QUALITY CONTROL AND INSPECTION

31 January 1951

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Publication No. L51-94

INDUSTRIAL COLLEGE OF THE ARMED FORCES

Washington, D. C.

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COLONEL DIEHL: The subject this morning is of real importance to every member of this class. The techniques involved are applicable not only to the production phase of engineering but throughout the entire field of engineering subjects. Our speaker, Dr. Juran, is Professor of Management Engineering at New York University. He has written a number of books and papers on this subject, and is a real authority in the field.

The subject this morning is "Quality Control and Inspection." Gentlemen, Dr. Juran.

DR. JURAN: Thank you very much, Colonel Diehl.

This subject is of even broader scope than just this country. I have here some quotations, if you will permit me to read them. This is from the well-known newspaper, "Pravda." Here is an item with respect to the Makeyevka Industrial Combine in Stalin Province. "Out of 7,770 cultivator wheels delivered to the Marivpol Metal Products Factory, all except 217 were defective. Chief Engineer Chvdakov and chief of the technical control department Radchenko, each sentenced to five years' imprisonment." "Coal mines, Stalin Province.--Production of coal containing a high percentage of slate. Manager Anisimov sentenced to five years' imprisonment." "Mechanical Foundry Works in Leningrad, systematic production of poor quality goods.--Chisels sent to other factories found to be unusable. Adjustable spanners (that is monkey wrenches to us) sent out with immovable screws and loose heads. Director Garibyan and Chief Engineer Glinchinov each sentenced to five years deprivation of liberty."

While the system of rewards and penalties is not quite the same in our industrial system, from the standpoint of the loss of materials, the loss of man-hours, and the rest, the effect can well be very much the same as in the instances cited.

In the last two days there has been discussion here of the sequence of events that commences with the designer's concept of a mechanism or device that serves a functional purpose, and the steps by which that designer's concept is, first, simplified so it can be manufactured in production; and, second, the system of production engineering or tooling and methods by means of which that design can be translated into three dimensions in such a way that the units are substantially alike. That has all been in the nature of preparation for manufacture. The manufacture itself then involves the utilization of these machines and methods, the cutting up of the materials, and

subsequently the testing to see whether the final result does conform to the specifications.

I am going to make use of a number of slides to show the principles involved in the testing and inspection of products and the manner in which those principles are used, not only to decide whether the products meet the specifications but also to assist in locating the causes of defectives and to remedy those causes so that things are made right in the first place.

We can simplify that discussion by noticing that when we talk of the quality of a piece of apparatus—an automobile, an electric lamp—we are actually talking about a collection of qualities. In order to make that lamp, some materials have to be held to certain limitations of chemical purity, physical strength, dimensional tolerances, and the like. Each one of those elements of the specification is a quality. We call it a quality characteristic. The total quality is a collection of these characteristics.

Chart 1, page 21, The Quality Atom.—Now, with respect to each one of these characteristics a whole series of events happens. For any quality characteristic to be designed, the designer has to have a concept of what he needs in order that this element shall contribute to the over-all quality. Having made that design concept, it needs to be specified.

I make a distinction there, because we should not give the designer a monopoly in the designing of what should be the tolerance. That should be a group decision which includes the production engineers, the manufacturing groups, and the like, so that there will be the best balance between the cost of that quality and the value of it. But, having reached that decision, then we give the designer a monopoly in specifying it. He is the only one who can issue the official log which specifies that quality.

Then we must engineer it. In order to be able to make it, we must purchase instruments in order to measure the performance of the operation using these machines and methods. We must have inspection, to judge whether what has been made conforms to the specification. That quality must be sold. Then it must be used. Then, based on the experience in use, we redesign it. In that way this spiral continues and that is the basis of our constant improvement of designs.

The over-all quality problem is a collection of separate problems, each surrounding some one quality characteristic. Those, of course, are not equally important. Some of them are exceedingly important. Others are trivial. Collectively they constitute the over-all problem.

Chart 2, page 22, Relation of Cost and Quality.—We now come to an important distinction between quality of design and quality of conformance. If I were to take a poll of this group by raising this question; Does higher quality cost more or cost less? some of you would answer that it costs more and others would answer that it costs less. Both would be right, because you would be thinking of different meanings of the word. By "quality of design" we mean a difference in specifications for the same functional use. The distinction between the Lincoln and the Ford is one of quality of design. Both serve the same functional purpose; but the precision, the materials, and other means of achieving that function are sufficiently different so they constitute separate designs. That difference always involves more cost.

There is an optimum to quality of design, as demonstrated here. As we increase the quality of design, the value increases, but not in direct proportion. The time comes when, however much we may increase the quality of the design, the purity of materials, the precision, and so on, the increase in value is very small, so that we don't gain by that added perfection. However, as we approach perfection, the cost of achieving that begins to go up remarkably, until it literally becomes infinite at perfection itself. The balance is struck where the tangents of these curves are parallel to each other. An increase of quality of design from that point means that, while we get an increase of value, represented by the amount "B," the increase of cost more than offsets that. If we drop below that, while we reduce the cost by the amount "A," the reduction in value more than offsets that.

This cost need not be expressed in dollars. It may be in time or it may be in materials. But cost is an important concept from the viewpoint of the designer, because he, more than anyone else, is faced with the responsibility of finding the best balance between the cost of quality and the value.

Chart 3, page 23, Quality of Conformance.—It is the same way with quality of conformance. That means the fidelity with which the product reflects the specifications. There again we have an optimum. It doesn't pay to be perfect. The cost of perfection is too great. If this represents the basic manufacturing cost—the materials, the man-hours, the machinery necessary to make the product at all—then if all the items are defective, the loss due to defectives is enormous. As we increase the effort to reduce this loss, to make these things right in the first place, we are able to reduce that loss due to defectives. But to achieve perfection, the effort for controlling would itself go up to infinity. Again we find that there is an optimum, and that optimum is what we should strive to achieve.

So far this is just in the way of theoretical principles. Let us see the application of some of them.

Chart 4, page 24, Facts as to Cost of Quality are Widely Scattered.—In order to strike a balance between cost and value we find that we need the facts. What is the cost? What is the value? In the organization we discover that those facts are widely scattered. If we try to discover from the various people who have information as to the cost of quality, we have to go to all these organizations; there is somebody in each of them that has something to contribute.

Chart 5, page 25, Facts as to the Value of Quality are Widely Scattered.—In the same way, when we come to the value of the product, that information is also widely disseminated. That points to another principle—that the balance between the cost and the value of quality has to be struck in the lower levels of the organization, not at the top, because there are too many problems of that kind to enable the top official to sit in on all of them. That is one of our most difficult problems—to find the organizational mechanism for settling these things at the bottom. The committee devices, the new product committees, the salvage groups, and other organizational means for striking this balance have to be used.

Chart 6, page 26, Pareto's Principle.—This is the principle that these quality characteristics are not equally important. The economist Pareto once showed that wealth is not equally distributed. A relatively small proportion of the people seem to control a relatively high proportion of the total wealth. In the same way, a relatively small proportion of the quality characteristics accounts for most of the trouble that we run into with quality. One of our problems is to identify what are these key qualities and to concentrate on those, because ordinarily to lick those is to lick the bulk of the problems.

It is much like crime in the big cities. There are thousands of people committing crimes all the way from running through red lights clear on up to the men who make the headlines in the tabloids. But, if the top one percent of those people are put into what is called the "clink," there would be an appreciable reduction in the amount of crime, even though authorities are putting away only one percent of the criminals.

Chart 7, (not reproduced), Process Capability Study—Tornos Screw Machine.—We can take a specific instance. This happens to be a problem in the manufacture of watches and the piece being made is a shaft. The diameter is a maximum of .0077 and a minimum of .0073. The difference between these two is the tolerable amount of variation. We call it the tolerance. Here it is four-tenths of a thousandth. That is a very tiny part, as you can see. That diameter is approximately only seven-thousandths. They are very tiny pieces.

In this department there had been for a good many years the situation that about 10 to 15 percent of these pieces were defective. When 10 to 15 percent are defective, it is always a practical question to ask; "If 85 percent of them can be made right, why can't the other 15 percent be made right?" The answer to that is more complicated than it seems on the face of it, because, if we ask the foreman, his answer is: "The machine is not good enough to do that job." If we ask the machine-tool builder; "Why isn't the machine good enough to do that job?" his answer is: "If the operators wouldn't try to go lickety-split, it would be good enough; and, besides, these tolerances are tighter than they have ever been before." If we go to the designer and ask him, "Why are these tolerances so tight?" his answer is: "I have never yet had a situation where the shop thought a tolerance was loose"; and so around the ring we go.

There was a Britisher who once said that the engineers' manner of setting tolerances--I am sure some engineers do it this way--is to think of the smallest number they can and then divide it by two.

Let me make clear to you at this point the great importance of the decision made by the designer when he sets his tolerance. He is writing out a check for the company's money or the Government's money, whichever it is. He is deciding what machines can be used for that job. He is deciding the amount of time that is going to be used and many other things. It is a weighty decision. Many times he doesn't realize the caliber of the decision.

How do we decide whether a machine can hold a tolerance? We do not ask the designer or the foreman or the inspector or any other person. We ask the machine. The machine gives the answer. In this case a series of 500 pieces were made and kept in sequence. Then they were taken into a measurement laboratory and measured very precisely. Here are the 500 measurements for this diameter. You can see that as the production proceeded, the machine was quite easily able to hold these tolerances. One line represents the minimum; another line represents the maximum. The uniformity is very good.

Not only that--these pieces take about a minute to make. For this day's production there was very little change from about the middle of the range, where the production started, until it began to get up into the upper half. So that machine has rendered the verdict that it can hold these tolerances, and that question is settled, as is usually the case where fact is thrown into a debate.

Here is another phenomenon. This was another element of debate that had existed. Were the gages available to the operators adequate for steering these machines? Notice how all diameters were within tolerance, and then suddenly all were defective. In this case the engineer who collected these pieces also kept a log of what was happening on the production floor. At this point (indicating) the operator had thought from the gage that the pieces were getting too

big. So he gave the machine a twist and began to make them all defective without knowing it.

At this point (indicating) the log showed that the roving inspector, the man who circulates around among the machines, had looked at these and thought they were too small, judging from his gage. He had convinced the operator that such was the case. The operator had untwisted the machine and again he was making them satisfactorily. That repeated itself over here, so that one-third of this production was defective without the knowledge of the operator.

Notice, incidentally, how the machine tells its own story. Two go down together and they go up together. Isn't it easy to tell from that without ever seeing the machine that the two tools that cut these diameters are on the same tool holder? There are some other things that you can identify here as you learn to interpret data like these.

So in this case it became clear from a comparatively simple gathering of facts that the machine was able to hold the tolerances, but that the operator's gages were unable to extract from the machine the inherent accuracy it contained. By a program of improving the precision of the gages it was possible—and it was achieved in fact—to reduce the fraction of the defectives from 10 to 15 percent down to less than one percent. And thereby it was possible to do away with a battery of about 20 inspectors whose job had been to detail-gage all these pieces after they were made, in order to sort the good from the bad.

Chart 8, page 27, Study of Process Capability—Plastic Molding.—Here is another example. This is a plastic molding job. The dimension in question is a .362-.364 dimension. The minimum is .362 and the maximum is .364. That is an essential dimension, as proven by engineering tests of trying some that were smaller and some that were larger, and discovering that they couldn't function properly.

