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DESIGN FOR INTERCHANGEABILITY

29 January 1951

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COLONEL CAVE: Gentlemen, if the production effort could be likened to a play, then certainly the designer is the one who always sets the stage and determines what props are going to be used and his influence upon the whole operation may very well determine its success or failure.

The General Electric Company is now, of course, in the aircraft gas turbine business to a very great extent, and recently it shifted its Mr. A. V. Feigenbaum from Director of Training of Manufacturing Personnel over to Assistant to the Manager of the Aircraft Gas Turbine Division, which, I know, has some very real problems. Mr. Feigenbaum is with us this morning to talk about "Design for Interchangeability." I take a great deal of pleasure in presenting him to you. Mr. Feigenbaum.

MR. FEIGENBAUM: Thank you Colonel Cave, and I would like to express my own appreciation for being present this morning, particularly to speak on the subject of "Design for Interchangeability."

If any single word could be said to keynote modern American production technique, interchangeability--of parts, of products, of methods--would certainly be that word. And because the concept of interchangeability has assumed so major a position in industrial thinking since Eli Whitney first gave it reality generations ago, it has come to have a variety of dimensions and of definitions.

In talking of design for interchangeability, we have, for example, referred to the subject of so manufacturing products that they or their component parts are capable of easy physical replacement in the field. Or, by interchangeability, we have brought up the entire field of so establishing channels of distribution that these replacements are geographically available on short notice as required. And, again, through the concept of interchangeability, we have made reference to the production engineering procedures for designing a product which (1) fully satisfies its purchaser performance-wise, (2) may be produced with the most economical and most flexible use of such scarce resources as materials, manpower, and machines, (3) can be manufactured with a minimum of internal factory rejections and a minimum of hand fitting and bending of parts, and (4) is subject to a minimum of field complaints.

It is to this production engineering dimension of interchangeability that we shall, with your permission, confine our formal remarks this morning.

Specific attention to production engineering design for interchangeability is no mere industrial luxury or whim. It is, in fact, based upon a solid foundation of manufacturing experience, showing the need for such attention, and showing the highly unsatisfactory results when such attention is not given.

For example, every factory has a product the quality standards of which have been continually troublesome to maintain. The quality problems resulting from manufacture of this product are often never solved because, in terms of the factory, "It would be too expensive to do so."

Similarly universal is the conflict between shopmen and design engineers on those parts tolerances which the shopmen insist are far narrower than the use of the part requires. On these parts, engineers may privately admit that "We call for plus or minus 0.002 inch only because it increases the likelihood of our getting plus or minus 0.005 inch."

When a situation of this sort exists it invariably results in a lack of respect for tolerances established on drawings and on specification sheets. It is also accompanied by excessive expense in securing and using manufacturing facilities of unnecessarily high precision. Unnecessarily great production rigidity conflicts with the flexibility objective which we have already accepted.

Again, there is the perennial case of the engineer who has carefully designed his product, rigorously tested two or three toolmakers' models which perform satisfactorily, then complained bitterly about the "factory's incompetence" when large percentages of the product fail to perform or assemble properly when produced in mass quantities. Yet this poor performance may have been inevitable, owing to overly great tolerance build-ups or to a statistically unsound pilot-run testing program.

There may be in the factory no organized means for pumping back to the design engineer information from the plant laboratory or from general national sources about new materials or processes. Mechanical inspection or electrical testing groups may be forced to wait for information on what they should inspect or test until production has actively started and many defective units have been scrapped. Parts tolerances may be selected with no knowledge of or reference to the accuracies that may be actually held on the plant's machine tools and processing facilities.

Sales efforts in product planning and merchandising may work in directions opposed to the design actually being developed. Desirable cost standards for parts inspection sampling and bogeys for manufacturing losses may be established only after the design has been in active production for a considerable length of time.

