

Experimental Statistics

NBS Handbook 91: Experimental Statistics [1] was first published in 1963. The material for the book was originally commissioned and printed in a limited edition by the U.S. Army as a series of five Army Ordnance Pamphlets OSRDDP 20-110-114. The publication was prepared in the Statistical Engineering Laboratory (SEL) of NBS under a contract with the former Office of Ordnance Research. Although originally intended for the needs of the Army, it proved to be equally useful to research and development groups, both within and outside the government.

The Handbook is organized in five sections; namely,

1. Basic Statistical Concepts and Analysis and Interpretation of Measurement Data
2. Standard Techniques for Analysis and Interpretation of Enumerative and Classificatory Data
3. The Planning and Analysis of Comparative Experiments
4. Special Topics
5. Tables

It is a monumental work which brings together under one cover the combined experience and expertise of the Statistical Engineering Laboratory. Mary Gibbons Natrella was principal author with overall responsibility for the entire publication, but there are contributions on polynomial and multivariable relationships, sensitivity testing, use of transformations, and expression of uncertainties by other members of the SEL. Chapters 1, 20, and 23 were written by Churchill Eisenhart, founding father of the SEL; Chapter 6 was written by Joseph Cameron, who later became Chief of SEL, and Chapter 10 is based on material prepared by Mary Epling. Some original tables were prepared by Paul Somerville; Norman Severo assisted with Section 2, and Shirley Young Lehman helped with the collection and analysis of examples.

Mary Natrella had a special gift for elucidating difficult statistical concepts, and these expositions are the strength of the book. The workbook style of the volume probably accounts for its popularity and acceptance by statisticians and non-statisticians alike. It is replete with examples; the page for each example is divided, with the statement of the problem and recommended solution on the left-hand side and detailed step-by-step calculations on the right-hand side. Mary



Fig. 1. Mary Gibbons Natrella.

Natrella also believed in attention to detail. The Foreword states that “some procedures in the Handbook have been explained and illustrated in detail twice: one for the case where the important question is whether the performance of a new material, product, or process exceeds an established standard; and again for the case where the important question is whether its performance is not up to the specified standard.”

The Handbook was an immediate success at NBS, in the Army, and throughout the Department of Defense. It eventually received wide acclaim in other government agencies, industry, and universities. Churchill Eisenhart was fond of quoting a statistician who said that “the best thing about the Handbook is that it is correct.”

The Handbook is recognized for its deep and long-lasting impact on the application of statistics to the planning and analysis of scientific experiments. It was reprinted in 1983 for commercial sale by Wiley Interscience as part of its Selected Government Publications series. In 1985, the American Society for Metals published a condensation of four chapters on planning and

analysis of comparative experiments as part of the Statistics Section of Volume 8 of the 9th edition of the ASM Handbook. It has been NIST's second-best selling publication, after the *Handbook of Mathematical Functions*, which is covered elsewhere in this volume. The material is still current after more than thirty years, and this year alone it received close to forty journal citations as measured by the Science Citation Index.

NIST still receives requests for this book, and its contents are the basis for training courses taught by the Statistical Engineering Division (SED) and companies such as SEMATECH that are involved in technology development. It has proved such an inspiration that a few years ago Patrick Spagon of the Statistical Methods Group of SEMATECH approached SED with a proposal for updating and recreating the book with examples directed towards the semiconductor industry. That proposal has evolved into a publication for the World Wide Web [2] that is currently under development by a

team that includes: James Filliben, William Guthrie, Alan Heckert, and Carroll Croarkin of SED; Paul Tobias, head of the Statistical Methods Group, and Chelli Zey of SEMATECH; Barry Hembree of AMD; and Ledi Trutna, a private consultant.

Mary Natrella joined the Statistical Engineering Laboratory of NBS as a mathematical statistician in April 1950 after Churchill Eisenhart noticed her work as a sampling inspection expert in the U.S. Navy's Bureau of Ships. At the Navy, she worked on a team that developed the now famous MIL-STD-105A, Sampling Procedures and Tables for Inspection by Attributes (1950), which was to become a government wide standard. Her "Report of Proceedings of the Subcommittee for Preparation of MIL-STD-105A," issued as a companion document to the standard, was distributed to government groups developing sampling inspection plans, as well as to professional and technical organizations, and was still in demand in the 1970s.

Additional Diagnostic Plots

Further residual diagnostic plots are shown below. The plots include a run order plot, a lag plot, a histogram, and a normal probability plot. Shown in a two-by-two array like this, these plots comprise a 4-plot of the data that is very useful for checking the assumptions underlying the model-building methodology.