This was a case of purchasing these parts from a vendor. The vendor couldn't do any better, so he thought. But the manager of the plant which was purchasing these parts was a fact-minded person. In the discussion there had been debate as to which of several possible plastics might be most suitable for this job. So he had all three plastics tried. He also had the product segregated by the die cavity. That is, in plastic molding quite often the die will have a number of cavities in it, all operating simultaneously. In this case it had 12 of them, just like the 12 cavities of an egg container. So the product was kept separate.

Notice in the case of plastic "B" the very high percentage of pieces below the minimum. Plastic "A" has a higher percentage of

pieces within the tolerance, and plastic "C" is better yet. But another phenomenon showed up—that within any one cavity the pieces were remarkably uniform. Any one cavity could easily hold the tolerance, but the cavities were of unequal size. Thereby, by plugging up this one and scraping out these that were slightly undersize, it was possible to produce pieces that were 100 percent good. The machine couldn't help doing it after that, as a matter of fact. And this was a culmination of a long debate in which the vendor took the position: "We can't hold these tolerances, and here are the pieces to prove it." He hadn't gone far enough into his own process. Again, the product tells on the process.

Chart 9, figure 1, page 28, Variations in Adhesive Tape—Here is a study of another sort of problem—the conserving of material in the manufacture of pressure-sensitive adhesive tape. That stickum material there is of surgical quality and represents an important expense. In this case the manager of the plant found wide variations in the amount of stickum on the adhesive tape. That is, by taking specimens every several inches and weighing them, them dissolving the stickum chemically and reweighing them and thus determining by the difference how much stickum was there, he found that which we named the "heartbeat." That was a variation brought about by the fact that the calender rolls, the two big rolls which sized this material, were not perfectly round. That being the case, they would separate from each other and then come back together again; that produced this variation.

In order to meet the minimum standard, it was necessary for him to raise the average amount of stickum so that the lower part of these heartbeats would never go below the minimum standard. But that meant that all the material up here was wasted. Whereas, if he could get a much more uniform product, like his competitor, he would be able to lower the average material that he put on this adhesive tape and still stay within the specified minimum. Notice, he was able here to measure the product made by his competitor. He bought up some of it and measured it and found these variations. But, being an enterprising fellow, he began to see what else is made by calenders of this kind.

Chart 9, figure 2, page 28, Sheet Rubber.—He investigated sheet rubber and found some real variations. The variations ran all the way from 19.2 ounces per square yard down to about 16 and some ounces per square yard. In the case of this rubber sheet, for the purpose of the minimum bursting strength, all that was needed was about this level (indicating) and all the rest of that rubber was wasted. If it were possible to eliminate that large amount of variation, that extra rubber could be saved.

Chart 9, figure 3, page 28, Variations in Plastic Sheets.—He also noticed that plastic sheets were calendered by the same process. Here he bagan to run into pay dirt. Notice the great uniformity here, with a variation of only about three-tenths of an ounce in the case of these plastic sheets compared to over three ounces in the case of the rubber sheets.

Chart 9, figure 4, page 28, Variations in Plastic Sheets.--Finally he found a new design of calender producing a sheet with only about one-tenth of an ounce of variation. So here, by having the product tell him how uniform the process was, he was able to decide what machine he should get in order to save this material.

Here is a different process altogether. This process is in the textile industry, making yarns; 88 yarns are delivered by this machine. I won't have time to describe the machine, but the yarns at the extreme end of it were always lighter, whereas the yarns in the middle of the machine were always heavy. That repeated itself no matter how many machines it was tried on. It was a characteristic of that kind of machinery. Having discovered that characteristic, it was possible for the mechanical engineers to get to work and arrange to feed more fibers to the sides of the machine and thereby to increase the uniformity of those yarns and thereby to improve the quality of the fabric.

Chart 10, page 29, Measurement of Samples Tells.--From the preceding examples there were certain principles we can draw--that when we examine the product, we learn a whole series of things. Here we have a product going down and being delivered by this conveyor. Over on the upper right-hand side we take samples.

Now, first of all, we learn from those samples whether the samples themselves are good or bad. That information doesn't do us very much good. But, having discovered whether those samples are good or bad, we learn whether the process that made those was delivering good work or bad, because the product tells on the process. These samples reflect the variations which were present in the process at the time they were made, and thereby they tell us whether the process was doing good work or bad.

Having learned whether the process was doing good work or bad, we can thereby learn whether the uninspected pieces which were made at the same time as the inspected pieces were good or bad. That is the basis on which sampling inspection can tell us the quality of the uninspected pieces. It tells us that, not because the uninspected pieces are neighbors of the inspected pieces. That is not the reason. It tells us about them because the two were made simultaneously by the same process, and that process has been certified to us by the inspected pieces.

Moreover, as we sample from successive lots, we learn whether the process is steady or not. We learn whether it is a consistent and controlled process. And, once we establish that it is consistent and controlled, we can predict the quality of the unmanufactured product.

Those are part of the sequence of things that we begin to learn as a result of inspection.

Chart 11, pages 30-32, Process Analysis through Histograms.--We see here a few more dramatic examples of the way in which the product tells on the process. If we take a series of samples from a lot and tally them, so many here and so many there, and then draw a line through the tops of those tally marks, we get a shape of that sort. If these represent the tolerances, the minimum and the maximum, then we see that this pile-up of products is rather comfortably contained within those lines, just as our watch parts were. Under those circumstances it is possible for an operator to steer that machine comfortably between those two tolerance lines. If he aims as an average over to one side, he begins to notice difficulty. If he lets that average drift still further, than these all become defective, even though the process is good enough. The process is just as good here as it is up there, but it is being misdirected.

Here is a case where the process is not good enough. It takes the utmost vigilance on the part of the operator to steer that in between those lines. Any false movement in either direction produces defectives. It is like this situation of having a blanket that is just barely the right length. You have to place it exactly right or else something is going to stick out. The slightest movement begins to produce defectives.

Chart 11, page 30.--This process is not good enough; and, no matter where the operator sets this machine, there are going to be defectives. Here is a case where there are two lots made by different settings. Either one of these produced defectives. This one was made too small, this one too large; and yet the process is good enough to do a good job. The means were available to the operator to steer that machine properly. When you buy something and the vendor has sorted it, he has taken out all the small ones, and this is what the information looks like.

Chart 11, page 31.--If his gage isn't like yours, then you will find that he left some in there. The gage is different by this amount.

And so it goes. I will not go through the rest of these. But you see the way in which the product can tell on the process, and the way in which we use the information of inspection to go back in order to regulate the process.

Chart 12, page 33, Screw Machine Program.--I mentioned that higher quality of design always costs more. But higher quality of conformance always costs less. It always costs less to make it right in the first place. Here is an example in one company in which by discovering why things were defective and beginning to cork up those reasons, they were able to reduce considerably the cost of their spoilage and to increase the production, because now they were making the pieces right instead of losing them in something over 10 percent, as in this case, and not getting the value out of that production.

Chart 13, page 34, Results of Quality Control.—As these facts are introduced on the shop floor, the production operators become able to regulate their machines and to manufacture with their eyes open rather than blindly. Here was an anonymous poll taken of a group of operators after having introduced means by which they could pilot these machines without having to do the large degree of guesswork that had been the case before. Did they understand their job any better? Of the group, 81 percent thought that they did. Did it give them more responsibility? A great majority thought that it did. Were they able to control the quality of the work any better? An overwhelming vote of confidence. Was it easier to get along with the inspectors? The inspectors were also asked, Was it easier to get along with the operators? Again there was an overwhelming vote of confidence. And yet the people hadn't changed. What had happened was that they now had facts instead of opinions to deal with; and, of course it was easier to get along.

Chart 14, page 35, Typical Organization of Quality Function.—Within one plant the quality function will ordinarily be divided in three ways. First there is a problem of acceptance. That is the job of deciding whether what has been made should go to the next operation or should go to the customer. The man in charge of that is called the chief inspector. He has people who inspect what comes from vendors. He has people who inspect the work between operations. He has people who inspect the work before it leaves the plant. He should have them if he hasn't. These represent auxiliary people to maintain the accuracy of the measuring equipment and to solve the day-to-day troubles. That is the acceptance job. That is the oldest of the recognized quality functions.

The next is the prevention job. That is the job of preventing defects from happening. In order to do that, you require fact finders. Most of the causes for defectives are rooted in the lack of facts. The fact finders are a small group of engineers who make these factual determinations, finding out why things are defective. It may be necessary for them to follow trial lots through the shop in order to design experiments for doing that. They design the sampling plans; they analyze the data; and they provide training.

This is still a different function. It is the assurance job. That represents the problem of reporting to the top management the score on what is happening with respect to the quality function. Part of it is the analysis of complaints. Part of it is the audit or the surveillance of the work of the shop, checking on the system rather than on the product. Part is to check on the product itself.

I might mention that the armed services are faced with an enormous problem of proving the quality of the goods bought from vendors. They are faced with a decision of whether to do that largely through a reinspection of the goods or whether to do it through a surveillance of the contractor's plant. We can develop that during the question period as the group dictates.

The sum of what I have covered is that there exist today and are available to industry, and to the services as well, the means of regulating the quality function through the use of facts rather than opinion. The idea of the scientific method is an old one, but the application of it to the regulation of quality of goods is comparatively recent. Part of that is brought about because the tightening up of tolerances has increased the difficulty of achieving the quality function.

With your permission, I will now close the formal part of this and leave the rest to be brought out during the question period.

QUESTION: Doctor, in this process of quality control do your studies reveal what portion of the production process expense, what percentage, should be spent for quality control? Is there an optimum?

DR. JURAN: Do you mean the proportion of people that you need as fact finders as compared to those who operate the process?

QUESTION: Yes. In dollars or some other measurement of effort. I was wondering if there has been anything developed in that line.

DR. JURAN: If I were to give a rule of thumb, it would be on the basis that for every 500 people that there are in the production line there certainly should be one man who is devoting himself to nothing but fact finding on why things are defective. For those industrial companies that have gone into the kind of fact finding that I have been talking about here, that seems to be about the present ratio. I don't think we have had enough experience to be more precise than that. This is exclusive of the inspection forces who constitute from 5 to 10 percent of the cost of production.

You have, of course, an opportunity on the part of the regular line inspection and production people to do some of this. But it is limited, because they are confined pretty much to their area of operations, and they are not able to follow something through a whole series of departments. That takes a special individual who does have the time and who also has the charter which makes him able to go through those departments, who has the engineering and in some instances the statistical skill to design an experiment in terms of how many data to collect and what to do with them after they are collected.

But as a direct answer to your question I would say that at the present time something like one fact finder in a staff capacity to 500 plant people seems to be about the prevailing ratio.

QUESTION: Are there any industry-wide organizations that foster this type of quality control, or do we have any labor-management industry-wide organization that does this sort of thing?

DR. JURAN: There are many so-called professional management societies, and they are concerned with all the tools by means of which we manage industries. There is one group that is specifically concerned with this problem. It is called the American Society for Quality Control. It seems that we can hardly have a function come up but what a society will organize to foster it. That group is about four or five years old, and has a membership by now of about 2,000 or 3,000. It has a journal and some of the other trappings of a professional society.

QUESTION: Suppose I were a contracting officer and went into a plant of a vendor and I want to make some sort of decision regarding this inspection problem confronting me, to determine whether or not the product is up to specifications. Can you tell us something about what I ought to look for in making my decision as to whether or not I would check all the stuff myself or would accept the vendor's inspection data?

DR. JURAN: I certainly can. To a large extent it would be the managerial caliber and the managerial attitudes as well as the precision of the machinery that you would be looking for. Is there an independent inspection department so that inspectors can work with their eye on the specification instead of on the foreman? Is there a means for maintaining the accuracy of measuring equipment? Is the information recorded and used to go back to regulate the processes? Does the management get reports on what is the out-going quality? What do they do with them? Are those reports up to date? Those are some of the evidences of whether these people are on the alert or whether they are just letting things slide; and the range that you find from progressive industries to the backward ones is right across the whole scale.

