Applications of By W. A. Shewhart, & others.

STATISTICAL METHOD

in Engineering and Manufacturing

IN DECEMBER, 1929, a round-table conference was called under the joint auspices of The American Society of Mechanical Engineers and the American Society for Testing Materials to consider the need for the use of statistical method in the interpretation and presentation of engineering data and to consider ways and means for developing the applications of statistical method in engineering and manufacturing. The meeting was under the chairmanship of Col. M. C. Rorty, then vice-president of the International Telephone and Telegraph Company, who incidentally was one of the first men in America to apply statistical method in engineering.

The majority of the seventy-six members of the conference represented large industrial organizations faced with practical problems in the solution of which they felt that statistical method might play a part. In addition, there were representatives from Government laboratories, universities, and scientific societies.

Prof. E. B. Wilson, then president of the American Statistical Society, spoke on behalf of the interest of this society, as did Messrs. C. B. LePage and W. H. Fulweiler on behalf of The American Society of Mechanical Engineers and the American Society for Testing Materials, respectively. Four papers were presented indicating some general and specific needs for the application of statistical method. Several members of the conference took an active part in the discussion of the papers. After the formal program a resolution was proposed and unanimously adopted that a committee be appointed to further the application of statistical method in engineering and manufacturing, to be composed of one member from each of the following societies: The American Society of Mechanical Engineers, American Society for Testing Materials, American Mathematical Society, and American Statistical Association. The following is a report of the committee formed in accord[2] with this resolution.

APPLICATIONS PRIOR TO 1929

It would be difficult to say when application of statistical method was first made in the engineering field. Certainly it dates back a long way if we include, as we should, the theory of errors and least squares as a part of the method. In a brief paper (1),[3] copies of which were sent out with the invitations to this round-table conference, the general nature of applications to research, development, design, production, inspection, and supply was indicated, together with a list of references bearing upon this general subject. A perusal of these references will indicate the sporadic nature of the applications made prior to this time in almost every field of engineering.

One of the first outstanding applications of statistical theory to the problems of manufacturing was that made by a man writing under the pseudonym of "Student." "Student's" work was carried on in a British brewery which is one of the largest in the world, and his publications date from 1907.

In Germany and America, active interest in such applications seems to have originated about 1922 to 1925. In fact, it was about this time that the interest of German engineers had developed sufficiently to warrant Dr. Hellmich, of the Normenausschuss der Deutschen Industrie, in calling to the attention of the American Standards Association the application of statistical method—*Grosszahlforschung*—in the German industries and asking if any like developments had taken place in America.

APPLICATIONS SINCE 1929

Shortly after the formation of the Joint Committee, a committee was formed under the auspices of the American Society for Testing Materials to treat of the applications of statistical method to special problems of this society. This committee now consists of about thirty-five members, among whom are representatives of many of the technical committees of the society. Regular meetings have been held in connection with the annual meetings of the society. In fact, a well-attended round-table conference was held this spring (1932) on the acquisition of good data, and most of the papers there presented will shortly appear in one place or another. At the present time Dr. Anson Hayes, director of research of the American Rolling Mill Company, Middletown, Ohio, is chairman of this committee.

Among other projects now under way is the preparation of a brief monograph of recommendations on the presentation of the data of this society, which is supposed to present the most efficient method for summarizing data in a way to admit of fullest information for the particular problems in hand. They also have under way the preparation of a monograph discussing the problem of rejection of observations from both a theoretical and a practical angle. The major contributions to this second monograph are to be made by Dr. E. W. Washburn, of the Bureau of Standards, editor-in-chief of the "International Critical Tables," Dr. P. R. Rider, of Washington University, and Dr. H. C. Dickinson, of the Bureau of Standards

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[1] Report as of August, 1932, of Joint Committee on the Development of Applications of Statistics in Engineering and Manufacturing sponsored by the American Society for Testing Materials and The American Society of Mechanical Engineers. For presentation at the Annual Meeting, New York, December 5 to 9, 1932, of The American Society of Mechanical Engineers.

