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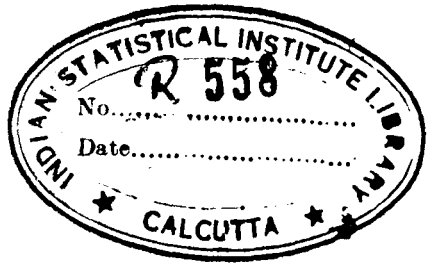
INSPECTION ENGINEERING

by

W. A. Shewhart



A discussion of the theory and practice of inspection engineering for the use of the members of the Inspection Engineering Department of the Bell Telephone Laboratories
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CHAPTER I

THE RÔLE OF INSPECTION ENGINEERING

1. Some Earlier Objectives of Inspection Engineering

According to the dictionary, to inspect is to look upon, view critically, examine, or investigate something. In this sense most of our conscious moments are spent in inspecting. In this sense every engineer is an inspection engineer.

One of the first serious attempts to outline in a broad way the objects of inspection engineering was that of R. L. Jones.[1] He stated two fundamental objectives: to protect the consumer, and to promote economy of production. In the same paper he went further and broke these down into five specific objectives, viz., a) determine economical percentage rejection, b) throw out defects at right point in production process, c) use sampling to minimize inspection work, d) detect trends in quality, e) find causes of such trends. Such objectives are far more definite than that of the older watch-dog conception of inspection. The phrase "protection of the consumer", however, requires amplification. As to promotion of economy of production, we need to differentiate between the part to be played by the inspection engineer and that played by development and production engineers.

It is natural that the following kinds of situations should influence the development of objectives. If an inspection engineer finds a piece of apparatus that does not conform with the requirements, what action is he to take? Often an inspection engineer is supposed to investigate complaints and make recommendations as to the action to be taken. Furthermore, he is expected to specify ways of inspecting the quality and to make a periodic quality report. In other words, the following four functions have become associated with inspection engineering:

A. Recommendation for handling of non-conformance cases.
B. Assistance in adjustment of complaints.
C. Writing of inspection specifications.
D. Preparation of quality reports.

Of course, there are other ways of classifying the functions that have come to be thought of as belonging to the field of inspection. Even a casual

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1. "Quality of Telephone Materials", Bell Telephone Quarterly, Vol. 6, pp. 32-46, January 1927.

consideration, however, reveals that the rôle of the inspection engineer is not clearly defined by a mere statement of such objectives. In fact, the attainment of such requires the cooperation of other kinds of engineers. Furthermore, it is recognized that inspection must enter at almost every, if not at every, step of the fabrication process from raw material to finished product. Hence, it is reasonable to ask two questions:

1. Is inspection engineering a distinguishable kind of engineering?
2. Does an inspection engineer require a special kind of training?

In this and the succeeding chapters it will be shown that the answer to each of these questions is "Yes". Evidence will be presented not only to justify this answer but also to indicate the outstanding significance of the field of inspection engineering and the remarkable opportunities to make important contributions in industry which lie before the properly trained inspection engineer. We shall find that inspection engineering is both a staff and line organization function and that outstanding opportunities lie before inspection engineers in both phases of this work.

Let us start by looking at what may perhaps be considered the general objective of engineering for the purpose of picturing in a broad way some characteristic inspection engineering problems.

2. Four Problems of the Inspection Engineer

The broad fundamental function of engineering and manufacturing is simply that of making use of physical properties and laws in the fabrication of things to satisfy human wants. For example, the American Telephone and Telegraph Company accepts as its duty the provision to the American people of adequate, dependable, satisfactory, and economic telephone service.[1] Here we have a definitely expressed recognition of the fact that the ultimate goal of engineering is to satisfy human wants in a certain way.

Often we think of their being the three following steps in attaining this objective: determine the specific wants to be satisfied in a given case, specify the physico-chemical characteristics of the standard thing that will satisfy in an adequate, dependable, and economic manner the given set of specific wants, and produce things that meet the specifications.

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1. See, for example, Mr. Gifford's statement in his report to the stockholders, 1927.

One of the earliest conceptions of the rôle of inspection is simply that of examining the product to determine whether or not it conforms with the specifications. It has been for many years appreciated, however, that to make 100% inspection at every stage in the manufacturing process involves an excessive expense, even though such inspection does not involve destructive tests. Very early in the history of inspection, therefore, it was found necessary to rely upon the results of sampling. Furthermore, in many instances the required tests were destructive and hence it was absolutely necessary to introduce sampling. Thus arose perhaps the first characteristic problem of inspection engineering, viz.,

Problem A - How large a sample shall be taken in a given case?