In those instances where you find an alert organization, they have all these checks and balances present. You are then able, by having them give you their certifications of their measurements on the product, to do most of your acceptance on the basis of those records. You will, in any event, still do some reinspection of their work and compare that with their findings.

I might elaborate on that, because at the moment the various inspection services in the Department of Defense are right up against that problem.

You can operate that on the basis of two extremes. At the one extreme you have a large body of inspectors. You reinspect the work of the contractor, and, based upon your findings and without concern for his findings, you do or you do not accept the product. That is a tremendous headache, I might say—not only the getting of that personnel, but the discovery of what goes on in operations that are not evident in the final product.

That is to a large extent the way in which the services did the job during World War II, mainly by reinspection of the contractor's work. The tendency now on the part of some of the services--and I can name the Air Materiel Command and the Signal Corps as two of them that I am aware of from personal meetings--is to put more emphasis on this surveillance type of inspection; namely, to understand what is going on inside the contractor's plant, and in those instances where they are satisfied with it, to use the contractor's inspection data as a large part of their assurance. They do that on the theory that, once you know the system is right, the contractor's inspector can read an instrument just as well as a government inspector. Those of you who may be thrown into that problem will certainly face squarely the very thing I have just been talking about.

QUESTION: This question has to do with the previous one. There used to be an organization called the Charles E. Bedeaux Company. Has it been one of the pioneers in this type of work?

DR. JURAN: No, it has not. The Bedeaux people were early in the game of measuring how much was a day's work. They are still in existence under a different name.

QUESTION: In a process such as you mentioned, to what extent does the expansion of both the machines and the material due to changes in temperature and humidity affect the process on very close work?

DR. JURAN: It has an effect. If we were back at the example of the watch part, you would notice there is a change from the first few pieces. So far as we know, that is a case of the machine temperature having stabilized itself. The amount of the change is very small and in that case is of no consequence, because, once it is discovered that a change existed, the thing to do is to run the machine and bring it up to temperature on a practice basis without worrying about production at the moment. But certainly, if the effect is there, it is possible by measuring the product to discover the extent of it and to make the proper adjustment for it.

QUESTION: I would like to hear you discuss any instances that you know of where the quality control people have gone to management and said: "Look, we are striving for too much perfection in this particular item. A wider tolerance would be just as acceptable and not affect the end item use." And then, if possible, will you tell us if you know of any cases within the defense establishment where our inspections have required too narrow a tolerance, for our general edification at some future date?

DR. JURAN: There is certainly no lack of mutterings on the part of industrial people about whether the Department of Defense specifications are realistic. There is a problem in both back yards on that subject.

The contractor at the outset of negotiations leans over backward in order to get a contract, and, even though his engineers see some tolerances in the specifications that they are gloomy about, the sales manager of the company will take the position: "We will find a way to do that" even though he doesn't know how at the moment.

I could take an afternoon just to talk about the Department of Defense specifications. That is a very complicated problem. We were talking yesterday in one of the seminars about a current problem. It had to do with one of the materials that is in short supply today and the final product is badly needed out in the field. Deliveries are not coming fast enough. Part of the reason is that there are some elements of the specification that are put there in order to give that product a high degree of shelf life; so that, even though it is in storage for several years, it will still be usable. As it happens, at the moment that requirement is unimportant; but you never know when it is going to become important.

Probably the biggest difficulty is the big separation in number of organizational steps between the government designer, the man in the arsenal or laboratory, and the man who is going to have to make it in mass production. They don't have too much chance to sit around the table.

The government designer has some ideas of what are his functional needs. If the industry designer tells him: "Now, look. If we could be allowed to make this modification, we could make it faster, we could improve our production process and the like," there is always a risk that this is misinterpreted and misunderstood, and that the government designer may feel: "Well, designing is my job. Your job is just to make it."

That is a very difficult situation, because it puts two people in a position of being in separate rooms and communicating through a keyhole instead of sitting around the table, as they ought to do. That, I think, is the biggest problem; not the technical problem, but the communications, the managerial problem.

QUESTION: Dr. Juran, I got the impression from the Monday seminar that you spent some time recently at Wright Field.

DR. JURAN: Yes, I did.

QUESTION: I notice they have established a staff department of quality control. I wonder if you could tell us how they are applying these principles of quality control to the service departments, which would be somewhat different from manufacturing.

DR. JURAN: They are attempting to put more emphasis on the surveillance or audit of the contractor's plant, and to use that information,

as well as information gained by check inspection of the product, to decide whether they are going to accept the contractor's goods or not.

Their story would be: "During World War II, we had 16,000 inspectors in the field. The contractors had several times that many. All those inspectors, whether government or contractors', were paid out of government appropriations. We can utilize that information better if we pool it together rather than in watertight compartments."

If the Government went whole hog on the basis of getting its assurance through audit and surveillance of the contractor's plant and his facilities and his records rather than reinspection of the product, it would take perhaps 1,000 engineers to do the job that 16,000 inspectors used to do. It may be harder to get the 1,000 engineers than the 16,000 inspectors.

The method of putting this into effect is to develop at the staff level the ways by which this kind of assurance can be secured; to feed that information out to their field offices; and then to stimulate the field offices, which have, of course, the day-to-day negotiations to carry out, to use that means to the extent they can, rather than to build up a large inspection force. But I must say that this is in the beginning stages.

QUESTION: It amounts to a reorganization of the inspection system, doesn't it?

DR. JURAN: It is altogether a different philosophy of inspection. Instead of a reinspection of the product, it will be a looking over the shoulders of the contractor. Based upon whether the contractor does the job in a way that is acceptable, the inspector can accept the product with very little inspection on his own part.

QUESTION: From a company standpoint, could you give us the optimum location or position for a quality control department?

DR. JURAN: There are several places where a quality control department could be located without making too much difference. Consider the nature of this quality control group. It is a prevention group. Its primary job is one of fact finding, of having the mobility to go from one department to another anf generate the facts.

Now, in industry at the present time there are already several departments that have that kind of charter, but for other purposes. The production engineers are one group and the industrial engineers are another group. The inspection headquarters are still another group. It is entirely feasible from an organizational standpoint to have the quality control men report to any of those groups. My advice to companies usually is to start it in that place where it will create

the least jurisdictional problems; so that for the first year they can be gathering facts instead of fighting out jurisdictional headaches.

One of the arguments for having the quality control group and the inspection group report to the same official is that for the most part the information used by the quality control group is the regular inspection data generated in the ordinary course of events by the inspectors. At the moment that is the most popular place to put it. The chief quality officer of the company is no longer the chief inspector. He is a man called the quality manager; he heads up both the inspection department and the quality control department.

QUESTION: Have you ever had experience in combining a service department with a quality control department--in other words, an organization that is out in the field finding out the difficulties in the field--combining those people or their findings with those within the plant?

DR. JURAN: That is of the utmost importance. There is a form of machinery for that. The information is usually called complaints. In the industrial companies there is an organization called the sales service department, which is the funnel for bringing those complaints to the factory.

I must say that this is far from being as effective as it ought to be. In one of the seminars we made a great deal of to-do about the importance of feeding the information on field performance back to the manufacturing people and especially to the designer, so that the most prevalent forms of field difficulty can be designed out of existence. We are losing many bets there because that information has so far to travel in getting back to the designer that it peters out before it ever gets to him.

QUESTION: The techniques that you have outlined to us apply directly to machine operations, where most of the variables are oriented around the machine and the materials or even the operator. But from this you go into finished assemblies and subassemblies, where operating characteristics become important. You may have already really answered this question when you spoke of the characters of the organization and the management in the organization; but would you like to extend those remarks regarding the acceptance of completed assemblies and subassemblies where operational characteristics and the possibility to plug castings and things like that may enter into the picture?

DR. JURAN: There is no difference in the principles that apply, but the application gets more difficult, because the thing is much more complicated at the final stage. When there is a defect in the final assembly, the things that might have caused it are much more numerous, because there are so many characteristics that combine in order to make the apparatus meet its final characteristics. Some of these things get

to be unbelievably complicated, and it takes very carefully designed experiments in order to focus down on what are the likely contributors to the failure and then to investigate those.

I mentioned in one of the seminars the problem faced by the textile companies when they have a shrinkage of fabric beyond the tolerable limits. When you think of what might have caused that--which looms wove the stuff or what combination of looms and dyeing vats did it; or was the yarn spun or twisted poorly, and if so, which machine did it, and so on--the number of variables that conceivably contribute to that final result gets to be very discouraging. The direct response to the question is that the investigations are more complicated. The principles surely are no different.

QUESTION: I would like to ask from a practical point of view, and along the line of military inspection, of course, whether you think it is possible to lay down a policy that a certain method of inspection will be used, such as making the inspector himself responsible for the goods that he passes. In other words, do you think we should leave it to the inspector and make him responsible for deciding whether to use a surveillance method of inspection, watch the inspectors in the local company, for instance, to make sure that each company doesn't have an entirely different tolerance, or whether he will sample a certain percentage of the products? Or do you think it would be more advantageous to the military services and the country in general to adopt some one system of inspection rather than leaving the responsibility with the local inspector? That is going on right now and it is a big problem. I would like to get your ideas on the subject.

DR. JURAN: I can give you a pretty direct answer to that. I am quite sure that until such time as by check inspection of the product you are convinced--and that is the proof of the pudding--that your other views based on inspection of the plant are sound, you cannot do away with check inspection of the product.

The most economical way of approving the contractor's goods is through understanding his system. If his system is sound, the goods have to come out meeting requirements. But it seems to me that no government inspector--I am talking about the man who is responsible for signing his name and saying: "I certify that this conforms"--if he is in his right mind, would go and look at the contractor's plant and the records and so on and, based on that, without any re-examination at all of the contractor's goods, would sign his name to that document. I certainly wouldn't.

But if, as he does some reinspection, it confirms what his beliefs are, based on the examination of the plant, then he is in a position to reduce that inspection to a very small amount. That would be very sound. But I certainly wouldn't start by assuming that if my observations of the plant were satisfactory, I would do no check inspection. As much

confidence as I have in the idea of surveillance, I wouldn't want to give up the other form of assurance. I would cut the premium down quite a bit, but I wouldn't eliminate it.

QUESTION: With products that are produced on a mass basis I understand how this will work. But there are some types of articles, say, finished airplanes, for example, where I wonder if the principle will apply. Must there not be in all such cases, for the safety of flight, almost a shakedown inspection on every product? You can't just accept a group of airplanes because one performs right. You just about have to inspect them 100 percent, or give them at least a shakedown inspection, don't you?

DR. JURAN: There is no question about that, when you are talking about finished airplanes. But there are quite a few mass-produced components that you get before you have a finished airplane, and as to those you can apply this principle.

When it comes to the final test, certainly no one in his right mind would make an acceptance without having the plane flown. You would have to do it particularly on something as complex as an airplane, where the number of things that have to be right is just legion. You can just take the mathematics of it. Assume that the chance of some one component being right is 99 out of 100 or 999 out of 1,000. That is a pretty high percentage. But if you bring together 10,000 components, then in terms of probabilities the chances that all 10,000 of those are right will be .999 raised to the ten-thousandth power; and that is a pretty small number. So you still have to apply in the case of the final assemblies the functional test. We are a long way from being able to jettison that one.

