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ROME, 6-12 SEPTEMBRE 1953

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W. EDWARDS DEMING

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ON THE TEACHING OF STATISTICAL PRINCIPLES AND TECHNIQUES TO PEOPLE IN INDUSTRY

By W. Edwards Deming

The Graduate School of Business Administration, New York University

I. Four Levels of Teaching Required in Industry

The teaching of statistical principles and techniques to people in industry is a four-sided job :

1. Management
2. Statistical administration (Vice President in charge of the statistical control of quality)
3. Research
4. Workers in the manufacturing plant (production, inspection, testing materials)

The aim of this paper is to set forth a few principles for the teaching of statistical principles and techniques to the four different groups.

Each of these four groups has an important role in industry. Each group presents its peculiar problems in statistical education because the work performed by each group is different. Moreover, the educational back-ground of the four groups will differ.

In order to decide what to teach to any one group, and how to do it, we must first enquire into the job that each group is expected to do, and into the possible educational background of the people that the group.

Management needs to know the principles and to have an appreciation for the uses of statistical techniques, although management need not be skilled in the techniques themselves. On the other hand, the statistical administrator (whose profession is described later on) must have a keen perception of statistical problems, some knowledge of the techniques themselves ; an intimate knowledge of the problems that confront the management and the ability to put statistical techniques to work to help to solve these problems. Some of the staff that work in research, development, and design, must possess penetrating knowledge and skill in the techniques with originality to develop new theory where required. On the production line, and in inspection and in the testing of incoming materials, an understanding of simple techniques like the control chart and acceptance sampling will be extremely effective and can be learned in a short while (e.g., in 8-day intensive courses), supplemented by supervision and stimulation of interest.

For all four groups of people, the statistical method is more than an array of techniques. It is a mode of thought-sharpened thinking. It helps anyone in any of the four groups, be he a machine operator or an executive, to make better decisions, and to do his work better, than he could do otherwise. The statistical method is especially needed where competition is keen, where the differences between the performances of materials, machines, methods, and processes, are small but vital for survival. Thus, in my own practice, I have helped to design experiments, aimed to discover which of two methods of carrying out a certain operation is the better, when the difference between the two was thought to be not more than 2%, yet that 2% saving was vital to survival. A wrong answer and a wrong decision based on it could have been ruinous.

II. Statistical Principles for Management

The job of management. Management is today the most important and the most neglected of the four groups, hence I shall be more explicit with respect to it than to the others. With regard to the importance of talking to management, I may venture the opinion that the rapid progress that has characterized Japanese industry since 1950 arose in large part from a clear understanding and appreciation for statistical methods on the part of a large number of Japanese executives.

With the confidence and understanding of management, statistical methods in industry achieve economies and improved operation. Problems of organization, and of the recruitment of competent statistical workers, along with assignment of their responsibilities, reach quick solutions. Without the support of management, the statistical method in industry is under a severe handicap. Mere tolerance of statistical techniques by management is not sufficient for effective gains. Hence it is important to talk to management in terms that will be of interest and which they will understand.

To talk to management, we must think on the question of what management's job is, and then show how statistical principles and techniques can help. Management's job is :

> To foresee what problems will arise, and to be prepared with information, statistical and otherwise, by which to make as many correct decisions as possible.
>
> To make decisions from time to time.

To achieve these goals, it is now possible, thanks to statistical techniques and method, to state in meaningful terms what management means by a particular quality, performance, uniformity, rate, or other characteristics that is desired. The same techniques will measure such characteristics with meaning, and with calculable and governable reliability, and with economy, utility, and speed unattainable otherwise.

In other words, with the aid of statistical techniques, much of the subjectivity of the information that management needs will disappear, and there will emerge the possibility of a science of management. Statistical techniques do not displace management : they aid management to do a better job.

The decisions of management deal with design and standardization, distribution, marketing, advertising, production, inspection procurement of raw materials including subassemblies, prices, and service to dealers and to ultimate purchasers. Management has also the problems of labor relations, wages, standard rates of production, methods of training the workers, capital investment in new machines, policy in regard to repair of machines. There are other problems too, but I mention only those to which statistical principles and techniques have made signal contributions.

Added to management is the problem to obtain good scientific personnel, and to apply the most effective methods and techniques, statistical and otherwise, throughtout the whole chain of production (Fig. 2).

As a first principle, it may certainly be assumed that management's job is to introduce any technique or device that will increase output and decrease costs, and to employ statistical knowledge wherever such knowledge can be of help.

Some ideas on what to teach management, and how. Management is not interested in techniques, nor in the technical language of probability. Management *is* interested in ways of achieving a better competitive position, and in producing a product and a service that will ensure this position.

Management should be told that statistical techniques may be able to help to achieve these aims. How? Through improved quality and uniformity AT REDUCED COST; through design of product and service better suited to the demands of the market; through increased output per machine, per man-hour, and per ton of raw material; through more effective inspection AT REDUCED COST; through better use of cheaper materials, better knowledge of materials; through improved sampling and testing; through better use of machines and of manpower; through better use of consumer research and of government statistics on population, agricultural, and industrial production and distribution.

Statistical theory is power. It can help in the solution of management's problems. In fact, in many of management's problems, statistical theory offers the only possible solution. It is possible to tell management's, in one lecture, how statistical techniques may help in some of their problems. Management need not learn the techniques themselves, any more than they need to learn vector analysis and quantum theory to make use of ideas in modern physics or organic chemistry to make a new or improved product.

In my own experience I have found that talks to management should be confined to topics like these:

a. The advantages of dependable and uniform quality. Commerce, domestic and international, depends more on uniformity and on certainty of the manufacturer's performance than upon high levels of quality without uniformity.

b. Principles of the statistical method, and brief illustrations on how it works.

c. Statements of results in past performance.

d. Kinds and levels of statistical work; education and qualifications of statistical workers.

e. Proper organization. The need for a broad statistical front in order to reap the fullest benefit in service, reduced costs, etc.

In one lecture, of about an hour and a half, it is possible to cover the basic points.

Statistical principles in production, from the standpoint of management. One may turn to the problems of production, for illustration. There should be continuous study to determine what problems in production are troublesome, or where production could be improved. Occasionally, management's first reaction to this proposal is that they have no problems. It is a fact, though, that experience shows that careful study will almost always, show wasteful conditions, such as excess idle-time of machines, and excess rework and waste of materials, wrong information about defects in quality and service. Great gains have been made in places where no difficulties had been recognized.