Dataplot 4plot

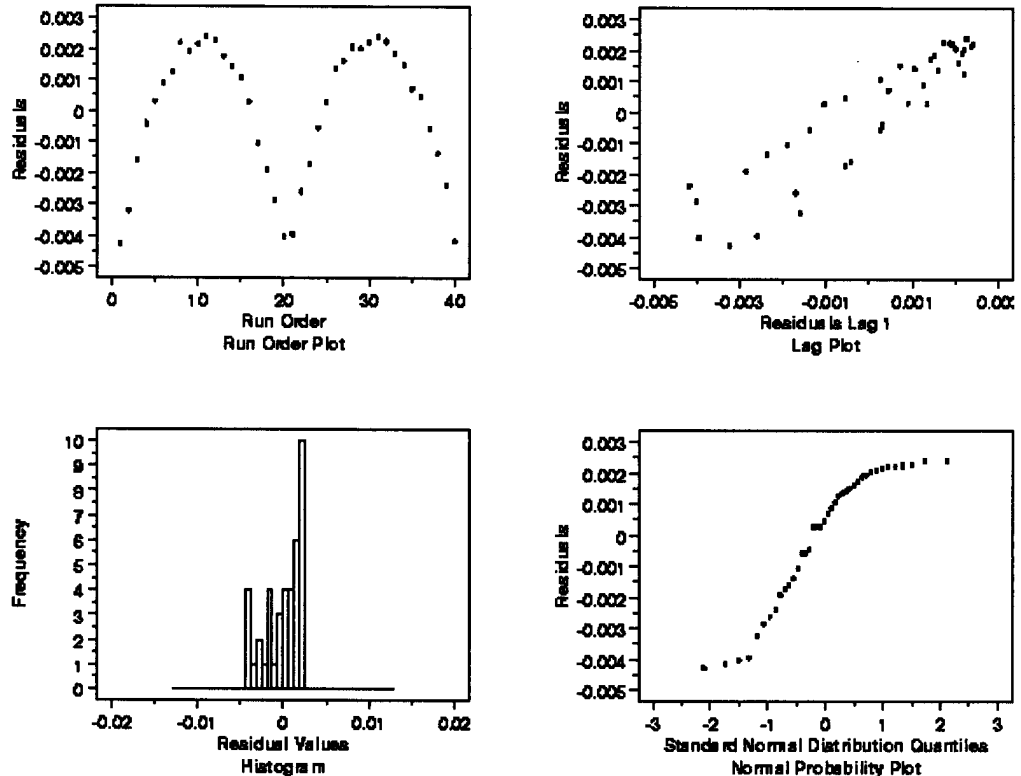


Fig. 2. Partial page from *NIST/SEMATECH Engineering Statistics Handbook* showing graphical techniques for deciding if the relationship between two variables is linear.

The SEL was a pioneering group dedicated to application in the physical sciences of the statistical methods developed by R. A. Fisher, J. Neyman, and E. S. Pearson in England and Walter Shewhart in the United States. Mary Natrella served as a consultant on statistical planning and analysis of experiments to NIST scientists, and her training course on “Statistics of Measurement” was heavily attended for many years. Her most notable publication is *Handbook 91*, which was 7 years in preparation and required all her talents as teacher and consultant. During this time, Mary also contributed several sections to *NBS Special Publication 300* [3] and worked with Carroll Brickenkamp and Steve Hasko of the NIST Office of Weights and Measures on *NBS Handbook 133: Checking the Net Contents of Packaged Goods* [4], which has been adopted by the National Conference on Weights and Measures. She performed her last service for the Statistical Engineering Division by serving as Acting Division Chief for the 2 years prior to her retirement in 1986.

The 1980’s brought the culmination of Mary’s career, with recognition on many fronts. She was elected a Fellow of the American Statistical Association (ASA) in 1981. In 1982, she received the Department of Commerce’s Superior Federal Service Award. She was a long-time member of American Society for Testing Materials (ASTM) Committee E-11 on Quality and Statistics. In 1984, for her work as chairman of Subcommittee E11.03 on Statistical Analysis and Control Techniques, she was awarded the Society’s Award of Merit, which carries the designation of Fellow.

In the year 2000 Mary Natrella has been further honored by the establishment of an endowed scholarship fund which will provide \$1000 scholarships each year for two students to attend the Quality and Productivity Research Conference (QPRC). The scholarships were established by the Quality and Productivity section of the American Statistical Association, under the chairmanship of Veronica Czitrom of Lucent Technologies, with funds donated by Mary’s husband, Joseph V. Natrella, and the QPRC Steering Committee. The purpose is to honor Mary’s 36 years as author, teacher, and consulting statistician and her many contributions to the statistical community.

Prepared by M. Carroll Croarkin.

Bibliography

- [1] Mary Gibbons Natrella, *Experimental Statistics*, NBS Handbook 91, National Bureau of Standards, Washington, DC (1963); reprinted 1966.
- [2] Paul Tobias and Carroll Croarkin (eds.), *NIST/SEMATECH Engineering Statistics Handbook*, (<http://www.itl.nist.gov/div898/handbook/index.html>), National Institute of Standards and Technology (1999).
- [3] Harry H. Ku (ed.), *Precision Measurement and Calibration: Statistical Concepts and Procedures*, NBS Special Publication 300, Vol. 1, National Bureau of Standards, Washington, DC (1969).
- [4] C. S. Brickenkamp, S. Hasko, and M. G. Natrella, *Checking the Net Contents of Packaged Goods*, NBS Handbook 133, Third Edition, National Bureau of Standards, Gaithersburg, MD (1988).