QUESTION: I would like to explore that question a little further. Suppose the Air Force is buying 40,000 altimeters for the planes in any one year. It is a difficult job to run each altimeter up and down and check it at various points. What kind of test can be used on 40,000 altimeters to insure that we are going to get a good product?

DR. JURAN: There we get back to this characteristic of sampling--which was that the pieces that we measure and get results from give us data which tell not only about those pieces, but also tell about the process that produced them. That in turn tells about the others that are produced by the same process.

If we take a number of these altimeters up in a plane--I suppose we could rig up means of taking up quite a few of them simultaneously--and find that the readings give a high degree of uniformity, it would probably become monotonous to keep taking others up.

Again, the product tells its own story. If, as we test out one after another, they test precisely or within very close limits as their

mates did, that gives a verification on the basis of experimental evidence—not on somebody's assertion but on experimental evidence—that the process which made those altimeters conforms.

I must say that I have some qualms in the case of an instrument of that kind of somehow having it put into somebody's plane without having some form of test. There the means of engineering might well be to develop in the contractor's plant some kind of simulated use test and then develop a relationship between that simulated use test and the actual use test.

Let me give you an example. In the case of lamps and vacuum tubes we have a requirement on length of life. That is a constructive test, just as in the case of firing ammunition or testing fuzes. There is a case where it is impossible to test every unit of the product. We must find some sampling technique.

What we do is to develop an accelerated life test. We apply that to samples of the product. To other units of the product made by the same process we apply the full life test. If the units tested by the full life test meet their requirements, we are able to develop a correlation between those units and units tested by the accelerated life test, and thereafter we are able to use the accelerated life test.

I am not able to put into a technical suggestion what would be the equivalent of that for the altimeters, but I am sure the ingenuity of the engineers will rise to that occasion. I have never yet seen an instance in which we had a destructive test but what somebody came up with an equivalent that gave us adequate coverage.

In your case, where it is not a destructive test, but an expensive one, there is a way of approximating it. Take the case of substituting a cheap test for an expensive one. In testing for tensile strength there is a very expensive test in which we have to machine the specimen very closely and try it on an expensive device, and so on. But the Rockwell hardness test is a very simple one. When we test a series of specimens for tensile strength on the Rockwell, we find a comparatively close relationship; and that means that the cheap test can be used to approximate the expensive one. A cheap test can be developed for the altimeter.

COLONEL CAVE: Dr. Juran, I would like to give you a small, but I am sure a representative, sample. During the break somebody said that you dressed up a dead subject. Another officer said immediately that the subject really was alive. Thank you very much.

(20 Feb 1951—650)S.

CHART 1. THE QUALITY ATOM.

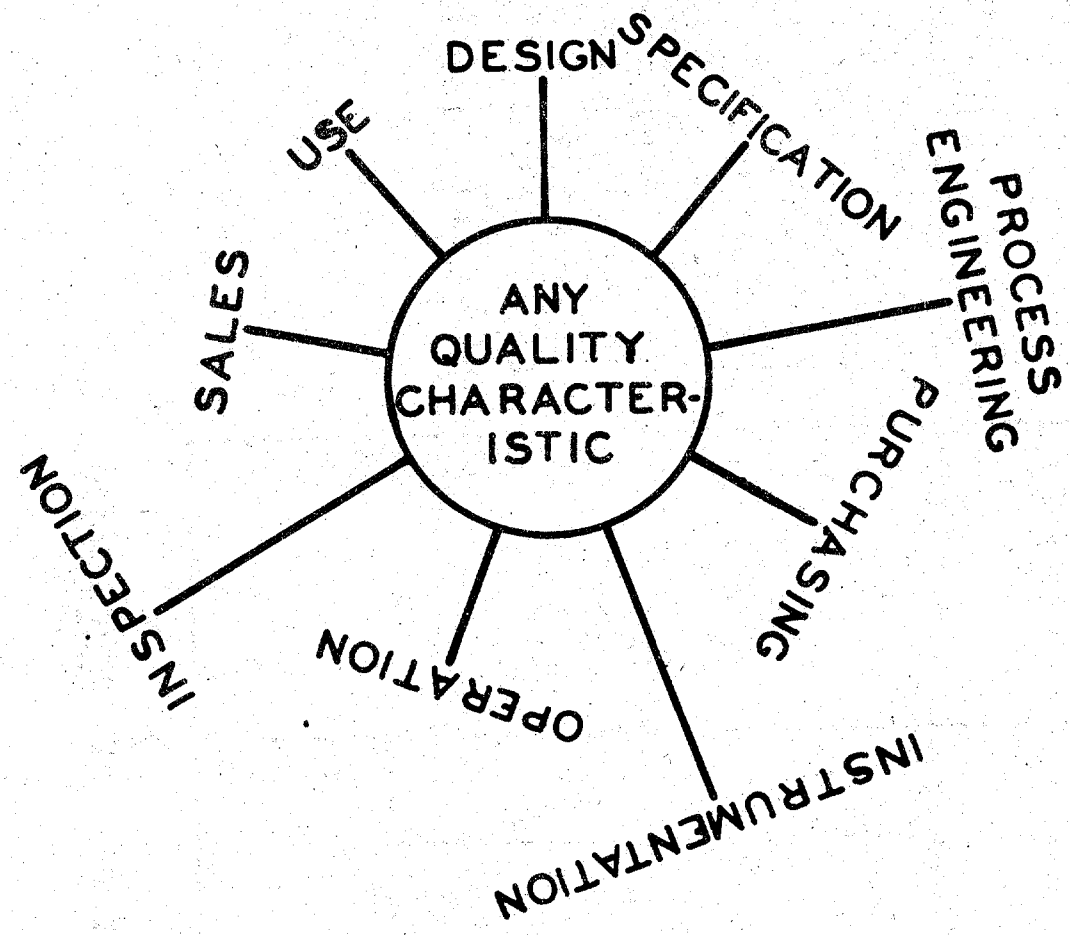
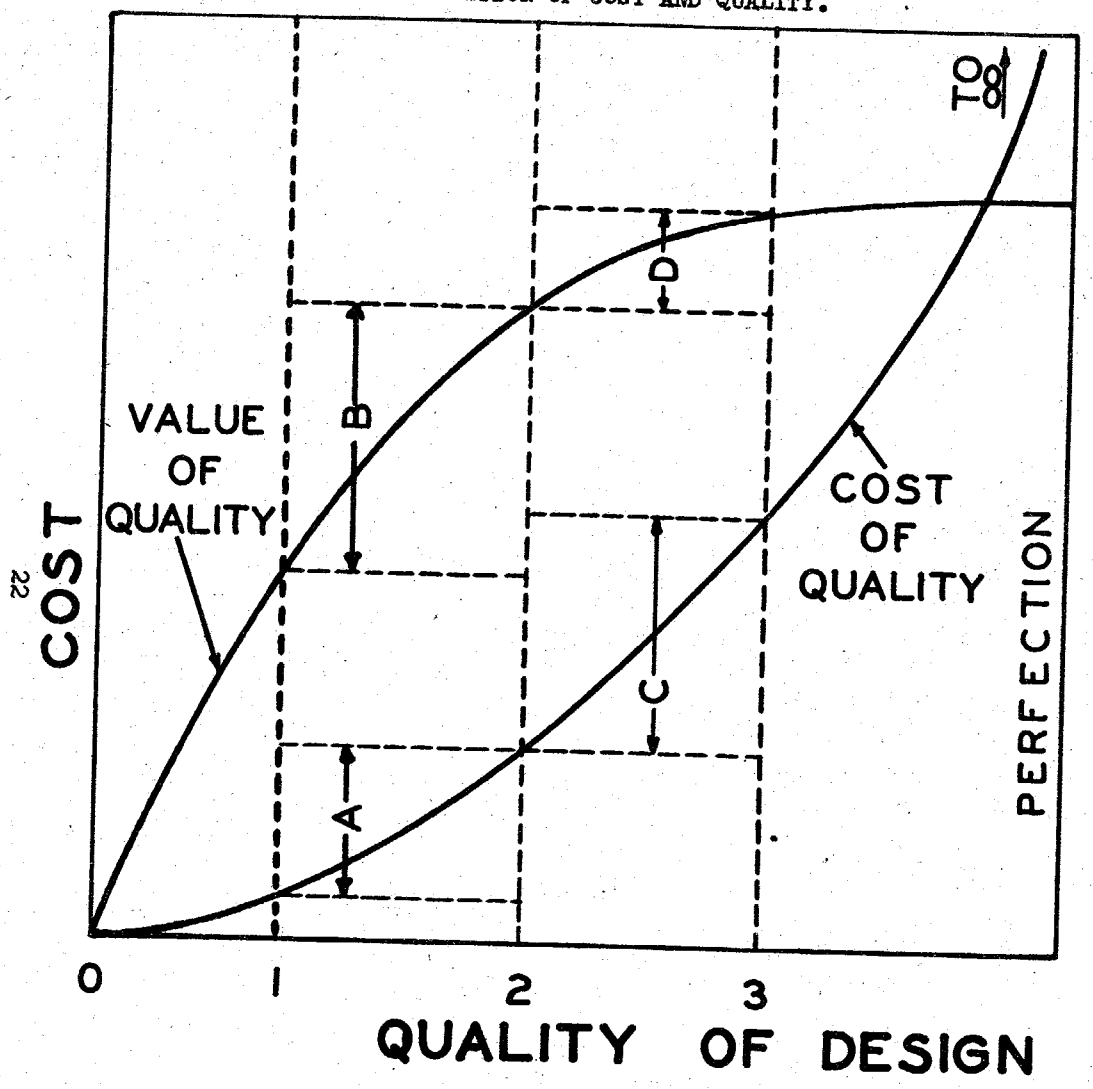


CHART 2. RELATION OF COST AND QUALITY.



QUALITY AT LEVEL 2 IS THE MOST ECONOMICAL. A DROP TO LEVEL 1 REDUCES THE COST BY A, BUT REDUCES THE VALUE BY B WHICH IS GREATER THAN A. A RISE TO LEVEL 3 INCREASES THE VALUE BY D, BUT INCREASES THE COST BY C, WHICH IS GREATER THAN D.

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CHART 3. QUALITY OF CONFORMANCE.

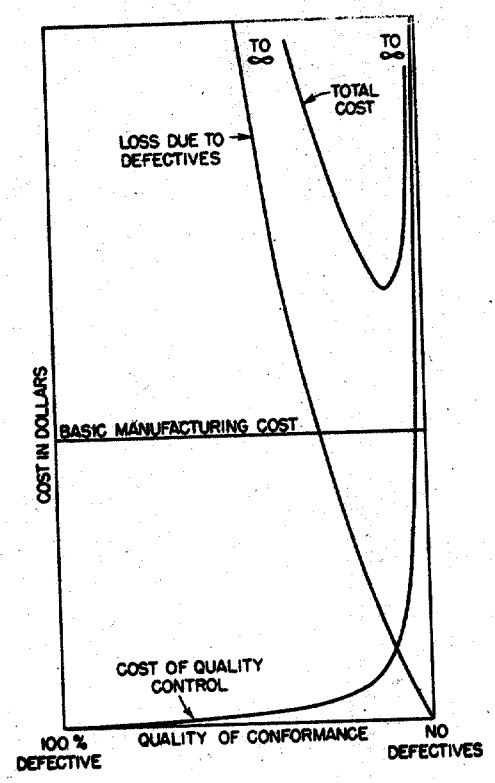

CHART 4. FACTS AS TO COST OF QUALITY ARE WIDELY SCATTERED.