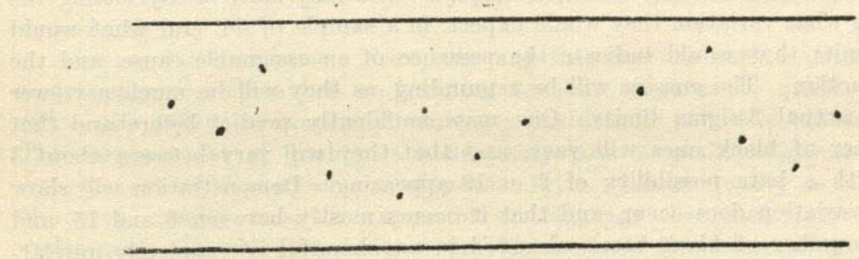
Statistical principles and practice applied to the regulation of a process, or to research or development, have for their aim the discovery of assignable (or significant) causes of variability. Their discovery is masked by chance causes. Elimination of the assignable causes, one by one, achieves greater uniformity, less waste, and reduces costs. First of all, there are two kinds of varibility, chance or random variability, and nonchance or nonrandom variability. The universal existence of variability, of one kind or the other, is the first lesson. No matter what care is exercised in production, all dimensions, weights, and other characteristics of manufactured product will vary. Production rates, for a given number of men or even of the same 16 men, will vary from one hour to another, even under what appear to be the same essential conditions. Production in any one operation will also vary from one office to another, even though the physical conditions appear to be identical. This is the hardest lesson to teach : that there is no such thing as constancy in nature ; that all things vary ; and that the range of variability, narrow or wide, does not determine whether it is chance or nonchance.

> *Chance (or random) variability.* This is the natural variability of an operation, whether carried on by machine, or by hand-work. Experience shows that any attempt to take " corrective " action when the variation is chance, is almost sure to result in greater variability than existed already, and in the demoralization of the workers. Hence :
>
> IT IS IMPERATIVE, FROM THE STANDPOINT OF MANAGEMENT, TO KNOW WHETHER VARIABILITY IN A PARTICULAR DIMENSION OR OTHER CHARACTERISTIC ARISES FROM CHANCE CAUSES, OR FROM NONCHANCE CAUSES. IT IS EQUALLY IMPORTANT NOT TO TRY TO FIND THE CAUSES OF CHANCE VARIATIONS.
>
> *Nonchance (or nonrandom) variability.* This is variability that is statistically significant, and should NOT be left to chance.
>
> NONRANDOM VARIABILITY SHOULD BE INVESTIGATED ; it arises from an assignable cause, which one should now discover and also remove, if the removal of the cause would pay a dividend in greater production or in improved quality or uniformity.

The statistical method provides a standard criterion by which to discriminate between chance and nonchance variability, as illustrated in Fig. 1.

It is important to make a clear distinction between what is statistical and what is not. The determination of whether a particular variability is chance or nonchance is a statistical problem (except in extreme cases where conditions are so bad and so inefficient that the answer is obvious). The discovery of an assignable cause of NONCHANCE variability, once statistical techniques discolose its existence, requires judgment and experience. The decision on whether to remove an assignable cause, once it is discovered, is not a statistical problem either, but one in economics, for management : will it pay to remove the cause ?

Variations like this should be accepted as natural and normal, for this particular process. One will do only damage by trying to take action because one point is higher or lower than another.



On the other hand, a point out of control signifies that an assignable cause of nonchance variability is present. Its removal will bring better efficiency and uniformity.

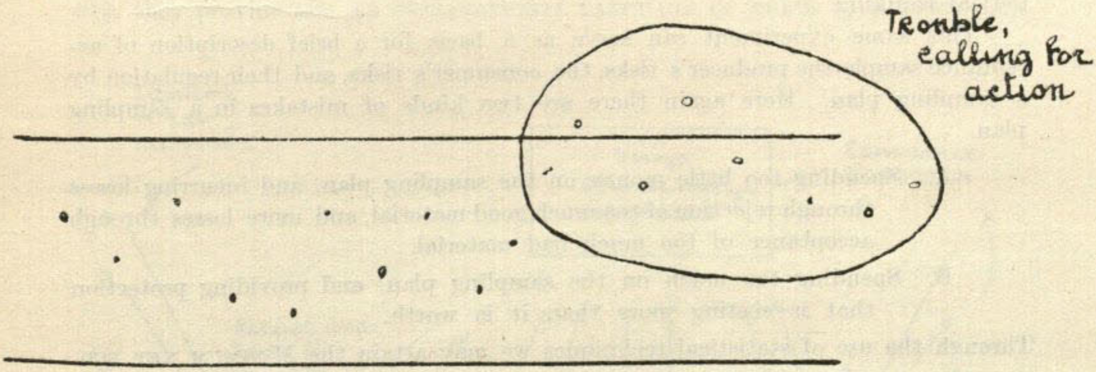


Fig. 1 - Illustrating the definite criterion for recognizing chance and nonchance variability.

Experience shows that mere judgment, left to itself, without statistical aids, makes two kinds of mistakes.

Mistake A. It leads to "corrective" action in cases where the differences are merely chance variations, not significant. Such a mistake does severe damage, as mentioned earlier.

Mistake B. It fails to perceive that some differences should NOT be left to chance, but should be investigated. To fail to investigate, when a difference is statistically significant, causes loss through failure to improve the operation when improvement is possible.

It is impossible to avoid both mistakes altogether, but simple statistical techniques (such as the Shewart chart) guide management and workers into MI-

NIMUM NET ECONOMIC LOSSES. A wealth of experience shows that without the aid of statistical techniques, the losses from the two mistakes are almost sure to be of serious magnitude. Even with statistical methods, mistakes A and B are both possible, and must be expected once in a while.

At this point it is a good plan to conduct a short experiment to illustrate random variability. One may take a bowl of black and white beans, perhaps 20% black, mix them thoroughly, and draw a small handful of about 50 at a time, with through mixing between samples. One may start off by letting the men guess what variation they would expect, in a sample of 50, and what would be the limits that would indicate the presence of an assignable cause, and the need for action. The guesses will be astounding, as they will be much narrower than the actual 3-sigma limits. One may confidently predict beforehand that the number of black ones will vary, and that they will vary between about 3 to 17, with a bare possibility of 2 or 18 appearing. Demonstration will show that the variation does occur, and that it occurs mostly between 6 and 15, and that the number of black beans observed in any handful is completely unrelated to the preceding handful. Enquire what whould be the result on a machine or on a force of skilled workers if management insisted that something was wrong every time an observed number fell (*a*) outside the limits that they predicted, or (*b*) below the average. Yet that is what men do without the aid of statistical thinking.

This same experiment can serve as a basis for a brief description of acceptance sample-the producer's risks, the consumer's risks, and their regulation by a sampling plan. Here again there are two kinds of mistakes in a sampling plan.

A. Spending too little money on the sampling plan, and incurring losses through rejection of too much good material, and more losses through acceptance of too much bad material.

B. Spending too much on the sampling plan, and providing protection that is costing more than it is worth.

Through the use of statistical techniques we may attain the MINIMUM NET ECONOMIC LOSSES from these two mistakes.

Some history of past successes is helpful. Examples abound in the journal Industrial Quality Control (cf. footnote in Part II, p. 8).

