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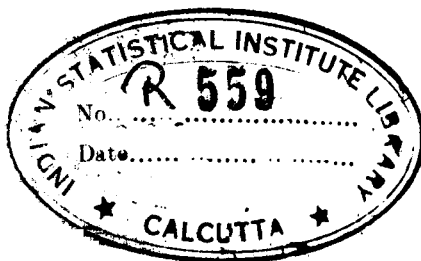
NATURE AND ORIGIN OF STANDARDS OF QUALITY

by

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A discussion of the importance, from the viewpoint of judging quality, of: a) the end to be served by a standard of quality, b) the nature of the accepted binding force of the standard upon the acts of those interested in the standard, and c) the rôle of the judge of quality in shaping the standard in terms of natural law, authority, specification, custom, and precedent.



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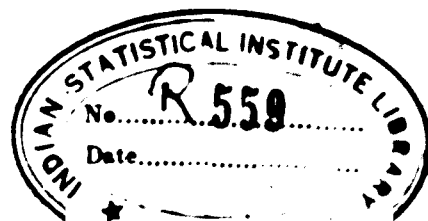
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OBJECT

The control of quality of manufactured product involves three coordinate functional steps: the specification of the aimed-at standard of quality; the production of pieces of product that will be of standard quality; and the determination of whether or not product thus made is of standard quality. These three steps are respectively legislative, executive, and judicial in character. The object of this paper is to consider the nature and origin of standards of quality from the viewpoint of judging the quality of product.

Such a judgment as herein considered is made the basis of one or the other of two kinds of action: 1) the acceptance or rejection of a piece of a given kind of product for service; and 2) the adjudication of a complaint about the quality of a piece of product in service. The two judgments are of the type: J_A - This piece of product (or this lot of N pieces of product) is (or is not) of standard quality, and J_B - This piece of product (or this lot of N pieces of product) was (or was not) of standard quality. In either case, it should be noted that the judgment is rendered in respect to the quality of a piece of product that is already in existence at the time the judgment is rendered - it is a judgment after the act of specifying and after the act of making the piece of product in question. This problem of judging the quality of a piece of product after it is made is definitely different from the legislative problem of specifying prior to the making of a piece of product what its quality should be in the light of information then available; and different from the coordinate executive problem of making a piece of product that will have the standard quality.

Judgment, in the sense here used, implies a comparison of the quality of a piece of the given kind of product at some particular time with the standard for the piece at that time in the light of the evidence then available. If it were possible to specify completely and in an operationally definite and verifiable sense the standard of quality for things of a given kind, and if it were possible to specify the operational technique that would determine with certainty whether or not the quality of a given thing was that specified, the problem of judging would be routine in nature. But neither of these operations is possible. Hence in judging the quality of product, we must take account of the fact that a standard cannot be specified in this rigorous sense and that the



practical standard of quality is determined not alone by written specifications of the quality characteristics prior to the making of a particular piece of product but also by natural law, authority, custom, and precedent, existing at the time the particular piece of product is being judged. In other words, the quality judge is not, as it were, handed a standard of quality already made with which to compare the quality of a given piece of product. Instead he is only handed the stones with which to build such a standard. Through his interpretation of specifications, custom, precedent, natural law, and authority, the quality judge in a sense gives operational meaning to the standard of quality in much the same way that a judge gives operational meaning to the law of the land, whether it be statutes, custom, precedent, or constitution.

Obviously, therefore, before a quality judge may render a judgment of either type J_A or J_B , he must "determine" the standard that is to be used. But what is there to guide such determination? It goes without saying that he is not free to act as he pleases. In what follows we shall see how the acts of the quality judge in determining the standard depend upon: a) The intent of the standard, b) The nature of the binding force that the standard is presumed to have upon those concerned, and c) The available source or sources from which a standard must be derived.

To begin with, we shall consider the nature of a standard of quality as a means to an end, as this will give us a background for considering in turn the binding or constraining force of a standard upon the acts of those making use of it and then the origin of a standard in natural law, authority, specifications, custom, and precedent.

STANDARD AS MEANS TO AN END

Dr. Gaillard of the American Standards Association recently defined a standard as: "A formulation established verbally, in writing or by any other graphical method, or by means of a model, sample or other physical means of representation, to serve during a certain period of time for defining, designating, or specifying certain features of a unit or basis of measurement, a physical object, an action, a process, a method, a practice, a capacity, a function, a performance, a measure, an arrangement, a condition, a duty, a right, a responsibility, a behavior, an attitude, a concept, or a conception."

This definition stresses one important characteristic which is commonly attributed to a standard, namely, that it is something fixed. The definition of standard here is very broad indeed; it would seem to include the rules of mathematics and formal logic, the rules of syntax of a language, and even legal statutes. In fact, it also includes social mores and customs. All of these in some way or other satisfy the condition of being established for a time in one or the other of the ways specified in the definition. In fact, social intercourse is made possible only through standards in this broad sense.