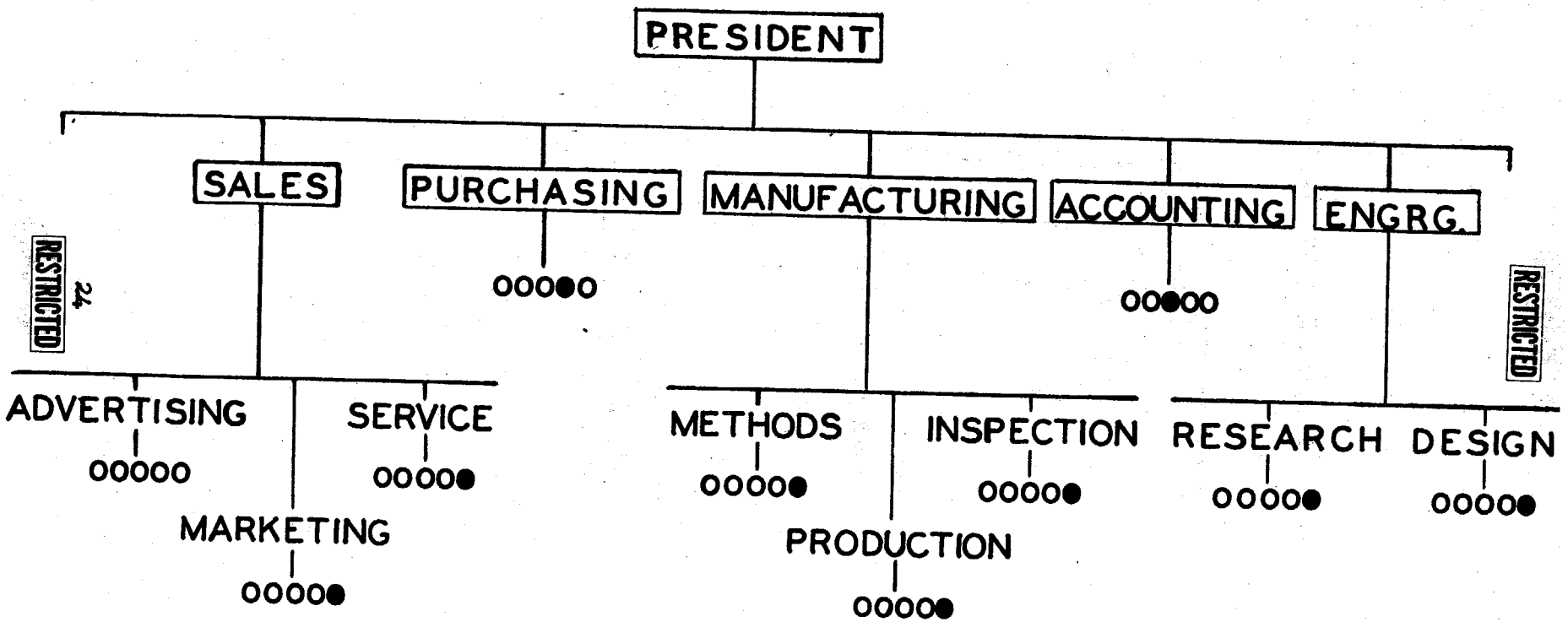

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CHART 5. FACTS AS TO THE VALUE OF QUALITY ARE WIDELY SCATTERED.

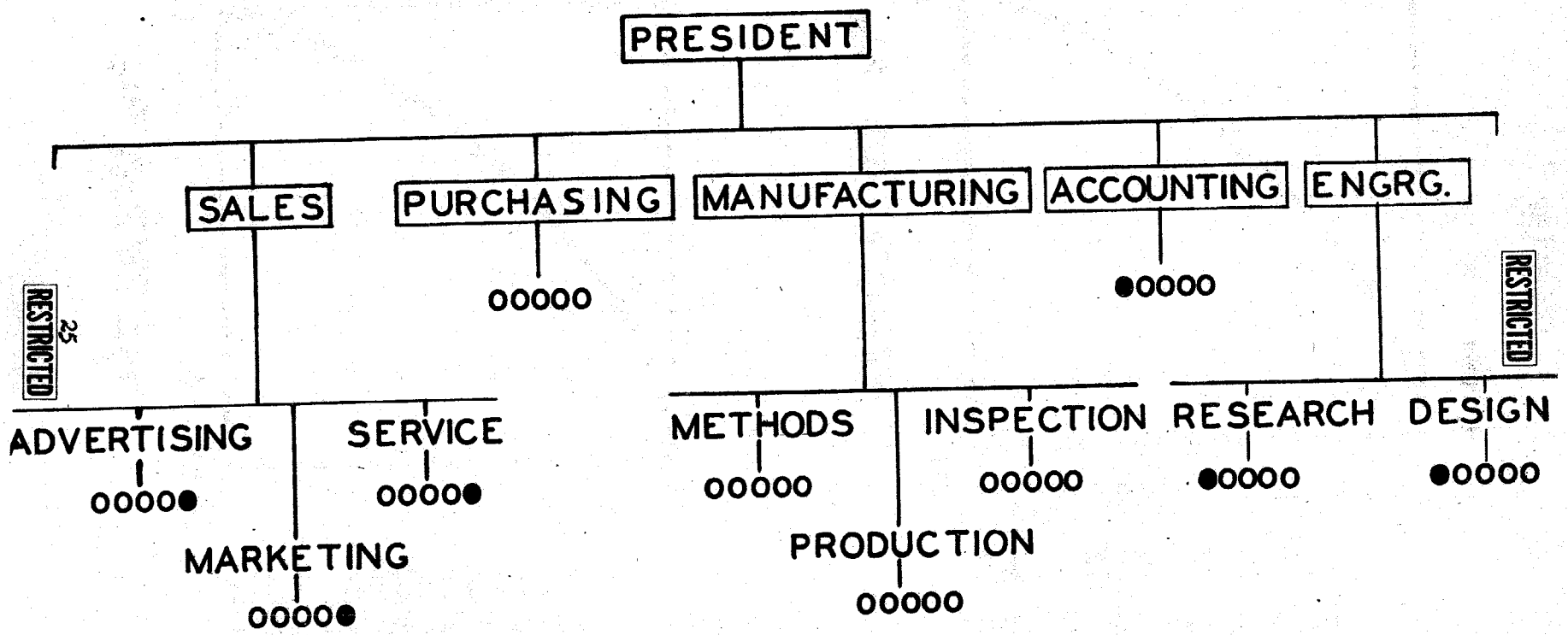

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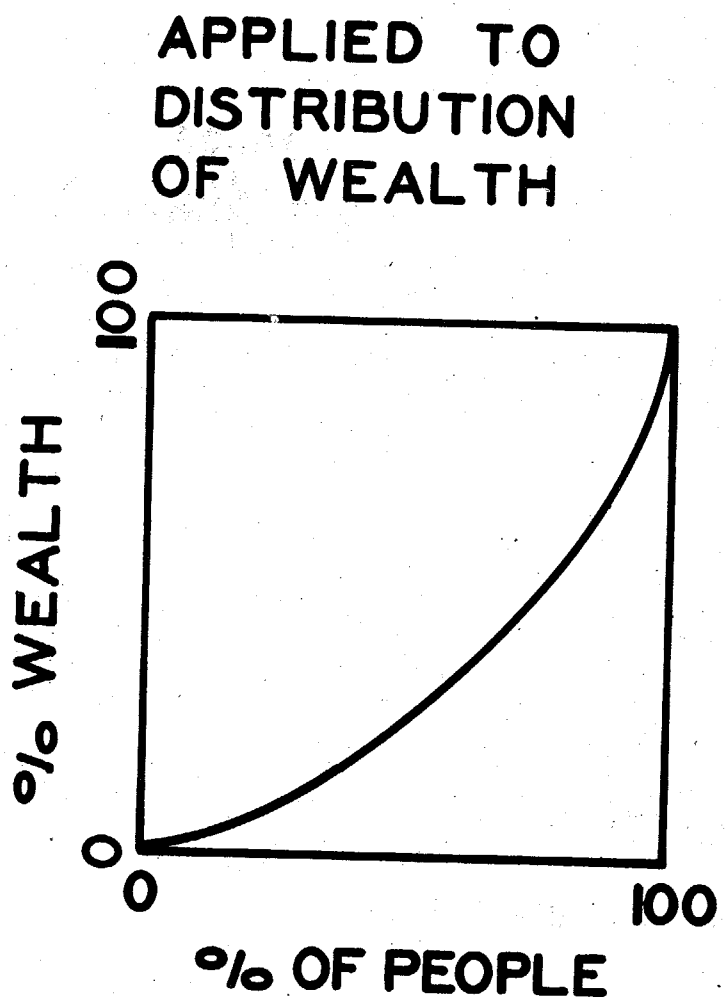
CHART 6. PARETO'S PRINCIPLE.



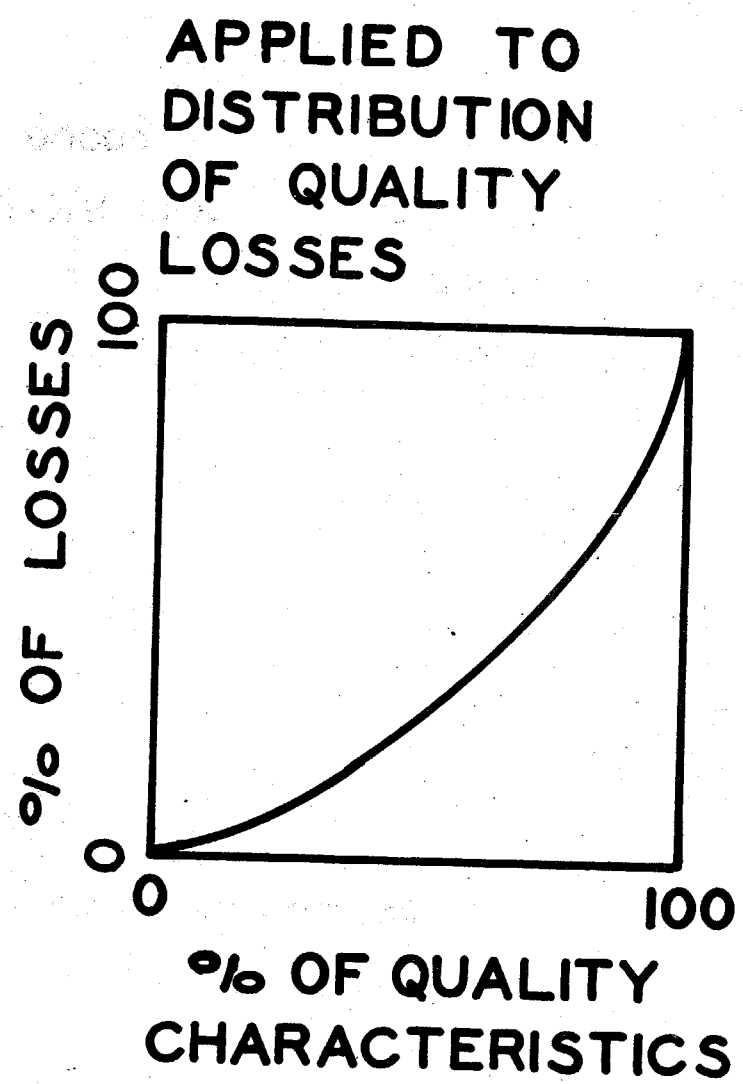


CHART 8. STUDY OF PROCESS CAPABILITY--PLASTIC MOLDING.