What is the statistical control of quality? From the standpoint of management, the statistical method in industry must work all the way from raw material to consumer and back again (Fig. 2). If any possible application is omitted, the result is economic loss in one way or another. As it is the business of management to see to it that losses do not occur, then management must employ statistical techniques wherever they can be helpful. From the standpoint of management the following definition may be adopted :

> THE STATISTICAL METHOD IN INDUTRY IS THE APPLICATION OF STATISTICAL PRINCIPLES AND TECHNIQUES IN ALL STAGES OF PRODUCTION, DISTRIBUTION, AND ADMINISTRATION, DIRECTED TOWARD THE MOST ECONOMIC PRODUCTION OF A PRODUCT THAT IS MAXIMALLY USEFUL AND HAS A MARKET.

Les us see what this definition means. First of all, what is quality? Quality is meaningless without reference to the consumer's demands. Hence, the first step in the statistical method in industry is to learn something about the demands of the market. I wonder how many firms which are justly proud of their statistical charts in production have looked at the problem from this standpoint. Yet without looking at it in this way a manufacturer may find himself using the finest statistical techniques in production and inspection, making a beautiful product, very economically, for a market that he misjudges one way or the other.

Let us think of price. Price, like any fraction, has both a numerator and a denominator. Price has no meaning without reference to quality. Price is miles per gallon, or so many cents per extractable pound of usable material. The measurement of quality is a necessary part of quality control, and a necessary part of any statement of price. Price without quality is meaningless. Moreover, quality must be expressible in language that both buyer and seller understand. Statistical techniques provide methods for determining whether a particular test of quality is valid, and they provide the results of a test in a language that is known and understood world-wide. Thus, statistical techniques are vital for the expression of price as well as of quality.

Statistical methods not only help to produce uniform and dependable quality, they provide also AN INTERNATIONAL LANGUAGE IN WHICH TO EXPRESS QUA-

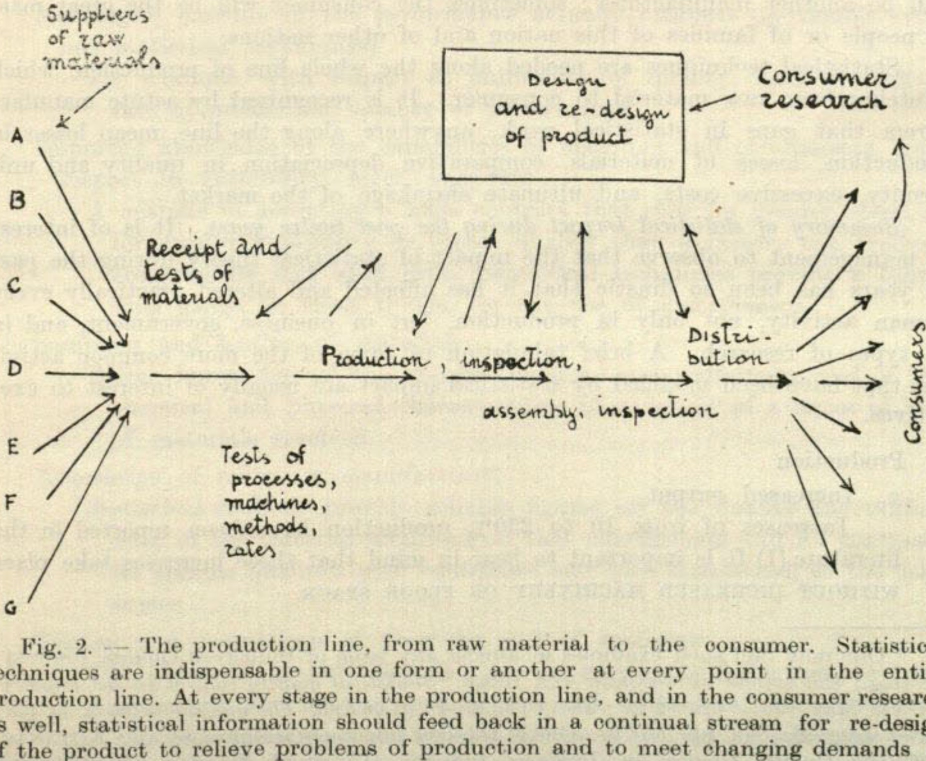


Fig. 2. — The production line, from raw material to the consumer. Statistical techniques are indispensable in one form or another at every point in the entire production line. At every stage in the production line, and in the consumer research as well, statistical information should feed back in a continual stream for re-design of the product to relieve problems of production and to meet changing demands in respect of quality, uniformity and quantity.

LITY and in which to conduct negotiations, even though buyer and seller be in different parts of the globe.

The statistical solution of the problems that confront the management sometimes go by the name "operational research." The name is not important: the problems and their solutions are.

Impact of statistical theory on production and distribution. In order to exhibit the use of statistical techniques in industry, from the standpoint of management, I have found it useful to think of a production line (Fig. 2) which starts with raw materials from suppliers A, B, C on the left.

Material must be received, tested, accepted, rejected, paid for, and sorted for use. The sampling and the tests of materials must make statistical sense, otherwise the buyer may accept poor quality and high variability, and the buyer or the seller may be subjecting himself to systematic over-or under-payment. Much of the best work in the statistical method in industry has extended back to the plants of the sources of raw materials, in recognition of the fact that a certain amount of uniformity and dependability of raw materials is necessary if a manufacturer wishes to put out good quality himself. But he must define "good" and "uniform" statistically in terms of the demands of the consumer.

Next comes the production line with its various operations and assemblies, tests, and final inspections. Then the product starts for the market through various channels of distribution. Sometimes the consumer will be only another department of the same company across the corridor. Sometimes the consumer will be another manufacturer; sometimes the consumer will be the great mass of people or of families of this nation and of other nations.

Statistical techniques are needed along the whole line of production, which stretches from raw material to consumer. It is recognized by astute manufacturers that gaps in statistical work, anywhere along the line, mean losses in production, losses of materials, comparative depreciation in quality and uniformity, excessive costs, and ultimate shrinkage of the market.

Summary of statistical impact during the past twelve years. It is of interest to management to observe that the impact of statistical theory during the past 12 years has been so drastic that it has affected and altered practically every human activity, not only in production, but in business, government, and in all types of research. A brief tabulation of some of the more common activities that have been modified by statistical impact are usually of interest to executives.

1. Production

   a. Increased output

   Increases of from 10 to 230% production have been reported in the literature.(1) It is important to bear in mind that these increases take place WITHOUT INCREASED MACHINERY OR FLOOR SPACE.

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[1] One may find such examples in almost any issue of Industrial Quality Control; see (e.g.) the article by GEORGE VER BEKE *Statistical quality control in the foundry*, vol. vii, May 1951 pp. 82-86; also CUYLER P. HAWKES, *The quality problem on purchased material*, ibid., pp. 66-70. One of the best documentations is by K. KOYANAGI *Statistical Quality Control in Japanese Industry* (Union of Japanese Scientists and Engineers, Tokyo: May 1942); p. 40 for example.

How ? Through more efficient use of materials and machines ; improved quality ; less scrap and re-work.