Perhaps the earliest conceived end to be attained in the process of standardization was that of attaining a certain more or less fixed order so that one might know, as it were, where one was at any time. We needed to have from the very beginning of social experience a more or less fixed meaning to symbols or words. In order to avoid utter confusion it was early recognized to be necessary to maintain a certain status quo. Typical statements of objectives expressing this end found in the literature of standardization are to stabilize production, eliminate purely traditional practices, eliminate indecision in production and distribution, place competition on basis of essentials, protect buyers, and decrease litigation. A standard from this viewpoint is comparatively fixed and judicial interpretation of the standard must stress the significance of the past. It is an instance of the type; "If it is good enough for father it is good enough for me".

The first national standardizing society was formed in 1901 and since that time twenty-four others have been formed, most of them shortly after the Great War. The literature on the subject would seem to indicate that the most influential objective at that time was economic in character. Witness, for example, such objectives as: to decrease indirect expense, reduce expense through decreasing the variety of necessary tools, reduce investment, increase output of workers, make selling easier, make possible more efficient and more economic design.

As soon, however, as engineers began to stress the economic advantages of establishing standards of quality, they sensed the necessity of allowing for a comparatively rapid change in factors affecting the economies to be attained through a fixed standard. To secure these economies it was necessary to maintain

a certain degree of fixity but at the same time it was also necessary to allow for changes. This was particularly true in the light of the rapid development in production processes and types of material, where the economic situation might change over night. As a result, judicial interpretation of standards established for the purpose of effecting economies had to lay more emphasis on discretion and less on the fixity of the rule or letter of the written specification than it did when the standard was primarily considered as a means of maintaining the status quo.

It was not long, however, after this comparatively recent beginning of the expansion of the functions of standards of quality that other than economic advantages began to be stressed in the literature in such statements of objectives, for example, as: to stimulate research and development by bringing out the need of new facts in order to determine what is best and to make possible a higher average standard of living. Such expressions are but symptomatic of the recognition given by engineers in recent decades to a broader interpretation of the social objectives of mass production; of the attention being given to the problem of harmonizing and satisfying the many wants and interests of a group rather than laying emphasis upon one want, such as maintaining the status quo or securing economies of production, to the practical exclusion of others. Within recent years we are coming more and more to think of standards as a means for harmonizing and satisfying the greatest number of human wants in a given group at a minimum of cost. Certain companies, for example, operate under an expressed policy of attempting to give a quality of product which is adequate, satisfactory, dependable, and economic from the viewpoint of all concerned. In the attainment of such a policy it is obviously necessary to have the advantage of the established order provided by standards and the economies that accrue through standardization but the advantages of order and economy must be considered in the light of other wants.

Whereas it was necessary in order to attain the economic end to lay greater stress on discretion and less on the fixity of a standard than it was in order to maintain the status quo, so likewise in order to attain the harmonization and maximum satisfaction of human wants imposed by many production policies of today,

we need give further emphasis to discretion and still less to the letter of a previously established standard. In other words, with the growth of the end to be attained by quality standards from the simple maintenance of order and the status quo to economies of production and finally to a quality that is satisfactory, adequate, dependable, and economic, there has been a corresponding decrease in the stability of the end which must be given due weight in the judicial interpretation of standards of quality. Not only must allowance be made for the rapid development of new processes of production and the development of new materials, but also for the rapid development and change in the wants of any given group.

As a basis for our further consideration of the nature of the binding force of a standard and later for our consideration of the origin of a standard in natural law, authority, specification, custom, and precedent, we shall assume that a standard of quality for a given kind of thing consists of the magnitudes of those quality characteristics of the thing which are necessary and sufficient in order that the quality of the thing shall be satisfactory, adequate, dependable, and economic from the viewpoint of those concerned with the standard.

THE BINDING FORCE OF A STANDARD

The existence of a standard of quality for a given kind of thing implies a certain responsibility on the part of producer and consumer to abide by it. If this were not so, the standard would have little practical significance. To begin with, it is desirable to distinguish between the way one is constrained to act by the force exerted by some external agency, whether human or otherwise, independent of one's own experienced interest or volition, and the way one is constrained to act in accord with one's own interest and volition in the light of one's understanding, knowledge, and belief about the external world. In the one case the binding exists even though it be not willfully and gracefully accepted and in the other case the binding exists only when accepted. An example will help to clarify the distinction. If there really exists a natural law corresponding to the first and second laws of thermodynamics then a perpetual motion machine is impossible no matter how much we will or desire to have one. The fact

is that we do not know with certainty that these laws are really laws of nature. The degree to which we willfully bind our acts in accord with these laws depends upon our degree of belief in the laws. There are, of course, some who every year try to patent perpetual motion machines. The following discussion is limited to a consideration of the willed or accepted binding. There are at least four kinds of accepted binding force to which attention need be given in the consideration of standards from the viewpoint of judging quality: a) natural law, b) authority, c) individual interest, and d) group interest.