Data on field tests and performance of units in the customers' plants may not be effectively reported by the field organization for use by the engineer in the design of products similar to the one under development. Guarantees may be established, based upon the performance of a few specially made models rather than upon a sufficient quantity of actual production units. Company efforts toward standardization and product simplification may be thwarted by the fact that the new design calls for many new and not required special parts. Manufacturing employees may be considerably handicapped by the nonexistence of adequate quality specifications.

These problems are too often faced and solved long after the product design has been frozen and a considerable investment has been made in inventory and in processing equipment. The latitude of decisions affecting process improvements or inspection schedules after the actual design has been completed is obviously much more limited than it is during the development stage of the product.

That problems of this sort should be faced, solved, and eliminated has, of course, always been recognized as a "good idea" industrially. But machinery is required to translate such good ideas into reality. We have such machinery in formally recognized programs of production engineering--which we have termed "design for interchangeability."

This design for interchangeability may perhaps be most clearly visualized against the backdrop of product quality broadly conceived, as a major portion of this activity--a very important portion--involves, (1) developing realistic quality standards and specifications for the product in such forms as bills of materials, subcontractor specifications, and vendor information; and, (2) laying the groundwork for practical, guaranteed maintenance of these quality standards when quantity production actually begins--in such forms as inspection standards and proper selection and analysis of tools and gauges.

Historically, design for interchangeability activity is nothing new to industry and has been carried on in varying degrees of informality for many years. More and more, however, recent years have seen the formalization of such programs to gain the fullest value from their benefits for factories, such as:

1. Improvement of product quality.
2. Improvement of product design.
3. Better utilization of materials and manpower by the building in of greater flexibility in the utilization of these resources.
4. Elimination of production bottlenecks which reduce the cause of design problems.
5. Improvement of processing methods.

The term sometimes used in industry to describe this activity is "New-Design Control" and it may be defined as follows:

"New-design control involves the establishment and specification of the desirable cost--quality and performance--quality standards for the product, including the elimination or location of possible sources of manufacturing troubles before the start of formal production."

This tool is a planned method for balancing the quality costs of a new product design with the service that the new product must render if it is fully to satisfy the customer. New-design-control procedures aim to minimize these costs and to maximize customer satisfaction.

New-design-control activity, performance-wise, includes all the quality-centered efforts on a new product while its marketable characteristics are being decided; while it is being designed, sold to the customer, planned for manufacture, initially costed; and while its quality standards are being specified and inspection and test routines are being established to maintain these standards. In the case of quantity production, new-design-control activities end when pilot runs have given proof of satisfactory production performance so that the product may be released officially from the manufacturing floor. With job-shop production, the routine ends as work is being started on the manufacture of component parts.

Application of this tool may perhaps be best approached by describing its relation to the over-all cycle for developing a new product. Ten typical key points in this cycle are:

1. A new design is contemplated.
2. Technical and marketing analyses are made of the design.
3. General specifications are written. They may be in the form of:

   a. Sales propositions in the case of job-lot production.
   b. Rough functional specifications for products that will be manufactured in mass quantity.
4. Preliminary design is made.
5. An extensive program of testing the characteristics of this is carried out.
6. Intermediate design is made, including production drawings.
7. Tests are made on this intermediate design.
8. Final design is completed along with final specifications, standards, guarantees, and production drawings. Life and performance tests are culminated before the completion and release of this final design; approvals for manufacture of production tools and facilities are given in parallel with final design completion.

Some steps of this sequence are quite general for both job-lot and high-quantity production; a few steps apply chiefly to units produced in mass quantities.

The fundamental elements of new-design-control routines mesh into this sequence. These elements are roughly four in number:

1. Establishment of the quality standards for the product. This involves analyses which culminate in specifications which incorporate performance requirements and the cost-quality balance for the article.

2. Design of a product which meets these standards. This activity involves the preparation of production drawings and of manufacturing and inspection specifications. It also may include field tests and performance studies of handmade samples.