A large pharmaceutical company reported that they were able to make a particular antibiotic with only 30% as much raw material as they had used six months earlier before they introduced control chart techniques. A large steel company reported the saving of one-third of their fuel over their performance the year before. Such results are not unusual : they are merely illustrative.

b. Better quality at less cost

c. Greater uniformity at less cost

d. Improved competitive position through increased production, better quality, better uniformity, better design, reduced costs.

e. A meaningful international language

— by which to express standards and specifications of the quality desired

— by which to describe the quality of a product already made

2. Management

Meaningful specifications (impossible without statistical techniques)

For example, with respect to uniformity of quality, rate of production, quality of performance

Meaningful measure of the performance actually attained (impossible without statistical techniques)

For example, with respect to uniformity of quality, level of quality, rate of production, quality of performance

Improved knowledge of the capabilities of machines and of processes, with respect to uniformity, level, and rate

A mistake in accepting a huge contract that calls for greater speed or for greater uniformity or higher quality than a factory can produce economically may spell ruin. Statistical techniques provide a continual gauge on these things, for the use of management.

Sampling and testing of materials

Better knowledge of the weight, quality, and uniformity and of the chemical and physical characteristics of a lot or of a series of lots of materials received.

Knowledge of materials manufactured

Statistical methods provide reliable figures on the quality and uniformity of the material produced, so that management can fill contracts for specific qualities with confidence and with satisfaction to the consumer.

Testing and comparison of processes and of materials

Two processes or two materials are to be compared for cost, and for uniformity and level of quality produced. Statistical techniques provide economical tests and reliable inferences to help management make the right decision.

Measurement of costs and of production rates

Statistical design of observations on costs and rates will give maximum reliability per unit cost expended, and will provide simultaneously an effective tool by which to increase the efficiency of an operation.

Timely approximations on production, sales, shipments, sizes and activity of accounts, for management purposes

Most economical inventories for retail and for wholesale stocks, and for service.

3. Consumer research (through modern statistical procedures, an essential adjunct to economic production ; *vide infra*).

4. Auditing and accounting

Verification and reconciliation of inventories and of accounting records, with improved reliability at less cost

Auditing, with improved reliability at less cost

Verification of bills payable, with improved reliability at less cost

Current determination of unearned income (interline and intercompany payments ; unused tickets ; unused deposits).

5. Determination of physical condition of plant ; estimates of repairs needed, by type of repair (telephone companies, railways, electric light service, gas service, etc.).

6. Chemical and physical measurements and experiments

Statistical designs provide improved precision and greater accuracy at reduced cost.

7. Standardization and specification

This is in large part a statistical problem. A standard and a specification should serve many needs ; and needs can be determined only by reliable surveys, and by reliable tests of performance.

Moreover, neither a standard nor a specification has any meaning unless it is written in terms of a test that can be brought into statistical control, and without too much expense or difficulty.

8. Standardization of drugs

Statistical control offers the best guarantee of the measure of potency of drugs and vitamins. Tests of potency must show statistical control if the dosage is to have meaning.

9. Improvement of the quality of clerical operations (better and more accurate results at reduced cost).

10. Safety (more effective results through more effective administration of a safety program, made possible by statistical definition of significantly high and significantly low rates).

It is difficult to resist expansion of this list, but perhaps the items in it are of the most interest to people in management. Brief mention should perhaps also be made of the accomplishments of statistical theory in agricultural production, medicine, and biometry. These were the earliest applications of modern theory. Some of the best applications are in the increased usefulness and economy of government statistical programs, information provided by which is of vital importance to industry.

What is consumer research? Consumer research is an integral part of production. Without consumer research the product has little chance of being maximally useful, or made in the most economical quantities. In fact, a manufacturing concern can hardly hope to stay in business today without vigorous consumer research.

Consumer research takes the pulse of the consumer's reactions and demands, and interprets the results as predictions for the use of management. The main use of consumer research is to feed consumer reactions back into the design of the product, so that management can anticipate rationally changing demands and requirements, and SET ECONOMICAL PRODUCTION LEVELS now for future demand months later. This is one of the most important aspects of production -regulating *quantity* as well as quality and uniformity.

Consumer research is not merely selling. Real consumer research, geared to design and production, is an indispensable modern tool for the problems of the industrial age. Good consumer research, combined with other statistical techniques, can help to build a firm foundation for private enterprise.

Consumer research is democracy in industry; it gives the user and the nonuser a voice in the design and price of the product. It is *communication* between the manufacturer and the users and potential users of his product, like this:

Manufacturer ⟶ The user and
Manufacturer ⟵ the nonuser

When the number of users and potential users is in the thousands or millions, as it is in modern industry, this communication must be carried out by sampling procedures. Through this communication the manufacturer is able to re-design his product, to make it better-better in the sense of meeting the needs of the people who may buy it, and of producing the quality and the uniformity that are best suited to the end-uses and to the prices that people will pay. Consumer research acts as a governor or servo-mechanism, which by probing into the reasons for the preferences of consumers, makes predictions to assist management to look ahead and see what design, what quality, and what uniformity the consumer demands.

Consumer research also enables management to smooth out the rate of production to meet the demand in the near future, with minimum net losses from under-production or from over-production. Such performance contributes heavily toward orderly and economic production, and better satisfaction to both the consumer and the producer.

Relationship of management to statistical workers. Management should not only understand the responsibilities of the statistical workers in the other groups, but also something about the conditions under which they can best achieve results, and something about their actual work. It is therefore desirable, in talks to mangement, to explain briefly to them : (*a*) some principles of organization for the statistical control of quality ; and (*b*) the kind of work that the other groups do, and their relationships to each other and to the whole organization. These points occur in the following sections.

Suggestions on principles of organization. Not all people engaged in management can hope to become proficient in statistical techniques, nor to devote time to pursuing applications. Management must depend on a specialist, who might be designated as a "statistical administrator," or as a vice-president in charge of statistical work (more on this later). It is important that management see the necessity for an organization that contains this function.

No particular organization chart will suit any particular need exactly without modification, but one may lay down some general principles that any organization chart must conform to. In the first place, the statistical method in industry is NOT merely the use of $\bar{x}$ and R charts or of acceptance sampling in isolated spots along the production line, nor in consumer research alone, nor of any other specialized technique. A company can not afford to do some excellent work with Shewart charts in one part of the plant, while it permits the sampling and testing of materials, of machines, or of processes, or its consumer research, to sag into lower grade.

Second, if statistical techniques produce savings and better quality at reduced cost, then they should be used wherever they may be found useful, and not just where they happen to grow up.

Third, statistical techniques must not be administratively subordinate to the testing of materials, to production, inspection, consumer research, design, or to anything else, yet they must serve all these functions. Statistical work can not be directed without knowledge of statistical principles any more than research in thermodynamics could be directed by an accountant. The statistical administrator must enjoy a position like that of the comptroller, whose job is to direct the methods and the techniques of the accounting throughout the company, wherever accounting is done, and to be responsible for the technical direction of such work.