Perhaps all of us have a certain belief in the fixity, order, and uniformity of the external world in which we live. We customarily admit the limitations of our human efforts to ward off death indefinitely, to build a perpetual motion machine, and to do a multitude of other things. We are bound, as we say, to follow the "laws of nature" be they physical, psychological, economic, or any other. In the next section, we shall consider the ways in which belief in natural law binds us in certain ways to conform to certain standards. We shall observe, however, the importance of the fact that the man-made nature of natural laws as stated has the practical effect of directing our attention away from an objective nature to the knowledge of nature possessed by the individual and the knowledge common to the group. Natural law is not something sticking out in the world that each and every one of us perceives with ease and certainty. Hence one cannot "prove" to one or more others the binding of a natural law in standardization until the others are convinced of the existence of such a law and then only to the degree of this belief or conviction. In rendering a judgment about quality in respect to a standard the quality judge must therefore take into account that it is not the citation of a natural law that is binding upon willful or interested acts but the belief in this law on the part of those bound and that this belief may be either rational or irrational or a combination of the two. In other words, the accepted bindingness of cited natural law upon an individual or group depends upon the belief in the validity of such law on the part of the individual and group.

Let us now consider the binding force of authority sanctioned by society at large. Such authority may be legal, potentially legal, or simply that of some

institution of society, such as a church. Assume for the moment that there existed a sovereign power in the group interested in a given standard such that a specification issued by this sovereign agent either could be made binding by force upon every member of the group, or was accepted as binding by every member of the group. Obviously the judicial findings of the quality judge would in the end have to be acceptable to such a sovereign power. Judicial interpretation of a standard in terms of specifications, custom, and the like, would therefore have to be made in such a way as to be acceptable ultimately to the sovereign authority. To be more explicit, suppose there existed a group such as a national or international standardization body that had sovereign authority to fix standards. The viewpoint of the quality judge would always have to be directed toward the intent of the standard as fixed by such a group in much the same way as a judge in a legal dispute in certain political systems must look to a king or parliamentary body for ultimate approval and sanction of his findings. But today there perhaps exists no group having sovereign authority in this sense in the case of quality standardization in mass production. In fact, even in political systems acceptance of sovereign authority as such would appear to be on the wane. The significant point to be noted for our present purpose is that the ultimate source of accepted authority is the group interest or, perhaps better, the common interests of the group. For example, it may be argued that insofar as the laws of a political unit or state are concerned today with the attainment of the harmonization and satisfaction of human wants, standards set in this way should be expected to be pretty much the same as those determined by the interests of the group - the ultimate sanction of the standard is not in the penalties laid down by laws nearly so much as it is in the evolving habits, opinions, interests, and emotions of the members of the group.

It may be justly argued that the last three aspects of constraint are hopelessly confused one with another in any given case. For example, it may be argued that one's personal interest, whether he be producer or consumer, in holding to a standard with the expressed intent of bringing satisfaction to others is in fact sanctioning the standard simply because he believes that this is the only way in which he himself may obtain certain advantages. Likewise, it is to

be expected that a producer must give attention to ways and means of satisfying the wants of others if he is to maintain the good-will so necessary in disposing of his goods. In turn, it is to be expected that the consumer must in certain instances be satisfied with taking something that the majority wants in order to attain the economic advantages of mass production. Why then is it desirable from the viewpoint of judging quality to differentiate between these sources of binding force, and particularly between that based on individual interest and that based on group interest?

At least one important reason is not hard to see. The individual interest is, broadly speaking, the activating element in bringing about a more or less continual change and improvement in a given standard, whereas the group interest serves as a constraint under which individual interest must operate. Individual interest helps to keep standardization from falling into a rut: helps in guiding the action which results in standards of tomorrow which give greater satisfaction and harmonization of wants than do the standards of today. But on the whole standards of today are physically far more complicated and involved than were those of yesterday. Progress depends to a large extent upon the element of change and in order to bring about this acceptable change the producer, for example, may be bound to hold more rigorously and to a more involved standard than would at a given time be demanded by the wants of those to whom he wishes to bring satisfaction or by the authority sanctioned by the group.

ORIGINS OF STANDARDS OF QUALITY

As a starting point, it will be helpful to consider briefly the meaning of quality as it will be made the basis of what follows. We shall distinguish between the following three types:¹ Type I - Those quality characteristics which make a thing what it is independent of human interest or volition; Type II - Those quality characteristics which characterize a thing A in relation to another thing B as a part to a whole and independent of human interest or volition; Type III - Those quality characteristics which make a thing wantable by some one or more persons.

¹. These types of quality were discussed in more detail in a paper, "Some Aspects of Quality Control", Mechanical Engineering, December, 1934.