3. Planning to assure maintenance of the required quality during manufacture of the product. This involves the planning of inspection, the development of close liaison between manufacturing and engineering, the securing of manufacturing facilities adequate to assure the proper quality of the new product.

4. Preproduction final evaluation of the new product and its manufacturing facilities; formal release for active production.

This involves, as we suggested earlier, pilot runs, field tests, customer studies, and so forth.

Let us illustrate the operation of a program of this sort by reference to an actual, quite simple product. In facing the problem of designing a new electromechanical switch for interchangeability and high quality, an eastern factory followed these four steps quite closely:

1. Establishing the quality standards.--The first step in establishing the quality standards for the new switch was a product evaluation. Existing switches were compared in regard to their mechanical and electrical characteristics, accessibility for repair, ease of inspection, and servicing. Mechanical and electrical-life tests were run on several samples of each switch type used in the study, and careful analysis of other characteristics was made. The result of that study was factual data on mechanical and electrical life and a tabulation of other desirable features for the quality required in the new switch.

   The wide background of experience available in the plant from previous new-design-control activities was a second source of quality standards. This know-how in the minds of the design

engineers draws them away from designs that might later be subject to trouble. It correspondingly draws them toward new standards of quality derived from knowledge gained from past mistakes and troubles or gained from specialized experience in the application of other switch designs. A similar type of experience was available in the form of various standards, such as NEMA (National Electrical Manufacturers Association) Underwriters, AIEE (American Institute of Electrical Engineers), and others. These standards contain many requirements set down as the result of experience in obtaining high-quality component parts such as inclosures and contacts which are major components for a switch of this sort. They are generally expressed in the form of data such as temperature rises, ratings, or test requirements, and other major characteristics of importance to the customer.

A third source of quality standards was new developments in materials, process, and understanding of the theory of electromechanical switch operation. These developments pointed the way to new quality standards. Many quality improvements incorporated in the new switch were made possible because of these new developments.

The accumulation of these quality standards resulted in the writing of functional specifications for the new product. These specifications outlined the performance standards required and fed into the second major phase of the new design sequence--completing the design.

2. Completing the new design.--The specifications that were thus written served as the bench mark for actual production drawings and samples of the new switch. The design engineers looked to these specifications for the required mechanical and electrical life, the standards to be followed, demands for corrosion protection, types of inclosures required for special conditions, voltage ranges, and other special requirements.

While actual design of the new product proceeded, consultants and experts from the engineering group of the plant and from its laboratory were frequently called upon for advice in the selection and use of materials and processes. Working through the purchasing agent of the plant, the design engineers and planning people cooperated with outside vendors to determine the highest quality parts available at acceptable cost, since even at this stage of the game this plant recognized that its emphasis upon incoming material control depended upon close liaison with its vendors.

3. Evaluating the new design.--After preliminary production, drawings were prepared and handmade samples of the new switch were manufactured. These samples were critically analyzed and tested. The test program amounted in effect to an audit of the new design by qualified people. The original functional specifications were used as the criterion of performance.

The evaluation carried on during this test program consisted of three phases. The first was analysis of over-all switch performance, having to do with such functional features as arc interruption, temperature rise, pickup voltage, and noise level. The second phase was materials examination by experts to evaluate whether or not proper use was made of material in the new design. The third phase involved mechanical and load-life tests on samples containing an ample number of switches. The objective here was to determine the life that could be expected from the new device. The three phases of this test program culminated in a report which was critically analyzed by the Product Engineering and Quality Control organization of the plant.

The results of these tests were incorporated into final production drawings. When actual production tools and facilities were available, a pilot run of production units was manufactured and a critical evaluation again made of switch performance. Any quality problems showing up in this pilot run were immediately analyzed, and the required corrections were made in the design of the new switch.

4. Groundwork for maintaining quality during actual manufacture.--One of the most useful means of assuring the maintenance of quality during manufacture was the completion of a program of tolerance analysis of all major mechanical parts and assemblies. This analysis was made an integral part of the production drawing structure, so that it could not be by-passed, and later be the cause of trouble, either on the manufacturing floor or in terms of failure of interchangeability in the field.