These thoughts run parallel to a principle laid down in the Hotelling report [1] on the teaching of statistics, viz., that the teaching of statistics must not be subordinated to the Department of Economics, nor to the Department

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[1] HAROLD HOTELLING and committee, *The teaching of statistics*, "The Annals of Mathematical Statistics, vol. xix, 1948, pp. 95-115.

of Mathematics, nor to the Department of Education, nor to anything else. Statistical teaching and statistical work in government and in industry are full-time professional jobs of their own.

Fourth, the use of statistical methods is not mere "application." There can in fact be no application of theory (or indeed of any "rule") without theory to apply. There can be no theory without knowledge, and there can be no knowledge without research, however humble.

Failure to provide proper organization for the wide use of statistical ability permits continued waste of materials, waste of manpower and of machinery, waste through ineffective tests for the purchase of materials and for the sale of product, wrong statistical information on consumer reactions and on the performance of the product, wrong and tardy information on sales, incorrect data concerning the company's services, ineffectual analyses and incorrect applications of current government statistical reports, lack of operating intelligence through failure to summarize their own reports and accounts, all of which could be improved by the use of modern theory.

Management must see the need to improve the traditional organization, and to introduce statistical administration at a high enough level to be effective.

Perhaps one of the greatest barriers toward better statistical procedures in industry is the vertical organization without review or coordination somewhere higher up. Bad statistical practices then merely propagate themselves. There is no channel for stopping them and none for improving them.

Professor Holbrook Working observed to me in 1942 and 1943 that the companies that seemed to make the most rapid strides were the small ones. My own explanation is not that the people there are smarter, but that horizontal motion of statistical ability from one point in a factory to another is usually easier in small companies. In too many big companies one finds superb statistical ability here and there, completely frustrated and helpless, bound by an inflexible vertical organization, with no statistical coordination from the top, while the really important statistical problems are like as not handled by people with no statistical ability.

Incidentally, the statistical control of quality is NOT installed. One sometimes hears of a company that is about to "install" the statistical control of quality, as if they were about to install a new air-conditioning system, or new linoleum, a new filing system, or even a new president. Statistical principles and techniques must be rooted and nourished with patience, support, and recognition from top management. One can not expect them to blossom out suddenly, although results sometimes come with astounding speed. They may even lead to a mistake now and then along the route to improved procedures, processes, and product.

III. Statistical Administration

The duties of the statistical administrator, or of the vice president in charge of statistical methods. As management can not engage in the intricacies of the technical statistical problems of procurement, production, and distribution, they must depend upon an executive who has the necessary qualifications. This function may be called *statistical administration*, or it may go by some other name, such as vice president in charge of statistical methods.

Statistical knowledge is a rare but productive commodity along the entire production line (Fig. 2) from raw material to the consumer. The placement of statistical techniques in the operations where they will be most productive is the chief duty of the statistical administrator. Statistical knowledge must serve all the stages of production, distribution, and design, yet it must not be subordinated to any of them. Proper statistical administration can only take place at a high level. It is not a matter for a single department to deal with. Each department has its own work to do and can not be blamed for doing it. The proper organization must be one in which statistical ability can be shifted about and directed toward whatever problems appear to be the most pressing from time to time. It must be an organization that charges someone with the duty of discovering what problems confronting the company are wholly or partly statistical problems, and of finding the best possible solutions. What was a satisfactory organization ten years ago is now completely outmoded.

The statistical administrator should report to top management, and be responsible only to them. He must know the plant, and the aims and problems of the board of directors and of the plant supervisors, and of the distribution of the product. He differs from other men of these same qualifications (*a*) by knowing IN ADDITION statistical principles and the power of statistical techniques; (*b*) by the ability to recognize statistical problems when he sees them, wherever they be, present or future, and whether they lie in nonuniformity of raw material, testing or sampling of materials, high costs or high fraction defective in certain operations, variable productivity, variable results in sales, need of management for statistical information from the company's records or from government agencies, need and evaluation of consumer research, design of the product, standardization, etc. He need not be a renowned statistician, nor even particularly skilled in statistical theory. However desirable these qualifications may be, amongst his other requirements, they are unrealizable in practice because of scarcity. The job requires that the incumbent be clever at adaptation of theory; clever in leadership, and in exposition. He should guide statistical research in the company with an eye to problems to be faced in the future. He must work in any and all departments of the company, and would place statistical knowledge in spots where it is needed, with the aim of improving any procedure or process. His work, like all statistical practice, is effected largely by cooperative efforts in experimentation and adaptation. People doing statistical work in the company should be responsible to him in regard to their statistical techniques.

The want of statistical administration in industry too often squanders what statistical ability there is on unimportant trifles, or discourages this ability, or buries it in a line organization, with the result that one will see simultaneously, in one company, some of the finest and yet some of the most horrible examples of statistical applications. This is a wasteful condition.

Study of controllable causes. To all four groups, the application of statistical techniques is largely the study of causes-is the variability significant, and why? why one method is better than another, and how much; why one raw material is better than another, and the difference in price, cost of working it, etc.; the causes why one treatment is better than another, one machine, one type of machine.

Sometimes the differences are very small, on the order of 1, 2, or 5%. The test to discover which is better must be designed properly, else the answer may be wrong, or the experiment to determine which is better may be far more costly than necessary.

The statistical administrator will concentrate his efforts on *governable* causes of trouble, and ways to effect improvement, wherever the possibility may exist. It does no good to study needlessly causes that are ungovernable. For example, if one possible cause of trouble in production is excessive humidity, while management knows full well that nothing will be done about humidity because of the expense of installing new drying equipment in an old building that will soon be abandoned for a new one, then it would be foolish to try to discover by experimentation, properly designed or otherwise, whether humidity has anything to do with the difficulties.

The making of a catalog of possible difficulties in production and of the possibile controllable causes thereof is the first step in a statistical study. This step discloses the likely spots for the application of statistical techniques, which should then be applied wherever judgment indicates that they might help to discover which of the suspected and governable causes of nonstatistical variability are actually guilty. The removal of a cause of nonstatistical variability improves uniformity and efficiency. Sometimes a clear statement of what are the possible assignable causes in particular operations will lead to some obvious solutions without the aid of statistical techniques. There is no use in applying statistical techniques to answer questions whose answers are obvious.

This first step may not appear to be a statistical problem, and indeed statistical techniques can not find the likely spots where they will be successful, yet this first step is absolutely essential for successful statistical work. The initiative must come from the statistical administrator whose profession will be described further on. This is one reason why anyone who expects to direct statistical knowledge in production must have the ability to perceive the problems of production, and to work with experts in various lines, such as production experts, engineers, designers, etc. It is up to management to select a man for statistical administrator who has these peculiar and exacting accomplisments.

In the problems of research and development, management must first of all appreciate the importance of research, and the contributions that statistical theory has made to the success and speed of research and development.

The statistical education of the statistical administrator. The statistical administrator is an executive. He must first of all know the problems that face the management today, and he must guess what will face them a year hence, and be ready. Statistical theory to him is a tool for finding better answers to the problems that will confront management next month or next year than would be possible otherwise.

The statistical administrator needs to know when these problems and decisions can be aided by statistical techniques, and he must have some idea of the principles involved, so that he can find a statistician with the requisite knowledge of theory to apply the proper statistical power to the problem.