It is necessary to note that the quality of a thing in this sense is that which characterizes the thing throughout its life. In what sense then can we speak of the quality of a thing, such, for example, as a relay, fountain pen, or any manufactured article, at any stated time? Thus what does it mean to say that my fountain pen is one that operates easily, gives a steady flow of ink, and does not scratch the paper? In more general terms, what does it mean to say that the quality of a thing is such and such? In the case of my fountain pen, my judgment that "it is one that, etc.," is based upon my past experience that it has under certain conditions and at some time or times in the past operated easily, given a steady flow of ink, and not scratched the paper. I imply by such judgment that under certain conditions and at some time or times in the future my pen, if used, will operate easily, and so on. In much this sense, the judgment that the quality of any thing is such and such is from a practical viewpoint equivalent to a judgment that it will be such and such. Moreover, such a judgment is based upon certain evidence obtained through certain operations on the thing or similar things in the past and implies that certain experience will result if certain operations are carried out on the thing in the future. From this viewpoint, the understanding of a statement or judgment about the quality of a thing necessitates that we treat it as a probable inference about potential experience that may be expected if one operates on the thing in certain ways and when each inference is based upon evidence or experience derived from previous operations on this thing or similar ones. Hence we shall consider first the origin of standards of quality in natural law or the uniformities of nature believed in as relating past to future experience.

Natural Law

Without the existence of uniformity in nature there could be no standards. However, a fundamental characteristic of natural law of immediate interest is that to a certain extent it is man-made and is not certain, that is to say, the formulation of natural laws depends upon a priori concepts as well as the experiences of human beings. Such laws in practice are but approximations to the laws or uniformities which scientists tacitly assume to exist. It follows that the statement of a law amounts to a probable inference based upon certain specific

evidence and as such is open to revision on at least two counts: a) the acquisition of additional pertinent evidence, and b) the discovery of an error in the formal procedures constituting a part of the generally accepted inductive processes of arriving at a probable inference.

The evidence upon which laws fix boundaries to attainable qualities of the first two types is that derived from the natural sciences, particularly physics and chemistry, whereas the corresponding laws determining the wantableness of a thing are derived not only from a study of physics and chemistry but also from a study of psychology, physiology, and other sciences, involving the human element.

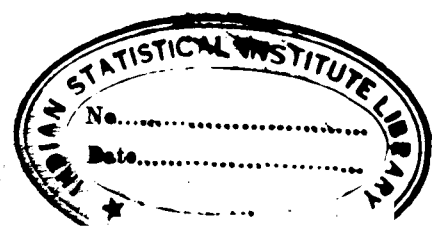
From the viewpoint of judging quality, we must, therefore, consider two consequences of the accepted fact that our knowledge of natural law is probable only: a) in the process of collecting evidence the quality judge discovers certain aspects of natural law which effectively shape the objective standard of quality, and b) the quality judge must allow for the fact that the accepted binding force of man-made approximation to natural law depends upon the belief in the validity of the law. This is particularly true in the case of economic and social "laws", for example, although the same is true to a lesser degree only in the case of other natural laws.

Now, in accepting the policy of attempting to make a thing whose quality is satisfactory, adequate, dependable, and economic, we tacitly assume that there is a set of, let us say, m_3 quality characteristics of magnitudes $Z_1, Z_2, \dots, Z_1, \dots, Z_{m_3}$, characterizing the objective standard which would harmonize and maximize the satisfaction of the wants of a given group of people. It is this set of values of these characteristics which is assumed to be fixed by real natural law and which it is the aim of research, development, and design to be able to specify prior to the start of production. Obviously, however, such a set of ideal characteristics can only be approached as a goal. Quantity production cannot wait until such a set has been discovered and made a part of a specification because to do so would mean that production in every case would have to be postponed indefinitely. This is true not only because of the uncertainty of our knowledge of effecting the best means to that end but also because research, development, and design engineers find it necessary to introduce modifications in their

original specifications as new evidence is brought to light through research in the natural and social sciences.

The point now to be considered, however, is that such needs for changes in specifications and accepted standards of quality arise not only from the evidence obtained in research proper but also from that uncovered in the process of judging quality in the light of evidence accumulated in the process of production and inspection and in the adjudication of complaints. It goes without saying, perhaps, that one of the very practical ways of detecting the failure of an apparently accepted standard of quality to satisfy the one who makes use of the product is the evidence brought to light in the study of complaints. There is, however, a more important although perhaps less generally recognized limitation imposed by natural law which falls pretty much within the domain of the quality judge to translate into requirements of a standard of quality. We cannot make things identically alike one with another in respect to any given characteristic; presumably there is a limit to which we may hope to go in removing the causes of variability of a given product made by a given process. In other words, there is a limit beyond which we perhaps cannot hope to go in controlling variability. There is also another limit of interest in the control of variability, namely, the limit beyond which it is not economic to go in a given case. These two limits, of course, are for the most part independent of interest or volition. There is, however, also a third limit which is of importance and this depends upon the human element, namely, the limit to the range of variation that will in any way influence the wantability of a thing.

For the most part, evidence which is pertinent to the determination of the first two kinds of limits arises in the production and inspection of product - in other words, comes from the data which the judge of quality must accumulate in the process of judging quality. It is but reasonable, therefore, that the quality judge should make use of such data not only for the purpose of judging the particular case at hand but also for the purpose of helping to establish the economic or desirable degree of control of the variation in quality about the aimed-at value. Again, in the study of causes of complaint, information may be obtained which may be valuable in helping to fix the limit of variation in the



physical quality of a thing from the viewpoint of its wantableness, particularly as evidenced by sensory experience. In general, of course, wantableness, particularly in the case of new product, is often not dependent upon what the trained experimental psychologist or physicist fixes as the minimum detectable difference. For a time at least a much wider variation will pass unnoticed from the viewpoint of wantableness and hence from the viewpoint of a user of a thing it would not be economically desirable to control the limits of variation within a narrower range than that thus determined.