The tolerance analysis program was also applied to many factors affecting operation of the device, such as the effect of coil turns and resistance on pickup voltage. The performance of the device throughout the possible mechanical variations of its components was thus established.

Early in the development of the new device, close liaison and a clear channel of communications were established among the design engineers, the planning people, inspectors, testers, and other concerned parties. As a result, the manufacturing and inspection organization understood why certain parts types were

required and why it was necessary to set up to provide the required quality for these parts. On the other hand, Engineering was informed about potential manufacturing difficulties in producing certain parts, about economies that could be effected by certain design changes, about flexibilities and specifications that would make the manufacturing program a much easier and much more effective sequence.

To assist the manufacturing people, specifications were established by Engineering to cover many often-overlooked shop details, such as screw-tightening torques--how tight should a screw be--screw and lock-washer hardness, and hardness of the contact tips.

As part of the pilot-run procedure, samples of parts from the new production tools were carefully inspected for variations in their quality characteristics. Statistical analyses were made as required.

The plant summarized the benefits it received from this four-pronged comprehensive new-design-control program on its new electromechanical switch: "As a result of this work, we know that the new line of devices is technically the best on the market--technically a line that will most fully meet our customer requirements. We have, along with the basic design work, established many of the controls and data necessary to guarantee the maintenance of this high level of quality as production proceeds.'

Examples such as the foregoing will naturally vary in detail from plant to plant and from company to company, depending upon such factors as products, personalities, and plant quality histories. Yet, if discussions in the current industrial management literature are any criterion, we can rather confidently suggest that the basic problems faced by production engineering design programs are quire common from factory to factory.

Perhaps key among trends in these problems are two:

First, there has been a great increase in the precision demanded of products by their customers in the last decade. The relay that was acceptable in 1940 must perform with much greater accuracy today if it is to serve certain portions of the modern market. The machined part that was once checked with a pocket scale must now be measured with a pair of micrometers or even an air gauge. Material specifications have become more rigid. Tooling has become a more critical factor. "Intangibles" such as dust in the air and humidity have become both extremely tangible quality problems and the objective of elaborate safeguards. Many methods for producing and measuring quality no longer meet present standards.

Second, there has been increasingly widespread decentralization of individual responsibilities in the modern industrial plant for preproduction product performance. Specialization to an ever greater extent, plant expansion, employee turnover have all contributed to this trend.

Failure to achieve interchangeability of parts when production begins on a new article may be due to unsatisfactory specifications written by the design engineer, to faulty interpretation of specifications by the purchasing agents, to inadequate testing standards established by laboratory technicians, or to unsuitable processing equipment installed by methods engineering.

Modern programs of what we have termed here "new-design-control" attack these two trends directly, and may, in fact, be most clearly identified in this fashion:

First, by the use in their programs of a number of techniques, both new and old, for dealing with, measuring, and thinking about, the increased emphasis by customers for precision in products. Among these methods are tool and die control, industrial statistics, modern gauging practice, pilot plants, operation, and tolerance analysis.

Second, by their use of up-to-date administrative procedures for coordinating the often uncoordinated approaches to design for interchangeability into an over-all new-design-control program for the factory, the plant, the company, as the case may be. The value of such an over-all, coordinated plan in place of sprawling, disjointed activities is well known in factory administration.

It may be of some interest if we review briefly and generally some of the highlights of these two aspects of modern production design for interchangeability.

First, **Coordination,**--Basic responsibility for this coordination rests, of course, on plant top management. In factories which are too large for this responsibility personally to be exercised by top management, a very small staff group--or functional group depending on the organization--reporting directly to top management, is delegated to carry on the required coordination. Titles of this staff group may have almost as many variations as there are plants, ranging from production or quality engineer to product service manager.