It is not necessary that a company have a world-renowned statistician in the job of statistical administrator. For many years to come, industry and government agencies will have to content themselves with men who have imperfect knowledge of modern statistical theory, but who know statistical principles and their power. The main requirement is NEW ORGANIZATION — some channel for review of the statistical procedures in a company that will stop some of the bad practices; some responsibility and ability, in the right place, to suggest new procedures and to help to adapt better ones; statistical research in theory to produce the techniques required.

Reorientation required in statistical teaching. We now have examples in the teaching of mathematical statistics and facilities for production of full-fledged theoretical statisticians in several well-known teaching centres. These teaching centres are the source of our future teachers and leaders in statistical research, including the 3d group under consideration here (see Part IV). But for every high-grade research man, industry and government need hundreds of men in executive positions, such as statistical administration-men who think statistically, who know when to use techniques, and who know when a technique is valid and when it is not. The need is greatest in executive positions, because here lodges the power of placing statistical ability where it belongs, and of recognizing and protecting real statistical ability.

There is no short and simple cure. The chief reason lies in the fact that, in spite of inspiring exceptions, executives by and large have simply not had the requisite background of education or experience in the use of statistical techniques.

Our schools of engineering, commerce, and business administration have not yet in general provided the opportunity for the studies that executives require. The statistical teaching there is too little and is 15 and 20 years out of date, with no life in it, nor recognition of the vital power in the methods of statistics and in statistical thinking. It will be even further out of date by the time our present students find out what they need. Something in the overcrowded curricula will have to go out to make room to teach statistical thinking.

Industry will therefore have to proceed in the visible future on the assumption that there will be a severe shortage of people who have had more than a rudimentary and unsatisfactory introduction to statistical principles.

For this reason, it is especially imperative that management see the need for proper statistical administration, to make the best possible use of the statistical knowledge that does exist.

Our schools of engineering, commerce, and business administration should teach statistical theory, not as an end in itself, but from the functional angle, as power, TO SOLVE PROBLEMS, illustrated by the sampling of human populations, the sampling of materials, the testing of materials, the testing of procedures, the testing of the performance of machines, statistical problems of standardization, of control of processing, of acceptance, of consumer research, of design, of inventories, etc. The aim should be to use statistical techniques to furnish reliable information at lowest cost on which to base predictions for the decisions of management, or for increasing man's knowledge. The aim should not be merely studies of the analysis of variance, sampling, design of experiment, testing hypotheses, discriminant analysis, etc.

The basic theory and statement of principles are the same for all sorts of application. This is why a small amount of theory, learned well, is such a powerful tool. No subject taught in school has such universal applicability, or can contribute so much to the acquirement of the empirical knowledge that is so necessary in modern industry.

What would happen if industry awakened to the need for theoretical statistical work from raw material to consumer? Increased production and all that, of course, but I am wondering about the supply of statistical brains. There would be a worse vacuum than there is now. Too sudden an awakening by industry could only draw incompetent statistical help, perhaps resulting in a set-back of statistical progress.

Meanwhile the statistical administration of industry will have to get on mostly with the aid of men who had their introduction to statistical techniques in short courses, or in home-study, because only a pitiful few oft he schools of engineering, commerce, and business administration have started to produce statistical administrators.

Statistical consultants. One partial solution of the shortage of statistical ability is to share this ability by making more use of statistical consultants. A consultant possesses several advantages: 1. He possesses specialized ability; 2. He does not know too much about the traditions of the company, nor about its business. Instead of a disadvantage, this is actually a strong point for the consultant. He may find solutions that people too long within the company could never have been able to see; 3. He puts the company on trial: if they fail to produce results, he will terminate his services in favor of more responsive clients. The consultant thus imparts an incentive to produce results.

IV. Research

The work performed by this group. The work performed by the men in this group is extremely varied. They assist in long-range assignments such as redesign of an old product, design of a new one, possible uses of cheaper raw materials, tests of machines, of alternative processes and treatments, interpretation of data from studies of consumer research, interpretation of data from government statistics, and many other types of problems. They work on short-range problems, here, then there, as trouble arises. Sometimes their research is conducted to settle a dispute between (e.g.) production engineers and design engineers. The power of statistical theory is particularly helpful in the design of experiments for distinguishing between two machines, two processes, two materials, or for the development of a new product, especially where the differences are small. Answers can be obtained by trial and error, in the good old-fashioned way, but the answers so obtained may also be wrong. They can be right half the time by tossing a coin. Something better is demanded. In today's competition for output and uniformity, and for the development and marketing of new products, speed and reliability of the answer is necessary, while the cost of the experimentation must not be too high. As little as 2% saved here, 5% there, etc., adds up to a superior competitive position and better service.

Statistical education required for research. There is no limit to the statistical applications that this group may work on. They will require daily the theory of sampling, design of experiment, testing of hypotheses, analysis of variance, and other techniques. They will require new theory for new problems. They must possess ability for research in new fields. Some of this research may be new statistical theory, or new adaptations of existing theory.

The statistical education for this group is ideally several years at a first-rate teaching centre in mathematical statistics. However, many successful men in research have not had this opportunity, but have sought their statistical education by home-study and in special courses.

Attendance at meetings and at lectures should be treated as an important part of the job of this group. They should be encouraged to take courses at a local university on company-time : it is a wise investment. A good library in the company is requisite, and the research men should be urged to use larger libraries in the city. Publication in journals and publication of books should both be encouraged.

In the United States we have no system to provide continuous education of this group of people, as well as the other groups, like that worked out by Mr. Koyanagi at the Union of Japanese Scientists and Engineers in Tokyo. This "institute," as it would be called in our country, and I believe in European countries as well, provides training for all levels, including management. There are afternoon meetings once or twice weekly for people who can come regularly in Tokyo. There are courses that last one week, two weeks, and three weeks, some of them continued after an interval of a month or two, to permit engineers, economists, and other workers to come from far parts of Japan to study a while and then return to their work. This "institute" is certainly one further reason for the rapid expansion of the statistical methods in industry in Japan, in addition to the good start made by management in 1950. So far as I know, there is nothing like it anywhere else.

A word on the design of experiment. [1] The central idea of the statistical design of experiment is that it will hasten (as from 2 years to 6 months) the result of the development of a new product, and that it will greatly increase the number of research projects that will lead to definite conclusions that are acceptable to all concerned. The statistical design of experiment achieves successful results in several ways :

(*a*) By making certain in advance that the results will be used. Through preliminary examination of a proposed project : *i*. one determines in

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[1] It is a pleasure to acknowledge help from Dr. W. J. YOUDEN of the National Bureau of Standards in this paragraph.

advance, all the possible results ; *ii.* secures agreement, in advance, on the interpretation or action reasonably associated with each of the several possible results that may be obtained. This preparation will greatly enhance the usefulness of the experimental program, and it will avoid confusion, dispute, and loss of an experiment.

(*b*) By reducing the experimental error through use of various devices.

(*c*) By the use of efficient designs (factorial designs, confounding, fractional replication, randomized blocks, etc.).