It is, of course, true that this question arises whenever any engineer or scientist makes any series of measurements, but the practical significance of the answer is not such as to arouse the same general interest as in the case of inspection where the cost of taking unnecessarily large samples becomes excessive.

The first concerted effort to develop the technique for applying sampling theory to the determination of the size of sample was launched within the Bell System about 1924 under the direction of R. L. Jones.[1] To be able to place much reliance in a judgment as to the quality of a lot from an examination of a sample from that lot, it is necessary that we know as much as possible about what the quality of the lot may be expected to be prior to taking the sample. It was early recognized, therefore, that the conditions for minimum sample sizes are those since described as the conditions of economic control.[2]

As pointed out by Jones[3], however, it is not sufficient to determine as best one can the quality of a given lot from a sample, but it is also desirable to detect causes of variations in quality greater than should be left to chance; hence a second problem peculiar to inspection engineering is:

Problem B - How to determine when the variation in quality of product is greater than should be left to chance?

This problem like the former one is handled in the developed theory of

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1. Loc. cit.

2. Shewhart, W.A., Economic Control of Quality of Manufactured Product, D. Van Nostrand Company, 1931.

3. Loc. cit.

quality control.[1]

When we consider what should be done with non-conforming material or how to settle a complaint, we note that it is no longer sufficient to consider simply the relation of the thing in question to the specification. Instead we must go back to the human wants themselves. In the case of complaints we must try to determine whether the complaint about the quality of the thing is justified. As a basis for forming a rational judgment in this case, the third characteristic problem arises, viz.,

Problem C - How shall we determine when quality of product is satisfactory, adequate, dependable and economic?

It might be argued, of course, that the same principles should be used here as are used in translating the human wants in question into a set of specifications. Since, however, no well-developed and well-recognized principles have been provided in industry, it falls to the lot of inspection engineers to develop such principles. Of course, one might also argue that, since the development and production engineer relies on his judgment as a basis for writing the specifications, it is reasonable that the inspection engineer do likewise. The result would be that the judgment of the inspection engineer would be pitted against that of the consumer without any rational basis for comparing the two. Hence the consumer has a right to expect a decision on the part of the investigating inspection engineer supportable on rational[2] grounds.

Furthermore, it should be noted that the consumer complaint is not based upon failure of the apparatus or thing in respect to some well-defined and measurable physico-chemical characteristics. Instead it is usually based upon his reactions to the thing. Hence the inspection engineer must be able to consider in an intelligent manner such grounds for complaint.

To begin with, it is necessary to determine what is meant by quality in the sense that it satisfies human wants. Does such quality reside in the thing itself? Is it a special kind of property of the thing? Is it the same as either or both the goodness and value of a thing. If so, how can it be detected and measured?

In the previous section it was noted that the preparation of a quality

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1. Shewhart, W.A., Economic Control of Quality of Manufactured Product, D. Van Nostrand Company, 1931.

2. The full significance of this term as here used will be developed as we proceed.

report was ordinarily classed as an inspection function. So long as we limit ourselves to a concept of quality specifiable in terms of measurable physico-chemical characteristics, an inspection report can easily be made to show how the observed quality differs from that specified and to indicate the likely causes of such variation. In fact, if the specifications are properly written and the tests are non-destructive, the production of such an inspection report is pretty much of a routine matter. If, however, for some reason or other the quality specified must be induced from measurements made on a sample, the inspection report should indicate (even under the ideal conditions assumed) the degree of rational belief p'_b that is to be placed in the judgments made by the inspector as to the quality of the part of the lot not inspected. Hence an inspection engineer must be qualified to estimate such degrees of belief. In other words, we come upon the fourth typical general problem:

> Problem D - How shall one best arrive at an estimate of the degree of rational belief to be placed in a judgment as to the quality of an uninspected portion of a lot?

Up to this point we have made the very bold assumption that the wants of the consumer can be rigorously and once for all translated into specifications expressible in terms of measurable physico-chemical characteristics. The sanctity often attached to specifications indicates the tendency on the part of many to lose sight of the seriousness of this assumption, and at the same time suggests the reason why inspection engineering has often been looked upon as a routine.

Until we know far more than we now know about physical properties and laws and about human wants, we can never rest assured that the thing wanted can be expressible in terms of measurable physico-chemical characteristics. Hence there is need for a continual check as to whether or not the specified standard itself is satisfactory, adequate, dependable and economic. In fact, what is the advantage of insuring that the quality of a thing conforms to a specification if the specification itself fails to specify what is actually wanted? The function of inspection engineering is therefore much broader than simply comparing things produced with those specified: it includes the attempted comparison with the thing wanted.