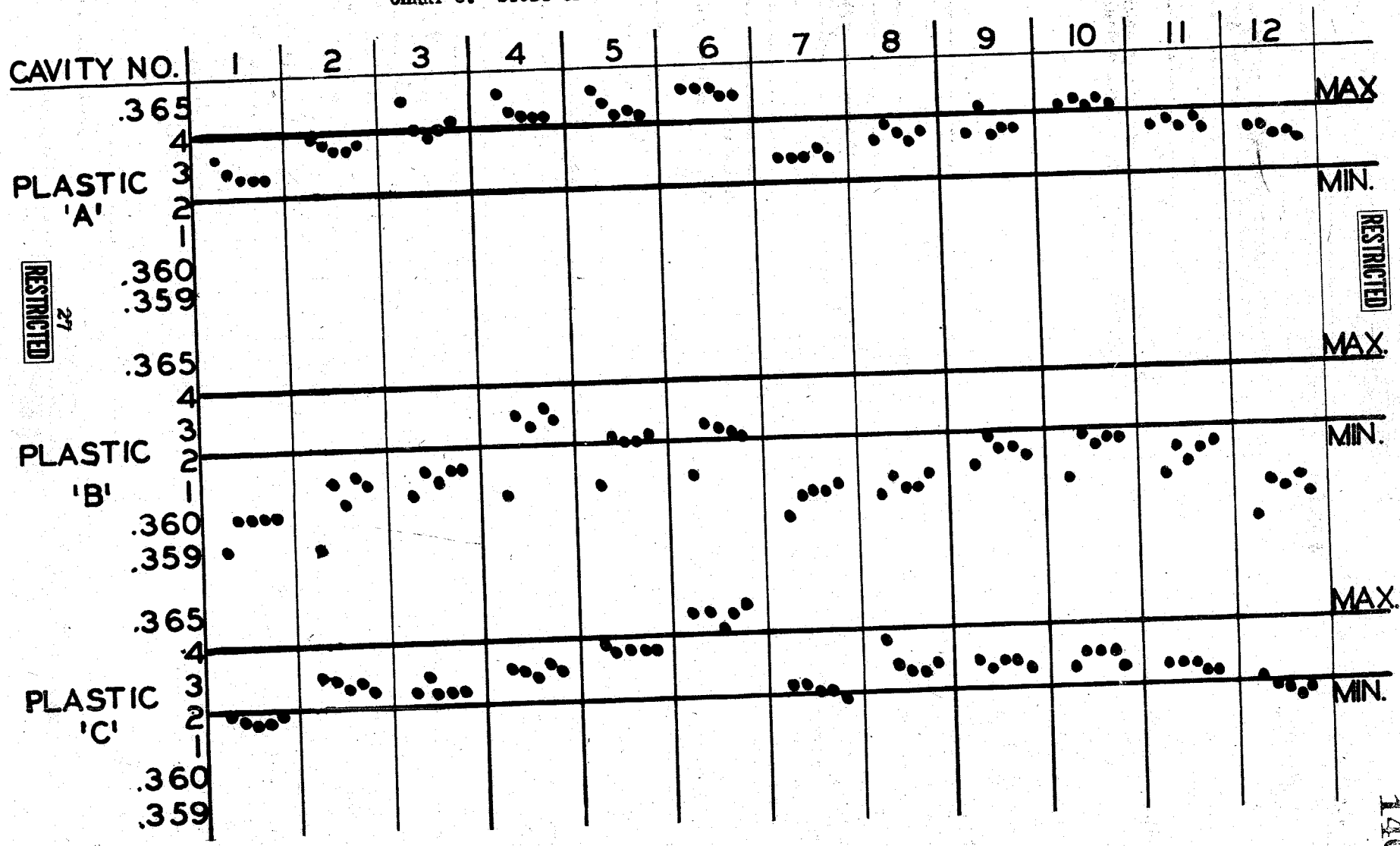


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CHART 9. LINEAL VARIATIONS.

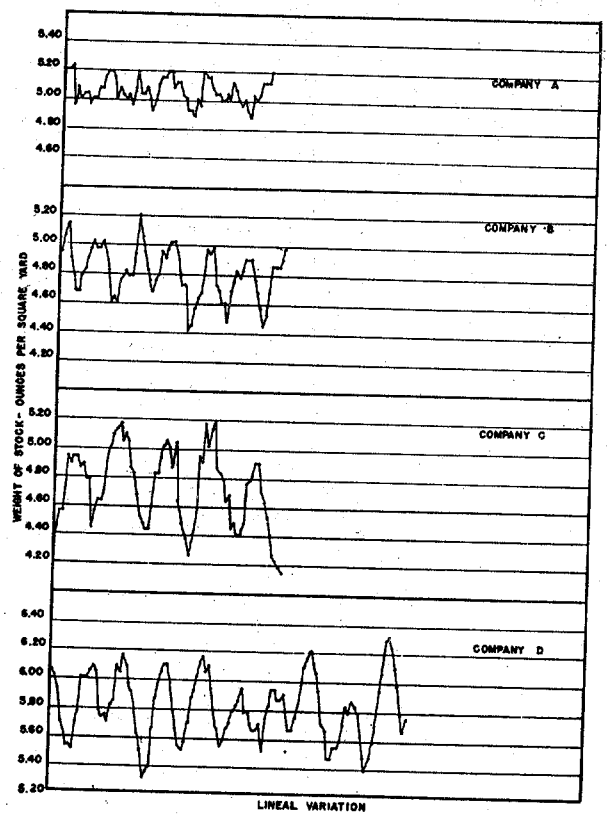


FIG. 1—Graphs on four different calenders, each from a different company producing adhesive tape.

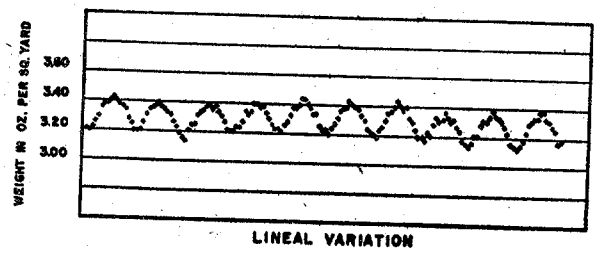


FIG. 3—Variations in calendered stock of polyvinyl chloride plastic from an old, but well maintained calender.

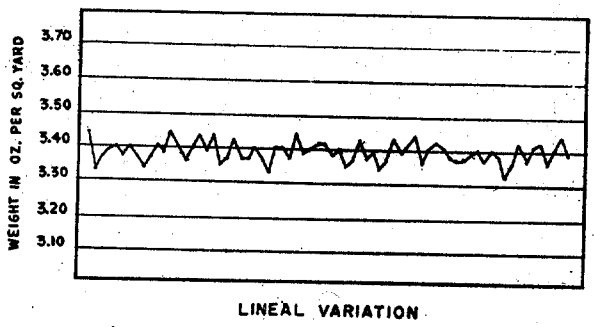


FIG. 4—Variations in .004" polyvinyl chloride plastic.

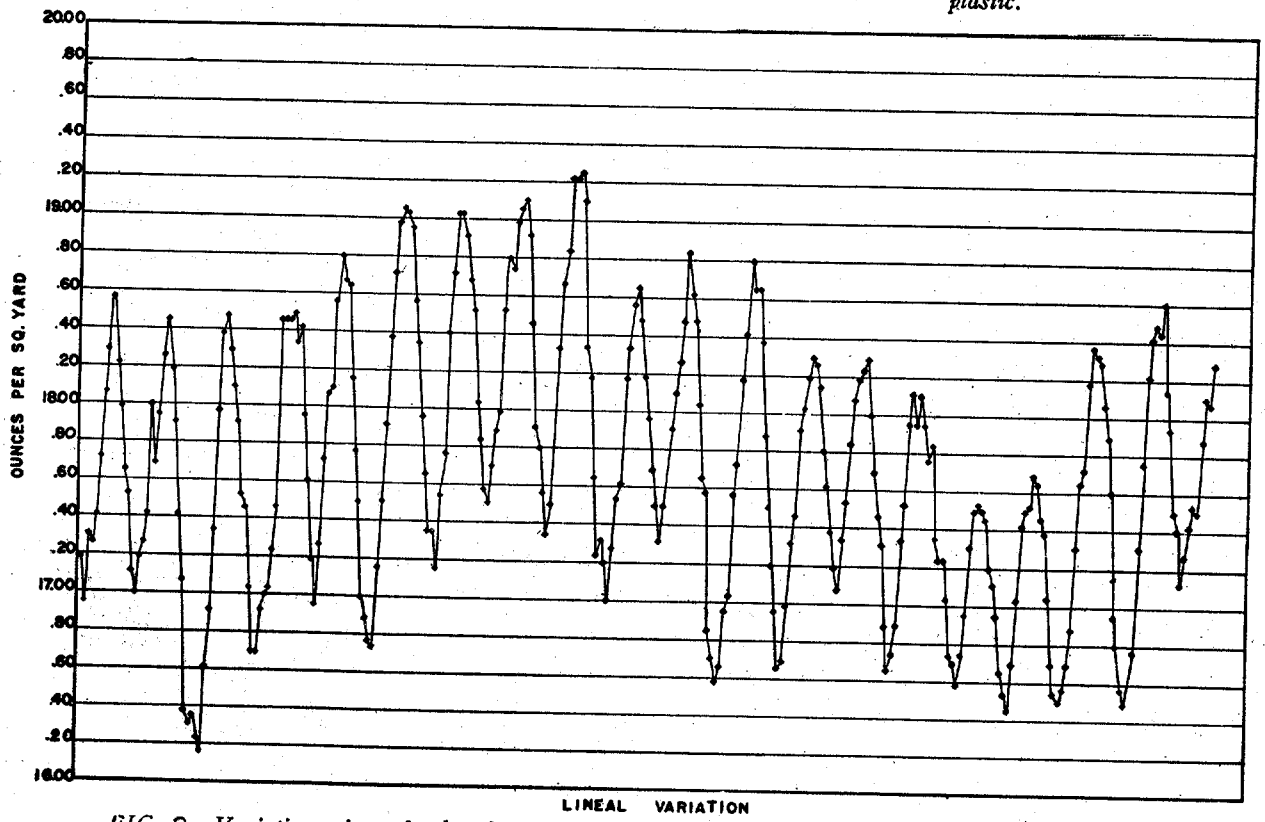
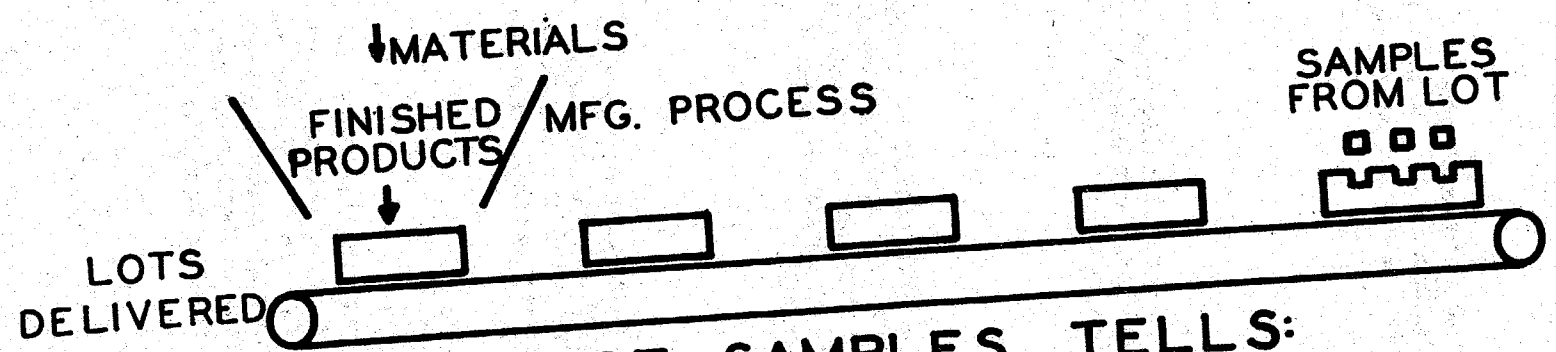


FIG. 2—Variations in calendered non-friction rubber stock produced on a new calender.