V. Workers in the Manufacturing Plant (Production, Inspection, Testing Materials)

The work performed by this group. The work performed by this group is highly varied, but every worker may be regarded as an administrator over a small domain, viz., himself and his machine, or the men under his care. This group needs the same basic principles that management needs (see Part II).

The 8-day intensive courses. In addition, this fourth group needs to know how to use some simple techniques. They can learn in 8 days :

The basic principles (Part II)
Some rudimentary theory of sampling
Techniques of the various Shewart charts
Acceptance sampling

It was the 8-day intensive courses, in simple language, initiated at Stanford University [1] in July 1942 at the suggestion of this author, and followed soon by many similar courses in industrial centres throughout the country, that gave the statistical control of quality its real start in the United States. Similar but shorte courses conducted by the Ordnance Department in factories that were making war materials did part of the job. Another aid, without which the results could not have been so pronounced, was the short texts [2] on the use of Shewart charts published by the American Standards Association in July 1942, just in time for the first intensive course at Stanford University. The text by Simon [3] (now Lt. Gen.) had just been published for people who wished to make deeper studies. The first step in anything new is the basic theory, and

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[1] The first intensive courses were 10 days, later reduced to 8 days.

[2] The American War Standards on the statistical control of quality bear these titles and dates :

1. Z1. 1-1941. Guide for quality control (April 1941).
2. Z1.2-1941. Control chart method of analyzing data (April 1941)
3. Z1.3-1942. Control chart method of controlling quality during production (May 1942).

[3] LESLIE E. SIMON : *An Engineer's Manual of Statistical Methods* (Wiley, 1941).

this had been provided by Shewhart's books [1] published in 1931 and 1939, and by papers published earlier by Shewhart and by Dodge and Romig.

During the years 1942-45 something like 2000 men attended 8-day courses. This training continues; there are at least half a dozen 8-day courses in various universities over the United States during a year, and many factories provide courses of similar content, under the tutelage of experts.

An important feature of the 8-day courses, even in the first one in July 1942, was the arrangement for organizing the students in any city into an informal group to meet monthly thereafter to study and to talk about problems. The American Society for Quality Control condensed upon these loosely organized groups in 1946.

It is important that statistical education of any group be continued. This is particularly true at the lower levels. A short heavy dose of statistical techniques for 8-days naturally leaves people dazed with many questions which can be cleared up only by further thought and by practice of the techniques learned.

Local chapters of the American Society for Quality Control and the American Statistical Association in many cities of the United States and in Canada, with monthly meetings, provide opportunity for continuation.

In Japan, the Union of Japanese Scientists and Engineers has provided a marvelously graded system of continuation study to suit all needs (mentioned in Part IV).

It is significant that in the United States and in Japan the statistical control of quality lay dormant 11 years after the theory was in book form; then spread rapidly immediately after a few hundred men had been trained in the 8-day courses. In Japan, the simultaneous education of top management made the growth much more rapid there.

Content of the 8-day intensive courses. The essential principle in the 8-day courses is to keep the content simple. The results are better if the instructors do not try to cover too much.

Although the amount of theory must be held to a rudimentary minimum in the 8-day courses, the fact remains that theory is all that one may safely teach. Practice without theory is misleading, because the next problem is different. The selection of the theory must be judicious. The theory should be taught as statistical principles, not as mathematical derivations from basic assumptions.

The courses should include basic principles in plenty, along the lines mentioned in Part II, illustrated by examples and by use of the various control charts (p, c, $\bar{x}$, R), with data furnished by random drawings of beads and of disks; and later with data furnished by actual data from manufacturing plants, preferably furnished by some of the students (described *infra*).

In my own teaching, I use the chart for sigma but once in a course, viz., to show that for samples of size $n = 5$, the charts for R and sigma present

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[1] WALTER A. SHEWHART: *The Economic Control of Quality of Manufactured Product* (Van Nostrand, 1931); *Statistical Method from the Viewpoint of Qualty Control* (The Graduate School, Department of Agriculture, 1939).

almost identical patterns, so that one chart may substitute fo the other. The easy computation of the range (R) decides the choice in its favor.

The content of the 8-day intensive courses in the United States varies with the instructors, and with the statistical preparation and experience of the students. Hence any list of topics covered in such a course can only be illustrative of what has been found practicable in a particular instance. An illustrative list follows.

1. Basic principles of variability; chance and nonchance variability (as explained in Part II).

2. It will not pay to look for the causes of chance variability.

3. It WILL pay to look for an assignable cause of nonchance variability.

4. The Shewart chart tells us when the variation may safely be left to chance, or when it will pay to look for an assignable cause.

5. Chance or random variability illustrated by actual samples.[1]

a. The p-chart, for the fraction defective.

i. Draw 25 samples of 50 beads froma mixture that contains 3200 white beads and 800 red ones. Return each sample to the mixture and stir it throughly before drawing the next sample. This experiment illustrates random variability. In my own teaching, the students construct a chart for the proportion (p) for 25 samples.

ii. Plot the 25 points.

iii. Compute the upper and lower limits, and discuss the appearance of the chart.

iv. Project the limits into the future through 25 more samples.

v. Draw a second set of 25 samples and observe that the points stay within the projected limits. This is an illustration of ***stability***, or the ability of the chart to predict, on the basis of 25 samples or more, a future distribution when the variations continue to arise from the same chance causes.

By changing the proportion of red beads from 4 : 1 to 3 : 1, one may illustrate how a new set of 25 points is definitely out of line with the preceding 50 points, and how the control chart discovers an assignable cause (viz., a change in the proportion red).

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[1] This author used crude but satisfactory apparatus for illustrating random variability in the first intensive course (held at Stanford University in July 1942). Later refinements suggested themselves. Mr. A. I. Peterson, then of New York University, designed a paddle with rows of depressions, 5 one way and 10 the other, which picks up 50 beads unerringly from a mixture of about 4000 10 mm. beads white and red in the proportions about 4 : 1. Some instructors have built elaborate apparatus to illustrate the formation of various random distributions. These mechanical aids may indeed be the best way to teach some of the important parts of statistical theory.

b. The c-chart, for the number of flaws per standard test. Draw 25 samples of 100 beads from a mixture that contains 4500 white beads and 500 red ones. The powers of prediction and of detection are illustrated as before.

c. The $\bar{x}$- and *R*-charts. Draw 25 samples of 5 disks from 200 disks, so marked that they constitute a distribution between -8 and +8. The distribution need not be of any particular shape, although it should perhaps be unimodal to agree with most stable conditions met in practice. The numbers may represent departures in units of .001 cm. from a nominal diameter of 1 cm. Plot the points for $\bar{x}$ and *R*. Compute the limits, and discuss the appearance of the charts. Draw 25 more samples, and observe that the original limits projected are able again to predict the range of variation that arises from the same chance causes.

d. Change the disks to a distinctly different mean, 2 units higher ; then to a distinctly different standard deviation, double the first one, with the same mean. Observe how the $\bar{x}$-cart, and then the *R*-chart, detect the changes.

e. A chart for sigma for 25 samples, plotted parallel and just below the chart for *R*, will be sufficient to illustrate the fact that the range (*R*) will serve the same purpose as the chart for sigma. As the range is easier to compute, the decision is in its favor.