For the new-design-control activity of a plant to be fully effective, a definite routine must be established and maintained for it. This routine is usually developed by the staff group in cooperation with the concerned functional groups such as engineering, planning, and inspection.

Before this routine can be initiated, a basic decision must be made as to the classifications of new products which will be subject to the new-design-control routine. Many plants include all their new products in such routines; others include only those products which are sufficiently costly commercial-wise or which are produced in sufficiently large quantities.

This decision is made--at least in terms of commercial practices--according to the economic circumstances in each individual shop, based upon answers to such questions as, Can we afford not to have a new-design-control routine for this product? and How extensive a testing program can we afford in the new-design-control routine for this article?

In the special case of those products upon which safety of humans and property is dependent, a complete new-design-control program may be required for all products, apart from direct economic considerations.

Once these classifications have been established, each new product that is subject to the new-design-control routine should then be geared directly into the steps of the routine in an automatic sequence.

Design engineering is the key functional group in new-design-control activities. As "quality planning," the activity is an important complement to the design engineer's main responsibility of developing the most useful and ingenious product possible.

Also important in new-design-control are other members of the factory technical groups, such as laboratory engineers, planning and methods people, and inspection and test personnel. Manufacturing supervision, production-control, marketing, and other groups act chiefly in a consultative capacity.

Committee-type organization, in those plants where the committee-type organization is effectively operating on a working basis, is particularly useful in new-design-control. Much valuable information is available in the engineering, manufacturing, inspection, and sales groups in a plant as a result of accumulated past product experience. Since the committee will be made up of representatives of these various groups, it can use past experience to the benefit of the new product design.

Second, Technical Methods.--A second area in which modern production engineering design for interchangeability may be discussed is technical methods. Numerous technical methods are used in new-design-control activities of the sort described above. These methods range from industrial statistics and product testing to the use of inspection reports and the results of process operational accuracy studies. Some of the more important methods are summarized below. Perhaps with your permission we can highlight a few briefly to illustrate the range covered by them:

1. Product Planning.--The new-design control portion of these activities is carried on from the standpoint of establishing the most economic quality standards for incorporation in a product which will sell well on the market and will satisfy the customer.

2. Statistical Analysis of New Designs.--Frequency distributions and "special methods" are especially useful in answering such questions as, Have enough test runs been made? Is the variation to be expected from this product too great for manufacturing purposes? What performance can we guarantee for this product?

3. Process Operational Accuracy Studies.--These are another very useful and relatively new technique. Records of the accuracies that can be maintained with the factory manufacturing facilities are of great value in decisions as to the type of product design and parts tolerances to be established.

4. Specifications.--Written specifications are essential means of communication in modern factories. Manufacturing, testing, and inspection quality specifications may incorporate in writing the characteristics to be inspected, the quality required of these characteristics, the amount of inspection to be applied to determine conformance to the specifications, and the type of inspection guides that are useful (charts and photographs). The entire administrative quality-control program for the new product is included in some forms of these specifications. The control charts to be used, the quality-control meetings that may be required, and the sampling tables that will be employed may be described. These with drawings will be the basic core of representing the new product, its tolerances and dimensions, materials, and guarantees.

5. Planned Inspection.--This is another very useful method in this regard. It is vitally important during new-design control to select quality characteristics to be inspected, the gauges to be used, and the physical location of inspection stations so that suitable guide cards can be prepared for the use and training of the inspection force.

6. Planned Packaging and Shipping.--This is the last method, and I will suggest it just as briefly as I can to illustrate the range in these techniques. The choice of the proper container and the proper shipping routine is important for the receipt by the customer of a satisfactory product with a minimum of shifts in adjustment, scratches in finishes, or other quality defects. It is entirely possible that a great deal of the quality emphasis in the factory can be very largely negated by inadequate attention to the proper shipment of the product while in transit.