[2] The committee consists of L. K. Sillcox, vice-president of the New York Air Brake Company, representing The American Society of Mechanical Engineers; W. H. Fulweiler, past president of the American Society for Testing Materials and chemical engineer for the United Gas Improvement Company of Philadelphia, representing the American Society for Testing Materials (R. E. Hess, assistant secretary of the A.S.T.M., alternate); E. V. Huntington, professor of mechanics at Harvard University, representing the American Mathematical Society; and W. A. Shewhart, engineer in charge of fundamental quality engineering, Bell Telephone Laboratories, representing the American Statistical Association.

[3] Numbers in parentheses are those of similarly numbered references given at the end of the report.

Important among the developments of applied statistics in engineering and manufacturing is that having to do with the development of methods of economic control of quality which has been recently made available in book form (2). Additional references to fields of application are given in the appendix to this book. During this same period, further contributions in this field were made by "Student," and, in addition, important contributions were made at the Shirley Institute, the research organization of the British Cotton Industry, by I. H. C. Tippett, who has within the past year published an excellent treatise on statistical method (3).

Among the active leaders in this field of application in engineering in Germany, we should mention Daeves, Becker, Plaut, Runge, Schaurte, Schimz, Schulz, and Kohlweiler. We understand that Mr. Werner Schaurte, president of Bauer and Schaurte, of Neuss, incidentally a graduate of Massachusetts Institute of Technology, whose interest in making use of statistical method in his own plant dates from about 1922, continues to be one of the most enthusiastic advocates of the usefulness of the method. Perhaps one of the most active leaders in the field of application is Dr. Karl Daeves, research director of the Vereinigte Stahlwerke Aktiengesellschaft. He is soon to publish a book, "Praktische Grosszahlforschung" (Berlin, VDI-Verlag), which will not only describe his own work in detail but will also carry a complete bibliography in this field. This book with that of Dr. Kohlweiler (4), the one by Becker, Plaut, and Runge previously referred to, and another 5 edited by Plaut, serve to cover in a comprehensive way the comparatively extensive work of the Germans. It appears that the principal engineering applications of statistical method in Germany continue to be in the steel industry, but its use is being rapidly extended to the glass, mining, electrical, and ceramic industries.

We may perhaps get the best picture of the role of statistical method in engineering by thinking of the engineer's job under three general headings:

1 Discovery of physical properties and laws
2 Presentation of experimental data
3 Use of physical properties and laws in the fabrication of goods to satisfy human wants.

It is recognized today as never before that discovery in this sense is founded on probability inference. Now, broadly speaking, statistical theory is concerned with the problem of drawing the best inference. It is, as it were, the cornerstone of the logic of discovery. The application of such methods begins with the laying out of the experimental procedure and not with the analysis of results as is so often assumed by those unfamiliar with the methodology. In complex commercial problems of research, as, for example, in the study of the properties of raw materials, important savings in the reduction of numbers of measurements to attain a given degree of precision are often made possible through the use of the method, as is evidenced, for example, in the work of Tippett already referred to and by the extensive work going on in the field of agricultural research at the Rothamsted Agricultural Station under the direction of Dr. R. A. Fisher (6).

In general, the committee believes that statistical methods constitute the best means for correcting data for errors of measurement; detecting assignable causes of variation in any phenomenon, choosing the best functional form, including estimates of parameters, for the expression of distributions and relationships, and laying out efficient research programs. The industrial applications in engineering and manufacturing previously referred to justify this belief.

Passing to the problem of presentation of data, statistical method presents the most efficient method of summarizing the whole of the information given by the raw data. This phase of the problem has been treated in some detail from an engineering viewpoint in Chapters V to IX of (2). Furthermore, having once decided upon the method to be used in arriving at a probability inference, statistical method indicates the most efficient statistic to be used. This is also discussed under efficiency in (2). Such studies reveal the need for modifications in the current methods of summarizing data, particularly in the statement of the properties of materials. This special field of application is being considered by members of the previously mentioned committee of the A.S.T.M. in the preparation of a monograph on recommendations for summarizing data for publication. These suggestions should be of practical value to many engineers. Our committee feels, however, that perhaps the engineering field of greatest economic significance for the application of statistical methodology is in the establishment of economic standards (7) of quality and procedures for effecting economic control of quality of manufactured product (2). Broadly speaking, statistical methodology makes it possible to establish limits within which variation in any quantity of interest to management should be left to chance. Only when variation extends beyond these limits is it economical to take action. The significance of this contribution from the viewpoint of management engineering has recently been treated in some detail by an authority in this special field (8).