Now, let us pass to a consideration of the nature of the binding force of man-made natural law upon all concerned with a given standard. Just as we noted in the beginning that it is likely that everyone would admit the binding of what is accepted as natural law, it is also reasonable to believe that the majority, at least, would agree as to what is to be accepted, if they had common training and had given due consideration to all evidence upon which a given law is based. Obviously, however, it is not feasible, in general, to attain a binding upon the basis of a common understanding and interpretation of all pertinent data. Such binding as does exist perhaps must arise upon the acceptance of those who make or state the man-made natural laws as technical authorities. More often, however, it is likely that the binding force of a standard fixed in terms of natural law upon the majority will be in terms of the reasonableness of such a standard in the light of more or less common evidence pertinent to the standard rather than upon all of the evidence which an experienced technical authority might make the basis of his decision. Hence, it may come about that the common acceptance of judicial findings will depend more upon the proper choice of the simpler facts than upon what the trained specialist would consider to be the more weighty although more complicated evidence. It is important, however, for the quality judge to keep in mind that what would be acceptable today on such a score is likely not to be acceptable tomorrow when the common store of pertinent evidence is greater. Hence in a certain sense the quality judge, if he is to allow for growth, is bound to consider the whole of the evidence even though for acceptance by the majority at the moment he need consider only a part.

Authority

In general the group of people interested in any standard of quality

constitutes a part of a larger group bound together in some political unit, federal, state, or otherwise. Each such political unit has its laws and rules of action, some of which apply directly, and others indirectly, to standardization. In other words, legislation by duly constituted bodies, both political and otherwise, has in many countries and over a long period of time constituted one source of standards of quality. As in our consideration of natural law as a source we chose the viewpoint of a quality judge, so here too will the same choice be made. That is to say, no consideration will be given to a critical appraisal of such a source except as may be helpful in judging quality under conditions where a legal standard is provided.

To begin with, let us consider the significance of the generally accepted binding force of law in the political unit fixing a standard of quality. Take first the case where authority is accepted as a consequence of a postulated divine right of a monarch to make law. The judgment of quality under such a condition would in the last analysis have to be acceptable to the monarch or his duly appointed agent. Under such conditions the accepted binding force of natural law would even be secondary to that of the law of the monarch. On the other hand, if we consider law not as an end in itself originating from a source on high whose authority is accepted without question but as a means to an end, the whole aspect of the problem of judging quality is changed. For example, if we choose the sociological end of law, current since the beginning of the twentieth century, expressed by Dean Pound of the Harvard Law School as the attainment of harmonization and maximization of the satisfaction of human wants, then the aimed-at standard under law would be that fixed by natural law in much the way we have already considered. Whereas a legal standard under the concept of divine right or other sovereign power must be that acceptable to the monarch or legislative authority, a legal standard under the sociological concept of the end of law expressed by Dean Pound is one acceptable only in so far as it is rational or reasonable in the light of natural law as understood at the time by the majority of those concerned with the standard.

Omitting any discussion here as to whether or not it is feasible or even desirable, if feasible, that legal statutes fix standards of quality, let us accept

the fact that attempts have been made so to fix them. There are at least four important reasons why it is exceedingly difficult to fix a standard by statute that might not later be judged in a legal court as unreasonable, assuming, of course, the sociological end of law: a) In the first place, it is not feasible to discover with certainty those quality characteristics (the Z's of the previous section) which would characterize the ideal goal. Hence new results of research obtained after the statute was passed might give rise to a need for change in the statute. b) Even though it were possible thus to specify the ideal quality, it still remains an exceedingly difficult and uncertain task (as will be exemplified in future sections) to specify, at the time the statute is passed, definite and verifiable inspection procedures that will give a detailed description of the conditions under which acceptance of product is forbidden or allowed. c) It would be practically impossible to establish at the beginning and once for all the economic tolerances that must be allowed because of the existence of unknown causes of variation which must be left to chance. d) Because wants as well as means of satisfying wants are constantly changing, there is a continual need for considering the desirability of changing a standard.

an important point to be considered in lay judging of quality in respect to conformance with legal standards where they do exist is that there is great room for legal interpretation of any such statute particularly if the sociological end of law is the one accepted. In fact, such a statute is likely to be pretty much what the legal judge interprets it to be in the light of available evidence. Hence the lay judge of quality must often look to court decisions and interpretations for guidance in giving definite operational meaning to a legal standard of quality when it does exist, in order that his decision may be in terms of the standard as it would be interpreted by the legal judge. In so doing, however, the quality judge effectively helps in shaping the standard of quality.