In broad perspective, therefore, the modern factory cannot take for granted--no matter how many or how talented its individual specialists--that it will automatically achieve interchangeable high-quality manufacture which takes advantage of the most up-to-date production engineering

techniques or new materials. To achieve this objective, it must specifically organize for this purpose a production engineering program which, first, coordinates the several individual internal plant efforts which point toward interchangeable manufacture and, second, utilizes the most up-to-date technical methods for facing and solving the problems generated by the increasing emphasis upon precision in product manufacture.

Such a program, which we have here termed "New-Design Control," points toward design of development of a product which (1) fully satisfies its customer performance-wise, (2) may be produced with the most economical use of scarce resources, such as manpower, machines, and materials, (3) can be manufactured with a minimum of internal factory rejections and a minimum of hand fitting and bending of parts, and (4) is subject to a minimum of field complaints.

A formal production engineering program of design for interchangeable manufacture is thus a major preliminary tool in progressive industry's kit bag for producing products into which quality and interchangeability is built and maintained at the most economical costs which yield full customer satisfaction.

Thank you, gentlemen.

QUESTION: In your discussions before coming up with this design for final production there will be times when you have fights that go on between maybe the Engineering Design people and the Production people. Do you have some policy board which settles these differences of opinion?

MR. FEIGENBAUM: We like to think that the truth comes out in discussion. I think that quite seriously it does in many instances. But in those cases where there has to be an upper echelon there are two instances that have to be cited: First, assisting in such resolution is a major function of this staff group I talked about coordination-wise; second, if we can't work it out in that fashion, top management has to make the decision, and on occasion does.

QUESTION: In the fight that goes on between the design people for close tolerances and your production people for keeping them down where they can get volume and all the other things they are looking for, do you find the design people are right and that the production people can do better than they think they can?

MR. FEIGENBAUM: Yes, there are times when we find that to be true. On the other hand, there are times when the manufacturing people are right. I have seen cases on both ends of the scale. There is one part I think about which "fits the air" on which a specification of plus or minus .003 inch was required. The shop challenged this requirement and, upon tracing it down, found that the drawing for that particular part was

taken from the files where it had been used for an earlier device and was not looked at in terms of the device with which it was to be currently applied. So we were able to put a fractional dimension on that particular part and thereby saved time and labor.

On the other hand, there have been many instances where the natural tendency of our manufacturing people toward the most flexible manufacturing tolerances has made it necessary for some of these resolutions by management to take place to indicate that "We must do it this way." I will say this, however, that in these businesses, in our industry, as I know them, where the tradition has been for a new product to be largely an engineering development and where the manufacturing organization gradually was built out from the engineering development rather than vice versa, there is not too much of a question in that respect. The manufacturing people recognize quite well that these close tolerances are required and there is not the conflict that tends to be in an organization which began largely as a manufacturing organization upon which engineering activity was superimposed. So I think the history of the particular organization is a big factor as to whether or not the problem you cite is a serious one. I think some of our businesses, particularly the newer ones since they started as engineering organizations, have been fortunate as some of that problem has been minimized.

QUESTION: I must have missed it, but it seems to me that somewhere in the liaison there is some lack of coordination of the maintenance problem of this end product. Who has that little headache?

MR. FEIGENBAUM: Well, that little headache, as you put it--and I think you put it quite well--is the basic responsibility of the production engineer in line with some of these other activities that are indicated. I had confined my remarks this morning only within the shop phase of the activity and so didn't devote my attention to the extremely important maintenance problem. Certainly it is essential to production which we are getting for defense operations, where such a characteristic is a major consideration, and that is taken very strict account of before actual release for production is given--again by the production engineer in the industry to which I refer.

QUESTION: This question is inspired by a rather selfish motive since I am in the process of preparing a paper on the Federal cataloging program. I wonder if you would comment on how the completion of a comprehensive Federal cataloging system would affect your production and your production planning?

MR. FEIGENBAUM: Well, I think I can only say quite generally that there would be many salutary effects of such a catalog in many ways.

