometimes been so altered as to make sure that no confidential information has been given; such alterations have not changed the statistical aspects of the illustrations.

EUGENE L. GRANT

GALLATIN GATEWAY, MONT.

August, 1946

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Part One

WHAT WILL STATISTICAL QUALITY
CONTROL DO?