Specification

Since 1900 and particularly since the end of the World War, the most important source of standards of quality has been that of specifications made and

approved by industrial groups. Within this short period of time, many national and international standardizing bodies have been formed. Throughout this period there has been a rapid growth in the development and use of specifications by separate organizations. In this section we shall consider briefly certain characteristics of a specification of particular interest from the viewpoint of judging quality. In particular, we shall consider the important part played by a quality judge in giving effective meaning to a specification and shall consider the sources to which a judge of quality should look in order to determine the binding of a specification.

First let us consider what it means to specify the quality of a thing in general. For convenience let us assume that for a given thing there are m_1 quality characteristics, $X_1, X_2, \dots, X_1, \dots, X_{m_1}$, of the first type; m_2 quality characteristics, $Y_1, Y_2, \dots, Y_1, \dots, Y_{m_2}$, of the second type; and m_3 quality characteristics, $Z_1, Z_2, \dots, Z_1, \dots, Z_{m_3}$, of the third type. In order to give operationally verifiable meaning to any one of these quality characteristics, it is necessary to specify four kinds of operations and in addition to specify the limits within which the observed results of these four operations should lie.

Thus for X_i we have:

- S_{X_i} -
1. Specify the method of perceiving or measuring the quality characteristic.
 2. Specify the number n of repetitions to be made of the operation of perceiving or measuring under the same essential conditions.
 3. Specify who is to perceive or measure.
 4. Specify the method of analyzing the results of the n repetitions.
 5. Specify the limits within which the observed results of the previous four operations should lie.

Similar expressions hold for any Y_i or Z_i . As previously noted, the ideal specification of the quality of a thing would state the necessary and sufficient verifiable operations to describe that quality which is satisfactory, adequate, dependable, and economic. Such a quality characterization obviously extends throughout the life of the thing. Fundamentally, this would require an indefinitely extended specification even if we assume a comparatively small number of quality

characteristics to be necessary and sufficient, and one that could not be verified except by examining or operating on the thing throughout its life in a prescribed manner. In practice, therefore, it is customary to specify certain requirements which a thing is supposed to meet up to the time that it goes into service. Of course, some or all of the specified X's and Y's might be those in which the consumer interest centers but in general they are not those directly sensed or experienced by the consumer but rather those which serve to characterize a thing physically. Witness, for example, the difference between those quality characteristics used in advertising an article and those used in technical specifications.

An important fact to keep in mind is that even though the quality of a thing satisfies the technical specifications of the form SX_i and SY_i , one cannot be certain that this quality will be such that it will prove satisfactory, adequate, dependable, and economic. All that an engineer can do in preparing a set of specifications is to choose that set which upon the basis of his interpretation (or the interpretation of a certain group) of the scientific evidence available to him (or to the group) at the time, constitutes grounds for a high degree of rational belief or probability that the quality of things which satisfy these requirements will also be found to be satisfactory in service. In other words, two factors must be considered, one the evidence E available at the time, and the other the degree of belief or probability based upon such evidence. Obviously, this probability may change with increase in pertinent evidence which may come about either through the process of continued research or through the information attained in the course of production and inspection as well as in the analysis of complaints. It is therefore necessary to recognize that specifications adequate upon the basis of evidence available at the time that they were written may not be similarly adequate upon the basis of information made available in the course of production, inspection, and use. Under these conditions, there are at least five ways in which the quality judge effectively plays an important rôle in helping to fix or shape standards of quality:

a. In judging whether or not a piece of product shall be accepted or rejected, the quality judge must take into account, in accord with the assumed

policy objective of production, any evidence which may have come to hand, particularly in the processes of production, inspection, and analysis of complaints, indicating the present specifications to be incomplete in that they do not include requirements on certain variables which it seems desirable to control. Quite naturally such requirements will sooner or later find their way into specifications, but the quality judge must, insofar as possible, act in accord with what he considers to be potential changes if the policy of accepting only quality that may reasonably be expected to be satisfactory, adequate, dependable, and economic is to be met. In other words, the quality judge must fill in the gaps in existing specifications in so far as new evidence obtained since such specifications were written would indicate to be reasonably desirable.

b. If the quality judge is to accept the theory that a specification is but a means to an end and is to take account of the fact that the justification of a specification rests upon an ever-changing body of evidence, it is necessary for him to use discretion in judging quality of product to be either acceptable or rejectable upon the basis of specifications alone. In other words, certain non-conformance cases may arise in respect to specified quality characteristics which may have under certain conditions little effect upon the experienceable quality of such equipment in use. In such a case it may likely be uneconomical on the part of all concerned to reject such product. Such action on the part of the quality judge is not, as it were, ignoring a specification but rather making a judgment upon evidence which was not available at the time the specification was written.