CHART 10. MEASUREMENT OF SAMPLES TELLS.



MEASUREMENT OF SAMPLES TELLS:

1- WHETHER THE SAMPLES ARE GOOD OR BAD.

2- WHETHER THE PROCESS, AT THE TIME THE SAMPLES WERE MADE, WAS DOING GOOD WORK OR BAD.

3- WHETHER THE UNINSPECTED PIECES MADE AT THE SAME TIME BY THE SAME PROCESS ARE GOOD OR BAD- PRINCIPLE OF SAMPLING INSPECTION.

4- WHETHER THE PROCESS STAYS UNIFORM.

5- WHETHER THE UNMANUFACTURED PIECES ARE GOING TO BE GOOD OR BAD- CONTROL INSPECTION.

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CHART 11
PROCESS ANALYSIS
THROUGH HISTOGRAMS

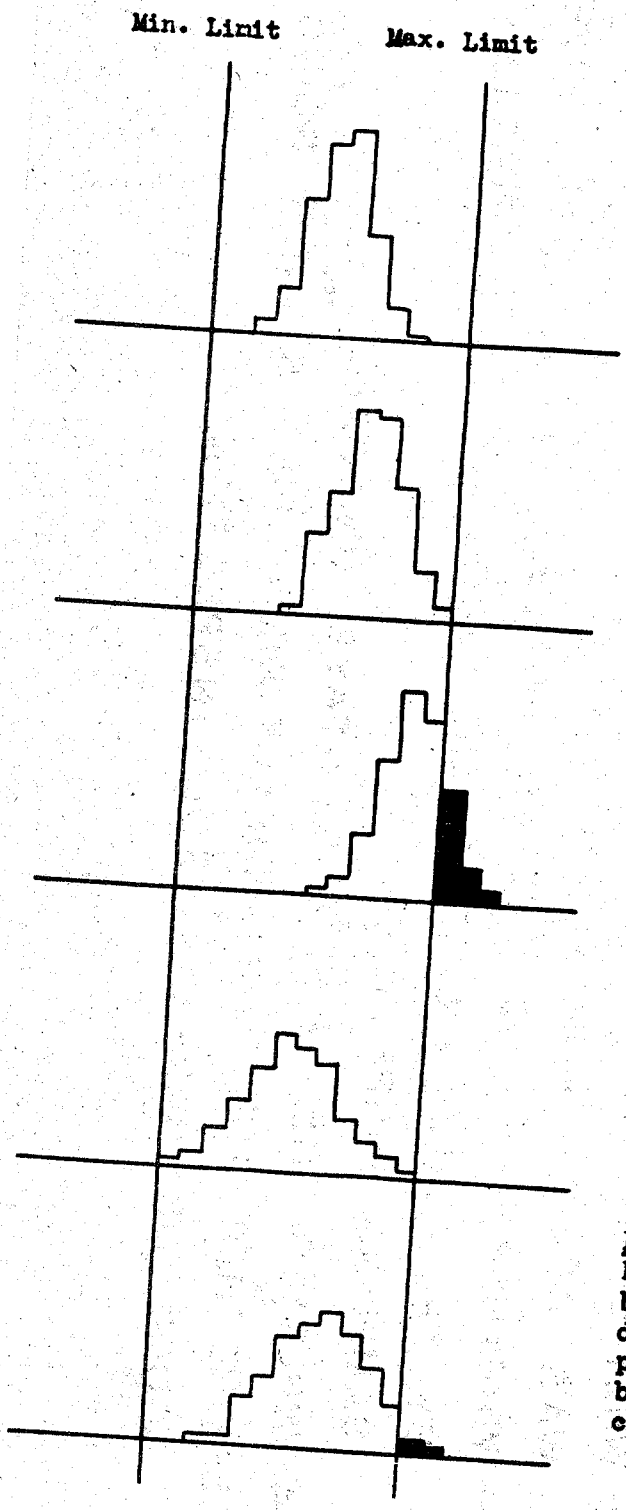

Fig. 1
Product range substantially less than specifie and distribution is well centered. Consider using smaller sample on subsequent lots.

Fig. 2
Product range substantially less than specifie but distribution is off-center. Production of defects imminent.

Fig. 3
Product range substantially less than specifie but distribution is badly off-center producing defects above max. limit. Vendor can meet tolerance and eliminate defects by centering the distribution.

Fig. 4
Product range approximately same as specified and distribution is well centered. Slight shift off-center will produce defects at one limit. Vendor may require increased tolerance.

Fig. 5
Product range approximately same as specified but distribution is off-center producing defects above max. limit. Vendor must reduce product range through change in process or by better control and distribution must also be centered. May require increased tolerance.

CHART 11. Cont'd.

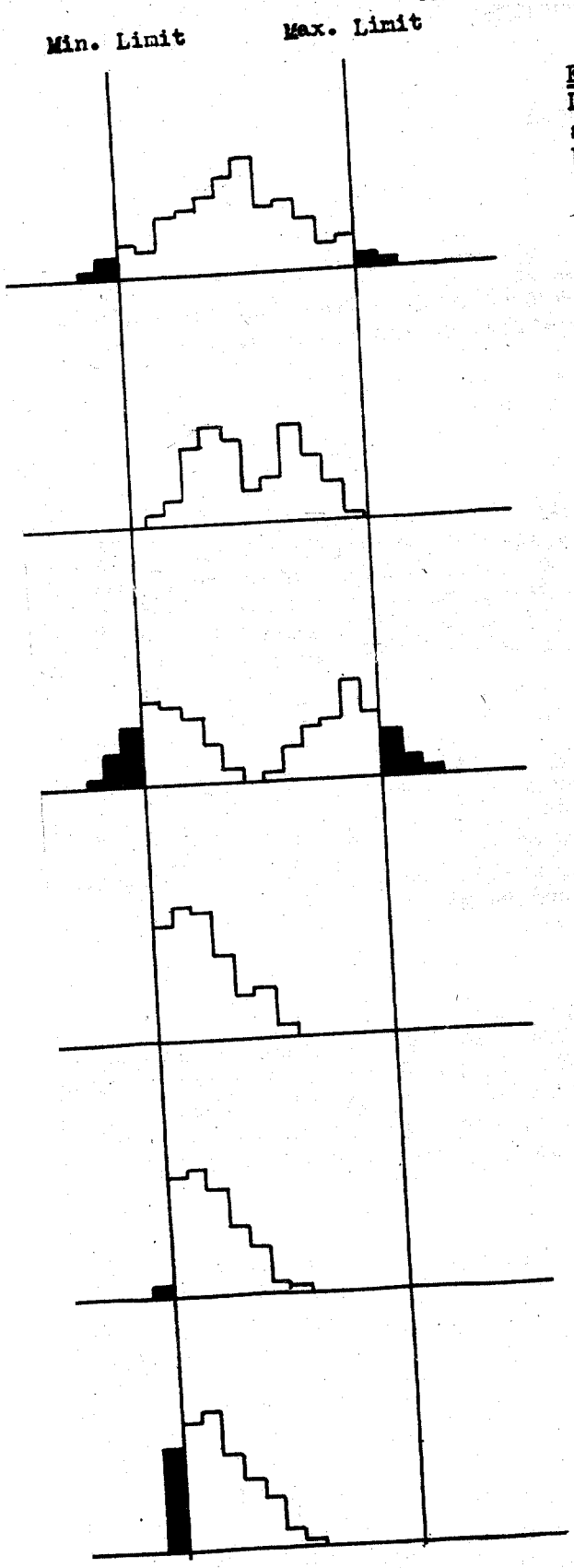

Fig. 6
Distribution is well centered but exceeds specified range and defects are occurring at both limits. Change in process or better control required to reduce range. Vendor may require increased tolerance.

Fig. 7
Double distribution suggests possibility of 2 sets of tools, change in process or material during running of this lot. Vendor can easily hold tolerance since range of either distribution is smaller than specified.

Fig. 8
Same as Fig. 9 except that the two centers are far enough apart to cause defects outside both limits. No increase in tolerance needed. Condition should be easily corrected.

Fig. 9
Distribution off-center to min. limit and lot has been inspected 100% before shipping. If production is centered vendor may be able to eliminate the 100% inspection.

Fig. 10
Same as Fig. 11 except operator is passing defects or gage is slightly off.

Fig. 11

100% inspection gages are probably not set to correct limits and defects appear below the min. limit. Operator may be having difficulty deciding borderline cases.

CHART 11. Cont'd.

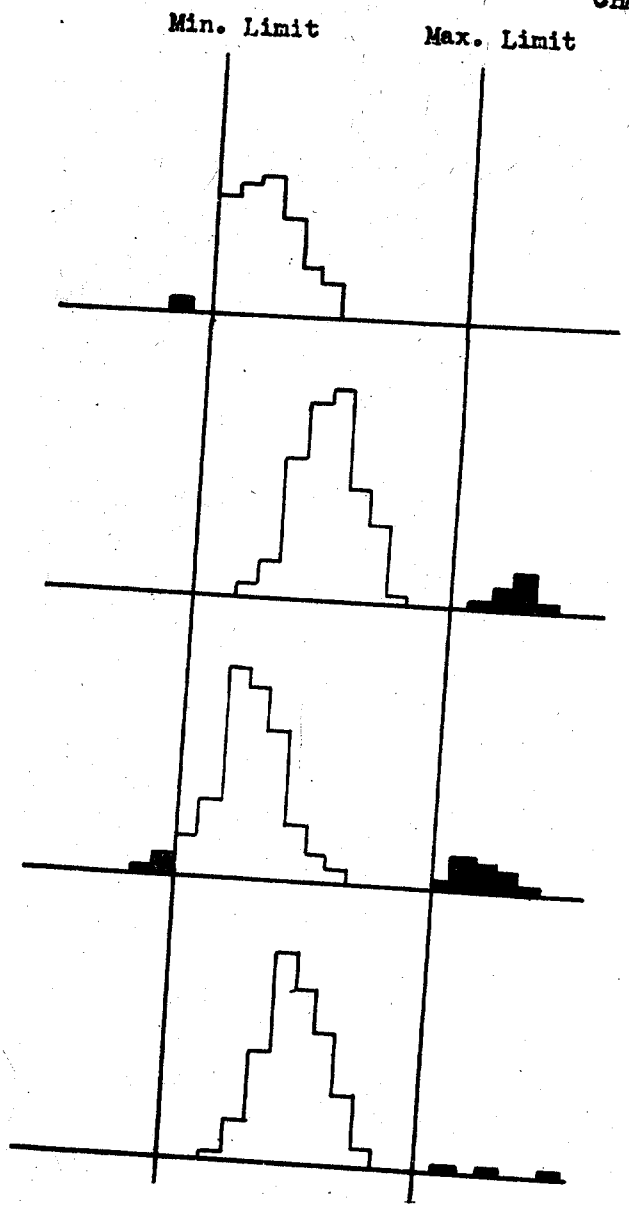

Fig. 12
Same as Fig. 11. Gages set correctly but operator has missed some parts.