It should be noted that individual corporations may hope to attain appreciable economies through the application of control methods. However, since control really should start with raw materials to attain the maximum advantages, it is desirable that engineers cooperate through organized societies in the development of economic standards, thereby rendering it possible to make more efficient use of materials and minimize the cost of inspection (9), to mention only two of the advantages set forth in the references above cited.

Quite recently the chairman of our committee, Dr. Shewhart, was invited to give three lectures on the role of statistical method in economic industrial standardization at the University of London. While abroad, he visited several of the industrial laboratories and plants in England and Germany where work of this character is under way. Arrangements were also made through the sponsor societies of our committee and the American Standards Association for him to discuss the work of our committee with the officers of some of the engineering societies abroad. While in England he had the privilege of attending a round-table conference called under the auspices of the British Standards Institution, and similar in character to the one called in 1929 by the sponsor societies of our committee. A resolution was passed organizing a committee under the chairmanship of Mr. B. H. Wilsdon, of the British Government Building Research Laboratories, to consider the development of applications of statistical method in engineering and to cooperate with our committee in this effort. While in Germany a similar round-table conference was called by the president of the Deutscher Normenausschuss which resulted in the formation of a committee under Dr. W. Hellmich, managing director of the Normenausschuss and co-director of the Verein deutscher Ingenieure, as chairman, with much the same objective as the British and American committees.

In general, these committees should be of considerable mutual help in focusing the attention of the engineering profession on important developments in applied statistical technique in the fields of engineering and manufacturing. The three round-table conferences mentioned above have already served to bring to light important contributions in certain

diverse engineering fields, and plans are under way to make this information available in published form.

Although there is general agreement that industry may profit materially in ways that we have tried to indicate in this report through the application of statistical technique as it exists today, there remains much to be done on the theoretical side. It is significant to note that these problems are being attacked not only by men in industry but also by men in the university field—in particular by Dr. Egon Pearson at the Biometric Laboratory of the University of London. Among other problems that Pearson has under way is a discussion of efficient specification of materials from the viewpoint of the latest developments in the mathematical theory of statistics.

PROGRAM OF ACTIVITY

Our committee plans to serve in every way possible as a clearing house of information: in particular, to issue from time to time reports in the journals of the sponsor societies, calling attention to the progress that has been made in this particular field, and to cooperate (*a*) with other committees representing societies and industries in America, such as that of the American Society for Testing Materials on the interpretation and presentation of data, and (*b*) with the general committees referred to in this report sponsored by the British Standards Institution and the Deutscher Normenausschuss.

> W. A. Shewhart, *Chairman*
> W. H. Fulweiler
> E. V. Huntington
> L. K. Sillcox.

REFERENCES

(1) "Economic Aspects of Engineering Applications of Statistical Methods," by W. A. Shewhart, *Journal of the Franklin Institute*, March, 1928. To the list of references given herein the following books should be added: "Anwendungen der mathematischen Statistik auf Probleme der Massenfabrikation," by Becker, Plaut, and Runge, Berlin, Julius Springer, 1927; and "Probability and Its Engineering Uses," by T. C. Fry: D. Van Nostrand Company, New York, 1928.

(2) "Economic Control of Quality of Manufactured Product," by W. A. Shewhart: D. Van Nostrand Company, New York, 1931.

(3) "Methods in Statistics," by L. H. C. Tippett: Williams and Norgate, London, 1931.

(4) "Statistik im Dienste der Technik," by E. Kohlweiler: R. Oldenbourg, Berlin, 1931.

(5) "Fabrikationskontrolle auf Grund statischer Methoden," edited by H. C. Plaut: VDI-Verlag, Berlin, 1930.

(6) "Statistical Methods for Research Workers," by R. A. Fisher, Third Edition: Oliver and Boyd, London, 1930.

(7) "Role of Statistical Method in Economic Standardization," by W. A. Shewhart, to be published in *Econometrica*, January, 1933.

(8) "Standards for the Economic Control of Quality for Manufactured Products," by F. E. Raymond, *Industrial Standardization*, July, 1932.

(9) "Need for Statistical Control in Sampling Inspection," by H. F. Dodge, to be published shortly in *American Machinist*.