c. If any one of the four items in S_{X_1} and S_{Y_1} are omitted in the written specification, it is necessary that such be supplied by the quality judge. For example, specifications sometimes simply state that some quality characteristic such as mass, length, capacity, resistance, or the like, shall lie within certain limits. Such a specification is incomplete upon the basis of the first four counts: it does not specify the method of measurement; the number of repetitions of the measurement; the one who is to make the measurements; nor the function of the measurements that is to be within the set limits. Another typical failure of a specification to be definite is illustrated by each of the following requirements

taken from actual specifications: "The zinc alloy shall be 99.99% pure", "The spark gap shall be adjusted to .008 in.". The quality judge here must supply not only the first four types of operations but also the missing limits!

d. In general, the specification engineer has in mind in writing his specification the limits within which the quality of a single piece of equipment should lie if it is to be that which he believes will prove to be wanted. True enough, he is likely to give weight to the data constituting his previous experience of production methods which indicates limits within which variability may be expected under production. Obviously, however, such evidence is likely to be very meagre indeed as compared with the cumulative evidence obtained after production starts. Experience shows that there is an economic limit to the allowable variation in the quality of product turned out in a given process. In other words, it is often found that it is more economical to discover and eliminate assignable causes of variation of quality than it is to leave these in the production process and reject that portion of the product that does not meet the required limits. The quality judge has an important rôle to play in devising techniques which will indicate the presence of assignable causes and of using these in helping the production department to establish economic control limits which serve as standards for future production.

e. We now come to what is perhaps the most important rôle of the judge of quality in giving operational meaning to a specification. Even though an operationally definite and verifiable meaning of quality is given in the specification, there are two reasons why it is often necessary to resort to sampling in order to determine whether or not quality meets the specification: a) it is often uneconomical to give 100% inspection, particularly where defective parts would be weeded out in final assembly or at the time of installation, and b) it is often not feasible to give 100% inspection because of the destructive nature of the method of verification of the quality, as, for example, in testing the tensile strength of materials and the blowing current for fuses. In such a case the quality judge must supply an inspection specification which will insure the following two things: 1) that a satisfactory amount of data or evidence will be accumulated upon which to render judgment as to the nature of the quality of the

unsampled portion of the lot, and 2) that an operation will be indicated to determine whether or not it should be rejected whenever the degree of belief in the satisfactoriness of the unsampled portion of the lot upon the basis of evidence thus accumulated is insufficient to justify the acceptance of the lot. The question, How much data?, depends in general upon the degree of economic control of quality previously obtained and hence the inspection operation specified must be such that it keeps abreast of the continual supply of information obtained in the process of inspecting product if such an operation is to give adequate assurance of quality at a minimum of cost.

We are now in a position to turn our attention to a consideration of the nature of the binding force of specification. In the first place, a specification may be made the basis of a contractual agreement between two parties, in which case it takes on certain legal as well as moral binding force characteristic of a contract. One of the conditions usually assumed for the validity of a contract is that the two parties to the contract be cognizant of the contents thereof. Of course, in many instances specifications of quality are extremely involved from a scientific and engineering viewpoint and hence it is to be expected that parties to a contractual agreement involving highly technical specifications of quality must be capable of arriving at a common meaning of such specifications. This limits the field in which technical specifications may be made the basis of valid contracts. The second source of binding is, of course, the requirement that the quality accepted as meeting the specifications be judged in the end as satisfactory by those making use of the product. In this case, however, we should note that the binding force is not so much that requiring that the quality of product meet the specifications as it is that requiring that the quality be found in the end to be satisfactory by those making use of the product. In this case, however, it must not be overlooked that there is a growing tendency on the part of the majority of users of most kinds of goods to place reliance upon the judgment of men or groups of men whom they accept as being technical authorities, such, for example, as national or international standardizing committees.

In the third place, as previously noted, a producer is sometimes bound because of his own future interests to adhere to a specification even when such

adherence would not be demanded at the time by those whose wants the quality is supposed to satisfy. For example, the appreciation of high quality often comes through experiencing high quality. One who has never heard what a technician would consider to be good music, good quality of radio transmission, good quality of telephone transmission, or good quality of some musical instrument, might never have the desire to experience such. Progress, therefore, often comes by living up to a specification of quality even beyond the limits wanted by the majority of those concerned at a given time. In other words, the producer's personal interest is often more binding than either or both the bindingness of a specification made a part of a contractual relation and the immediate interests of the consuming group, if he is to lead the way in evolving standards that will later be wanted by the majority.

Custom

All of us are more or less creatures of habit; all of us are more or less influenced throughout life by the habits and the common methods of acting of those around us. We early learn that society always takes a revenge of one form or another for a breach of any of its common ways of acting and hence as members of any group we feel more or less bound to follow the conventions of that group. For example, in our methods and means of communicating one with another, we are bound to a large extent to the customary use of symbols, either written or spoken. Even the meaning of a written specification of quality so far as the majority of a group or society is concerned inherently depends to a large extent upon the customary interpretation of words and other symbols used therein. It is to be expected that custom should play a part in the production of standards. Thus a long while before the development of written specifications of standards of quality there existed unwritten standards, as it were, fixed by the customs of certain groups. At least the meaning of certain words was sufficiently common to members of a group to enable the interchange of goods.