QUESTION: To what extent does international standardization enter into the design of parts and equipment in the General Electric process? We are faced with the constant problem now, especially in the North Atlantic Treaty, of standardizing Canadian and British equipment. Do you take that into consideration in your design?

MR. FEIGENBAUM: Yes, and that again varies from product to product. There are certain products which we have only on the internal market, commercial products, for example, where that consideration is not cared too much for, but certainly in products such as our engines, and many of our other activities, which are sold quite generally to our international companies as well as to our internal channels, we take that into account and must take it into account when we are examining our standards for design interchangeability. I don't think we are at all unique in that. I think that is quite general throughout the industry.

QUESTION: Do you have a research and development organization as such or is your research separated maybe in an ivory tower? I presume that your development part is done by your Design Engineering Group. If the research is separated, then how does it flow through the channels to where it ends up as a specification?

MR. FEIGENBAUM: I can perhaps cite a specific reference in some of our defense production. Our organization there is in terms of a Research Group and a so-called Project Engineering Group. The responsibility of the Research Group is to iron out, insofar as it knows how, the basic technology of the design, at which time the data are given to the Project Engineering Group which has the specific responsibility of utilizing this technology and bringing it into the development stage.

QUESTION: Does the idea flow from the Research Group to the Technology Group, or vice versa, or both ways?

MR. FEIGENBAUM: I think it flows both ways, but if we were, for example, confronted with a new development in a certain area, we would first put that problem to our research people, in terms of ironing out many of the problems. It is, of course, a coordinated effort in the sense that the Project Engineering Group will ask many pertinent questions in terms of basic technology relative to what questions they feel need to be answered before they are ready to get started on production design. In terms of our particular organization, we operate through several layers of laboratories. We have one large Central Research Laboratory which is concerned with general problems, not only in terms of specific projects, but in terms of quite general operations, and we have approximately five research layers. Coming down to one specific business, such as jet engines, to which I have just referred, the Research Group in the individual business may call upon any one of those other four layers of laboratories for assistance in its research work. Again, it tends to be a

coordinated effort at the research level as well as in the coordination between the Project Group and the Research Group at any one of the levels.

QUESTION: If I may carry that a little further, we have the Research and we have the Project, where does the design engineer come in? In other words, the man who designs this for the greatest ease of interchangeability.

MR. FEIGENBAUM: The design engineer is a member of the Project Engineering Group and in a product which has many components, the over-all designing engineer for the product will in all likelihood be the Project Engineer. He will be supported by a variety of individual designing engineers, one of whom may be concerned with, or several of whom may actually be concerned with, the design of a pump; several others with the design of a motor wheel, and so forth, each of them doing a portion of the design for the over-all program.

That basic design work or fundamental design work is being done by the Project Group and, after a while, at least in theory, it turns its design--after it has been in production satisfactorily--over to another link in this chain which we have called Production Engineering. Some of the activities involve shop engineering, which is more a maintenance problem, technical-wise, while the product is in actual production. So in a certain sense there are three engineering levels--the basic research while the product is still a "twinkle in someone's eye"; the project engineering for design; amd the shop engineering when actual production is under way and when design engineering is no longer emphasized, although even at the shop-engineering level it is only in theory that the design engineer is entirely out of the picture, since in directing the fast-moving activity within the plant there may be changes of design required by the Project Engineering Group.

QUESTION: I know that GE supplies many items in limited production. Could you tell us to what volume you would go before you would engineer for interchangeability?

MR. FEIGENBAUM: Many of the characteristics of the program that we have discussed this morning may be built into both a job lot as well as a high-quantity production system, the philosophy being the same although the techniques for each production type may be quite different. The pilot run--just to use that as an example of the difference in the two techniques--when we are building a single motor generator set which we will never see again, is obviously not feasible, so what is done there in terms of evaluation is, wherever possible, to have a very careful analysis of field results of motor generator sets that have been built over the last 25 or 30 years which have some degrees of similarity. In addition to this, field tests may be conducted at customers' plants of similar products. In other phases of the program the same basic sequence

obtains, that is, we still need to establish standards; we still need to maintain quality during production. But the emphasis on our job lot is more upon the standard-setting end of the process than it is on the product itself.