The experiments may be varied in an infinity of ways.

6. The effect of mixing the product from several sources. Now mix all three sets of chips together, and observe that the control charts for $\bar{x}$ and *R* show only chance causes. This experiment demonstrates the fact (*a*) that mixing the product from several sources renders a chart helpless to detect nonchance causes ; (*b*) that knowledge of the process is necessary in order to make intelligent use of the Shewhart charts ; (*c*) the interpretation of a run of 7 or more successive points above or below the central line.

7. Charts constructed from actual data. The use of data from several manufacturing plants, preferably supplied by the students, is particularly important, and the wider the variety the better, because such data may possess a familiarity to the students that will help them to " get aboard the train ".

8. Distinction between regulation of the process, and the disposition of product already made.

9. Acceptance sampling, and use of tables (content about equal to Chapter 8 in my book *Some Theory of Sampling*, John Wiley and Sons, 1950) ; use of the Dodge-Romig tables (Wiley, 1944).

10. Exercises, and examples, and reading from :

(*a*) The American Statndards pamphlets (cited earlier)

(*b*) Eugene L. Grant's *Statistical Quality Control* (McGraw-Hill, 1946)

Throughtout the 8 days, as in any course, the most important gains are the remarks and brief lectures by the instructors, who should be men of wide vision and experience.

Incidentally, the use of more than one instructor is advisable. In the first place, one man can hardly have the strength to do all the teaching, 6 hours per day, 8 days running. Second, a single instructor, no matter how good, can hardly maintain the interest of the students. Third, the students profit from the variety and different points of view of several instructors.

Nothing takes the place of good teaching. The teaching should not be an exhibition of the superior knowledge of the instructors, but should instead be the communication of theory and principles at whatever level and variety seem adapted best to the particular students in the class.

The educational perequisites for this group. The best single word for describing the educational prerequisites for learning the basic principles and some simple techniques for the statistical method in industry is NONE. The main requirement is an open mind and the eagerness to learn. However, students seem to do best if they have had some experience in a manufacturing plant, a fairly good schooling, with a liking for figures and for deductions from numerical data. People who have had a course in elementary statistics are at a distinct advantage. Today, in many of the 8-day courses in the United States one finds students who have had basic courses, and finds some who have been applying the statistical control of quality for some time. This background is excellent, provided the previous learning included enough statistical theory to guide the practice that the men have had.

When will savings commence ? This is a difficult question. It would be rash to predict just when savings will commence in any given plant. It is possible, however, to make some statements concerning past experience. In management knows nothing of the statistical method in industry, and if a worker has no chance to use what he has learned in an 8-day course, it is only by dogged perseverance that anything at all will happen. This was the condition of things throughout most of industry in the United States in 1942. People with some statistical training had a long fight. Occasional successes, in discovering troublesome assignable causes, in the face of opposition, broke through the resistance here and there. Gradually at first, then rapidly, the opposition broke down. Under more favorable conditions, aided by good luck, many plants have shown gains in a few months.

Résumé

Dans le domaine de l'industrie on doit donner quatre divers types d'enseignement des méthodes statistiques, car quatre sont les catégories de travailleurs qui requièrent leur usage, c'est-à-dire :

— Chargés de la direction
— Chargés de l'administration statistique
— Chargés des recherches
— Chargés de la production, des inspections et des réceptions.

En ce qui concerne la « direction », les techniques statistiques donnent des outils objectifs pour decouvrir et déterminer les tolérances appropriées, les taux-standards de production, les prix de revient, les modèles d'exécution de produits pour cela qui

concerne les machines et les ouvriers, l'aptitude des machines à travailler selon certaines dimensions et des autres caractères avec tolérances déterminées, les connaissances opportunes pour projeter ou pour reprojeter les travaux relatifs à un produit, les méthodes qui permettent d'essayer d'une façon moins coûteuse et plus satisfaisante les matériels en arrivage et les provisions. Les techniques statistiques assistent l'œuvre de direction pour découvrir les imperfections des produits et les méthodes les meilleures de refourniment, de production, de vente et de préparation des projets.

L'Auteur définit les méthodes statistiques dans l'industrie comme l'application des principes et des techniques statistiques à toutes les phases de production, de distribution et de préparation des projets, dirigées à la production et à la distribution d'un produit qui soit surtout utile et vendable.

L'Auteur relève que pour la direction il y a beaucoup d'importance dans le consommateur et dans les recherches sur les consommateurs. Le consommateur c'est le chaînon le plus important de la chaîne de la production. La satisfaction des demandes du consommateur et l'égalisation constante du projet et de la qualité aux possibilités de frais du consommateur deviennent plus parfaites et économiques avec l'aide des modernes techniques statistiques d'échantillon et des projets d'expérimentation.

L'administration statistique est une nouvelle profession, dont le but c'est l'usage le meilleur de la connaissance statistique chaque fois que cette connaissance peut être employée avantageusement dans la chaîne de la production, à partir des matières premières jusqu'au consommateur. L'administration statistique requiert la connaissance des principes statistiques mais n'est pas nécessaire une profonde connaissance des mêmes techniques. Ce qui est demandé surtout à un administrateur statistique c'est de reconnaître un problème statistique lorsqu'il le voit et de fixer les méthodes statistiques à suivre. L'administration statistique requiert une longue expérience et connaissance des problèmes de la production et de préparation des projets. Une bonne administration statistique ne se contente pas d'augmenter ses connaissances statistiques de temps à autre et occasionnellement. Au contraire, l'administration statistique gagne son but en appliquant ses enquêtes d'un problème à l'autre, dans l'intérieur de l'entreprise partout où ils se présentent d'une façon plus notable, soit qu'ils regardent la spécification, l'échantillonnement ou l'essai des matières premières, soit qu'ils se réfèrent à la chaîne de la production, soit qu'ils concernent les projets ou les modifications des projets basés sur des recherches relatives aux consommateurs.

La charge des recherches regarde la découverte de ce qu'on doit connaître en avenir pour satisfaire aux demandes du consommateur au prix le plus convenable qui est possible. La puissance de la théorie statistique est particulièrement utile dans les projets de comparaisons, par exemple, de deux procès, de deux matériaux, de deux méthodes d'instruction, particulièrement lorsque les différences sont petites mais très importantes pour l'économie de la production. Les théories statistiques les plus avancées sont d'usage constant dans les recherches industrielles.

Les travailleurs chargés de la production, des inspections et des réceptions peuvent appliquer les simples diagrammes de Shenhart. Ils peuvent apprendre quelques applications d'eux depuis peu de jours. Dans plusieurs usines chaque travailleur rédige son diagramme et il en fait usage. De simples méthodes statistiques, dans les mains du travailleur, lui donne un moyen rationnel de connaître la qualité de sa production et de l'améliorer.