With the development of mass production practices first introduced in the eighteenth century, there has grown up an ever-increasing appreciation of the economic advantages to be attained by securing a high degree of uniformity in the quality characteristics of a given kind of thing. It is significant for

what follows that there exist at least three ways in which customary quality may differ from specified quality in such a way as to constitute a part of the standard which is inherently binding upon the group.

In the first place, a given kind of product produced over an extended period of time in considerable quantities may exhibit a uniformity in quality characteristics not specifically expressed in the specifications of the form S_{X_1} and S_{Y_1} . In the second place, one or more quality characteristics may be specified to have magnitudes lying within a definite range although experience has shown that over a certain period in the past in which many pieces of this kind have been produced the magnitudes of the particular quality characteristics thus specified have differed from their specified values but in a way which has been acceptable from the viewpoint of use. For example, take the case where the production of a new kind of product is started in which the specification of one of the important quality characteristics, such as length of life, is that it shall not be less than some specified value. Let us assume that N pieces of this kind of product have been made and put into service and that the experience thus obtained shows that the lengths of life of these N pieces of product have been distributed uniformly about an average length \bar{L} considerably above the specified length S . Particularly if the number N of pieces of this kind of product that have gone into service is large and if those making use of this kind of thing come to expect an average life of approximately \bar{L} , even though the specification simply calls for a life not less than S , most producers would feel bound in certain ways to maintain a quality not assignably less than \bar{L} . It is quite likely, to say the least, that some consumers of this kind of thing might feel justified in registering a complaint if they should find in the future that the length of life of this kind of thing was significantly lower than \bar{L} even though it did not fall below S . In the third place, even though no specific mention is made of the fact in the specification, users of a given kind of product may reasonably expect that observed variability in the quality characteristics specified should be no larger than that which for economic reasons should be left to chance. For example, consider the class of users of a given kind of thing such as an automobile. If we find upon comparing notes with our neighbors or others

using the same make of car that ours differs from theirs in a way which we consider undesirable, we are likely to feel like registering a complaint.

In rendering quality judgments the quality judge must take into account at least these three ways in which custom may effectively constitute a part of the standard of quality binding in a given case. In fact, he not only must take into account custom in certain instances but in fact, as we have seen in the previous section, he must also in certain ways help in establishing custom, as, for example, in the analysis of results of inspection and the determination of economic limits of variability.

The ultimate source of binding force in maintaining uniformity is quite naturally the consumer's desire for uniformity. Such a common want, however, is in a certain sense potentially of legal binding in the sense that many statutes as well as common law have their origin in custom. In any case, the degree of binding depends among other things upon: the available evidence of the existence of a custom; how long and how continuously it has existed; whether or not the custom has been peaceably enjoyed; to what extent those affected have regarded it a duty to follow the custom; and whether or not the custom in question is consistent with all other accepted customs.

Precedent

To begin with, it is desirable to clarify the distinction here made between custom and precedent. Custom, as we have seen, is of the nature of an established practice that has more or less gradually come into existence. Precedent, on the other hand, arises in the judgment in respect to the quality of product that has already been produced as to whether or not it is or was of standard quality. Precedent arises, in other words, in the finding of the quality judge. If it were feasible to write specifications of quality that were ideally necessary and sufficient for satisfaction, adequacy, and dependability at an economic cost, and if it were feasible to determine with certainty whether or not the quality of a given article met such specifications, there would be little, if any, occasion to consider the rôle of precedent. Since, however, this is not feasible, there are three types of judicial findings which are important in quality control.

Cases of non-conformance with specified requirements are bound to arise where

the information available at the time justifies the judge of quality in concluding that, under the specific conditions existing in the case, the quality, even though non-conforming, is acceptable. Likewise, conditions are bound to arise where, even though the quality of a given thing does conform to specifications, it may not be acceptable. This follows at once from the fact that we are not able to state the necessary and sufficient quality requirements. This class of precedent arises as a natural consequence of looking at a standard as a means to an end, rather than as an end in itself.

Just as common law arises for the most part in the judicial recognition, interpretation, and formulation of custom, so also does the effective control of custom in standardization come about through the recognition, interrelation, and formulation of custom on the part of the judge of quality. Thus judicial declarations or recognitions of the existence of a custom constitute another source of precedent. In quality control one of the very important examples is the judicial decision as to whether or not a custom has been established with regard to the degree of variability which should be left to chance.

A third source of precedent is interpretation: first, interpretation of the operational meaning of a standard even in so far as it is specified; second, interpretation of the sampling technique required in order to give adequate information upon which to render a judgment; and third, interpretation of the rules of judging and interpreting evidence as to the quality of product.

CONCLUSION

The practical meaning and significance of a standard of quality is largely determined by the end which it is supposed to serve in use and by the nature and degree of the binding force or sanction accorded it by the group interested in or affected by the standard. The standard itself may originate in one or more of the five sources: natural law, authority, specification, custom and precedent. In any case the judge of quality is not handed a standard ready made with which to compare the quality of any given kind of manufactured goods - instead he of necessity plays an important rôle in shaping and determining the standard as derived from these sources.