Let us now examine some of the steps that are customarily involved in attaining the general engineering objective with a view to amplifying our picture

of the role of inspection engineering.

3. Function of Inspection Engineering

To begin with we tacitly assume that there is an objective thing to be made that will satisfy the given set of wants in an adequate, dependable, and economic manner. Now it is customary practice to produce a tool-made sample[1]; then to specify the characteristics of this tool-made sample so that they may be used as the basis upon which to judge the produced things. These steps are shown schematically in Fig. 1.

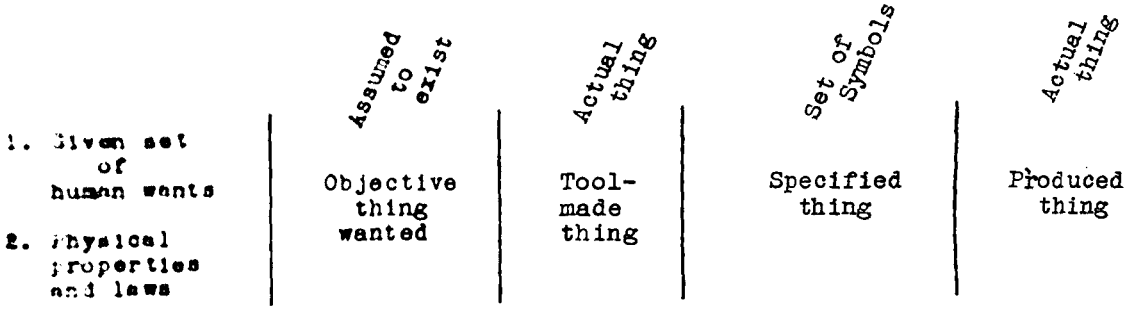

Fig. 1

The overall object or function of all the steps is to satisfy certain human wants in an adequate, dependable, and economic manner. Broadly speaking, it is the function of the operating engineer to determine what is wanted on the part of customers, of the research engineer to determine the physico-chemical properties and laws to be used as building blocks by the development engineer, and of the production engineer to secure the proper materials, and to produce the thing wanted in the most economical manner.

In this sense, what is the function of the inspection engineer? Upon first thought, one might answer that his duty is to examine the finished product to determine whether or not the quality thereof satisfies the given set of human wants in an adequate, dependable, and economic manner. Upon second thought, however, the impossibility of confining inspection to the finished product becomes apparent because the need for inspection begins with raw materials and is associated with almost every step in the production process. Then too, if we think a little further, we shall see that the validity of any judgment about the quality of a thing at a given stage in production depends upon how much we know about its past history. This point will be emphasized again and again as we

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1. This is upon the assumption that many things of a kind are to be made.

proceed. Even in the face of these facts, however, it remains necessary for the manufacturing or industrial organization as a whole to provide for the assembly of the necessary information from raw materials to finished product to justify at all times an adequate degree of rational belief that the over-all engineering objective is being met. In other words, when a company such as the Bell System assumes the duty of providing the American people with adequate, dependable, and satisfactory telephone service at reasonable cost, then it is necessary to insure such a coordinated check on all steps in the development and production of the finished product that the resultant accumulation of inspection data will justify at all times an adequate degree of rational belief that the accepted duty is being fulfilled in respect to the quality of the material and service delivered to the consumer.

We shall assume the following functions of inspection engineering:

I. To develop the principles and techniques for inspecting any thing[1] to determine if it is of SADE-Q.[2]

II. To specify the stages in the production of the thing from its inception to its consumption where inspection techniques should be applied and judgment rendered as to whether or not the thing at such stages is of SADE-Q.

III. To specify the manner in which inspection should be made at a given stage, to carry out such inspection, and to judge upon the basis of available data after inspection whether or not the thing is of SADE-Q.

IV. To arrange for the necessary accumulation of data to provide an adequate degree of rational belief that the delivered thing is SADE-Q.

These four functions serve to indicate the distinguishable characteristics of the field of inspection engineering. To be in a position to carry out these objectives, inspection engineers must be trained in the solution of problems A, B, C, and D of the previous section. To begin with he must determine what he is to mean by the term quality in the sense that it can be something that satisfies human wants in an adequate, dependable, and economic manner.

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1. "Thing" here used in the broad sense, including service.
2. Satisfactory, adequate, dependable, and economic quality.