Fig. 13
Principal distribution has narrow range and well centered. Small distribution above max limit may be parts from tool and set-up tryc not set aside. Vendor should be able to asc tain cause and correct condition.

Fig. 14
Similar to Fig. 15 except main product distr bution is off-center to min. limit producing defects outside both limits. Vendor should able to correct condition. No increase in tolerance required.

Fig. 15
Distribution has narrow range and is well centered. A few individual pieces are exceeding max. limit. May be due to misses by operator or machine. Vendor should have no difficulty in overcoming this condition.

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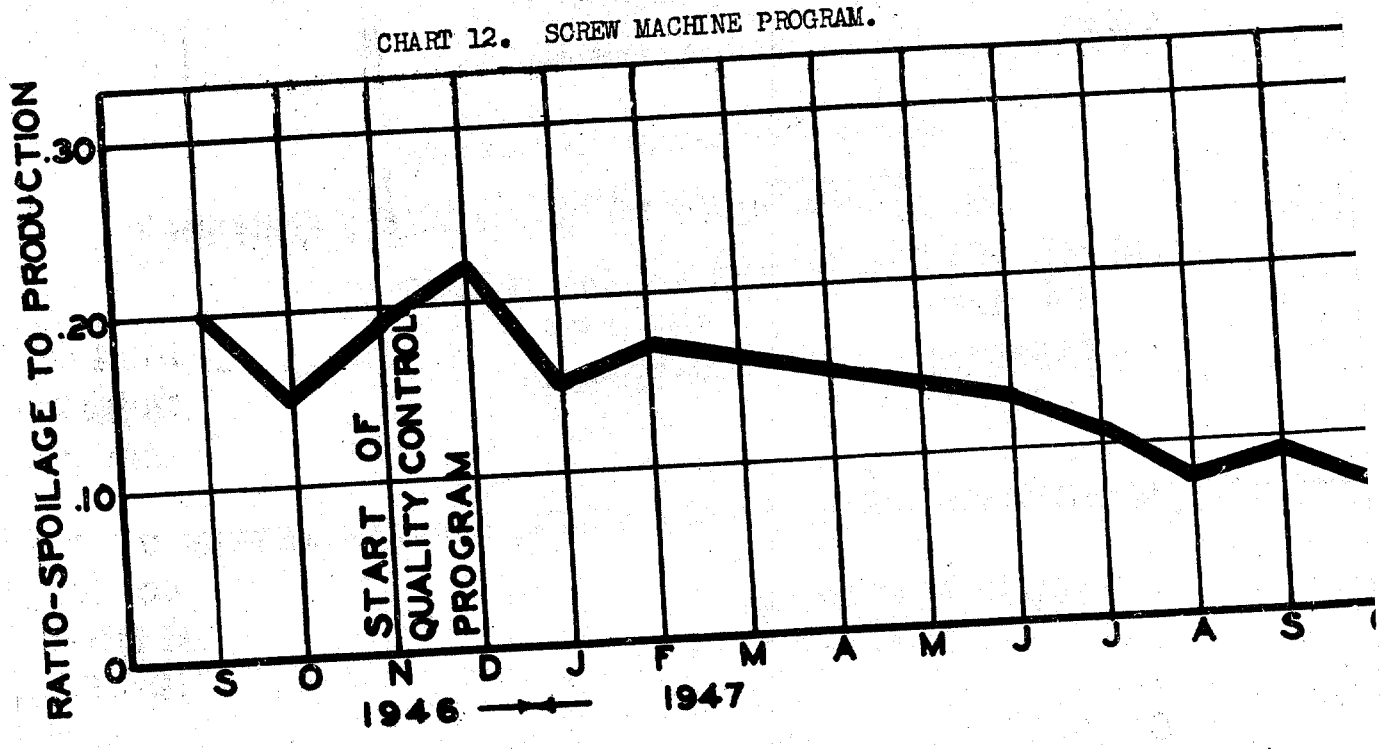
CHART 12. SCREW MACHINE PROGRAM.



	JUNK	RE-OP	BENCH INSP.	PATROL INSP.	COST OF SPOILAGE	VALUE OF PROD.	RATI
1946							
S	$ 2,978	$ 380	$ 3,643	$ 1,670	$ 8,671	$ 43,160	.20
O	4,032	256	2,383	1,522	8,193	54,067	.15
N	3,461	212	2,633	1,593	7,899	40,971	.19
D	4,550	378	2,397	1,738	9,063	41,949	.22
1947							
J	5,792	560	2,608	1,692	10,699	71,709	.15
F	5,049	747	2,398	1,815	10,009	53,153	.17
M	4,321	365	1,849	2,042	8,577	54,197	.16
A	4,323	530	2,230	1,980	9,063	60,417	.15
M	2,787	519	1,786	1,444	6,536	48,294	.14
J	2,568	336	967	1,313	5,184	39,361	.13
J	2,006	241	883	1,339	4,469	41,648	.11
A	1,202	51	258	1,111	2,622	31,774	.08
S	1,793	168	132	1,625	3,718	41,529	.09
O	1,747	179	180	1,789	3,895	54,522	.07
N	1,619	169	207	1,867	3,862	49,363	.08
D	1,614	230	130	1,721	3,695	45,340	.08

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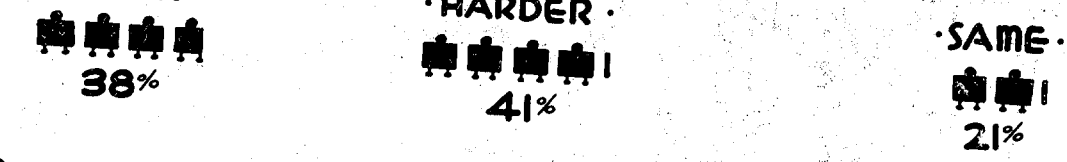
CHART 13. RESULTS OF QUALITY CONTROL.

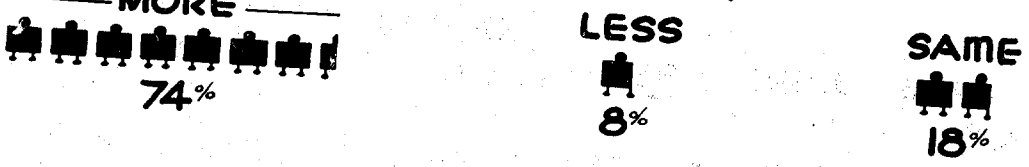
5 - BEFORE AND AFTER QUALITY CONTROL.

Q — IS YOUR JOB EASIER OR HARDER ?



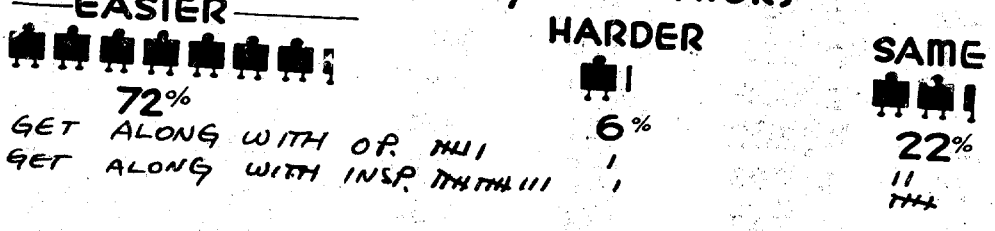
Q — DO YOU UNDERSTAND YOUR JOB ANY BETTER ?

Q — DO YOU SEEM TO HAVE MORE OR LESS RESPONSIBILITY FOR QUALITY ?



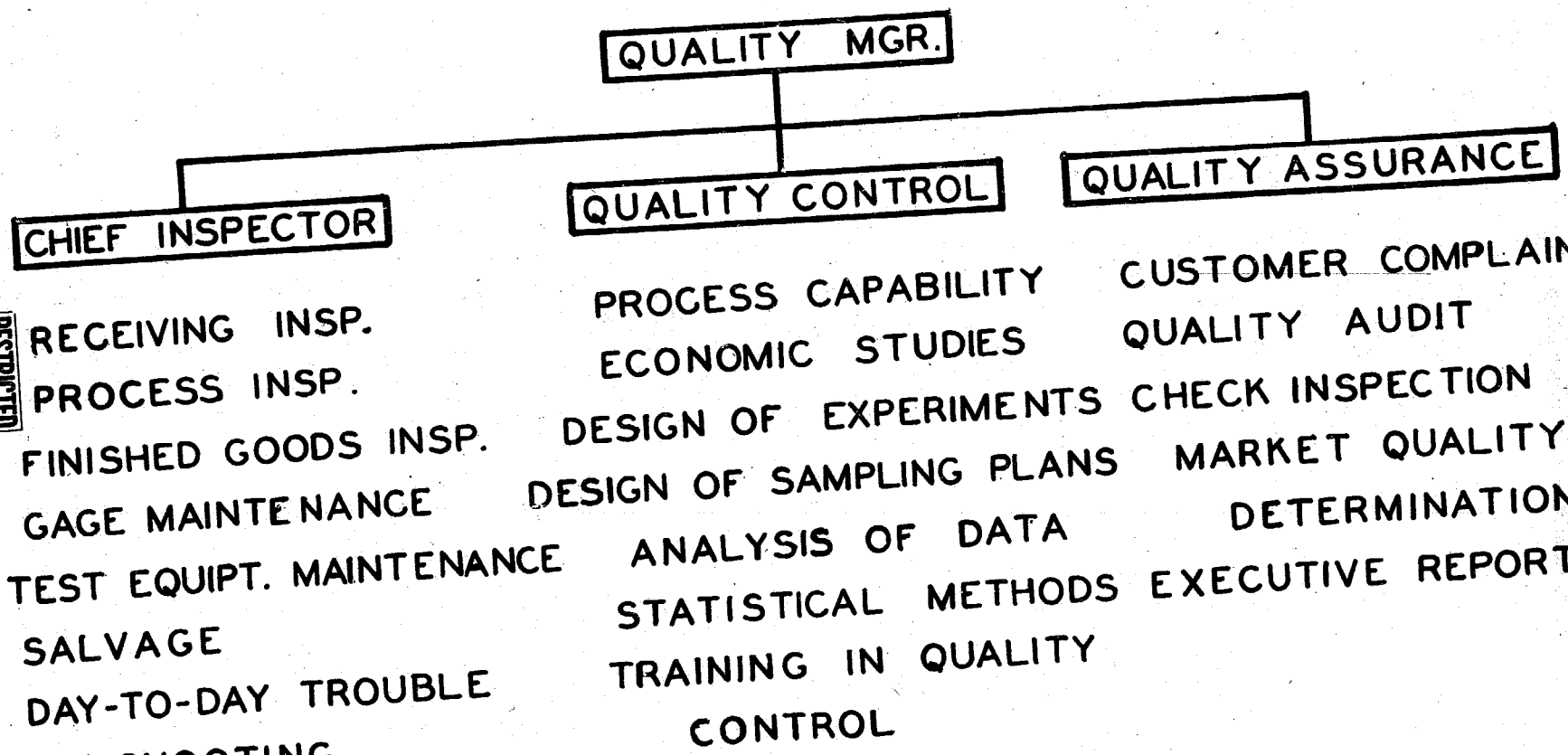
Q — ARE YOU ABLE TO CONTROL THE QUALITY OF THE WORK ANY BETTER ?

Q — IS IT EASIER OR HARDER TO GET ALONG WITH THE INSPECTORS / OPERATORS



INSP. GET ALONG WITH OP. ~~IIII~~ I
OPER. GET ALONG WITH INSP. ~~IIII~~ ~~IIII~~ III

CHART 14. TYPICAL ORGANIZATION OF QUALITY FUNCTION.



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