One other way of looking at it is this, that insofar as our Production engineering emphasis for maintaining quality relates to mass production, the emphasis is upon drawing number since the drawing number of parts going through the plant is the same, whereas the emphasis by job lot design is on the process, since we never have a job shop so widely diversified that we won't have common processes.

One further example in point: We may build a motor generator which may be almost as large as a portion of this room or a motor generator set as small as the width between my hands (indicating), but we still must use coils and rotors, and so forth, and our attention there would be on common control of the coil process.

QUESTION: I would assume that the availability of special sizes and shapes of material would have considerable influence upon design and production. Who is your go-between in General Electric and your suppliers for specialized shapes and sizes of raw material?

MR. FEIGENBAUM: Well, liaison there is in terms of the Purchasing Group which has the basic responsibility for procurement. In terms of the technical specifications end of that, it usually comes down to a team with our purchasing man as the coordinator and the liaison man, and the design or production engineer, as the case may be, who goes out to the vendor's operation. Considerable effort is made at all times not only within each product business but also with the company as an organization to keep special sizes to a minimum, and that is done at company level by a purchasing coordinating group.

QUESTION: I imagine that you put your men that are going to be in the Project Section for a considerable time in ths shops before they get to the Project Section so they will know the shop man's problems. I just wanted to confirm that, and also ask if you put your R and D men in your shops and Project Sections before going to Research and Development?

MR. FEIGENBAUM: We certainly would like to do that and it is our very definite hope that we can. By and large we are able to do so, through programs whereby most of the engineers who come into our company are not directly placed in the Project Engineering Group. They go rather through an indoctrination period of a year and a half or two years, varying with the circumstances, where they are actually employed on the shop floor doing a testing job, a manufacturing job, and others. Further than that, particularly for our project men, as you suggest, we very strongly like them to pass through production or shop engineering for a

so they understand shop problems rather than merely having the theoretical approach to designing something, say, this big (indicating) which can most desirably be this big(indicating).

The problem we run into periodically, in common with others, is that in periods of great expansion when we are called upon for a considerable expansion in manpower, we may have to cut down in some instances on the amount of time which those individuals have. Fortunately, however, because we do have a relatively large force of these individuals who have been in training for a considerable length of time, the basic people of our Project Group are individuals who have had that training.

Now in terms of research and development, we have not done so much of that as we would like to do--for the reason that the research man has generally balked historically at that kind of thing. He has felt his own objectives could best be served by emphasis in terms of a sound theoretical basis and a sound theoretical background, but it is becoming more and more recognized that such practical shop background is desirable, even for him. For example, we have had in our company for some 15 years a creative engineering program which is not only a matter of training men in theoretical operations, but it also takes these very theoreticians and tries to inculcate the inventive approach. Our experience, which is now being found after 15 years of the experiment, illustrates that in development such practical training represents a very healthful program.

QUESTION: Do you consider simplification to be an aspect of design for interchangeability?

MR. FEIGENBAUM: Yes, I do, sir, and a very important one.

QUESTION: We are going to be in an age of critical materials probably for some time. How can the designer be sure when a certain type of material is out for the purpose that he is interested in that he gets the next best or even something that is probably in advance a little bit of what has been specified?

MR. FEIGENBAUM: That is a very important and a very difficult problem, so for that purpose in our industry many of our laboratory engineers or laboratory technicians have the specific problem of specializing in certain areas. As an example, in the field of beryllium copper, where diaphragms are very critical matter, each plant may have an individual of individuals whose responsibility is not design but responsibility of keeping abreast of the particular materials development in beryllium and other copper alloys. The design engineer must also call upon the purchasing man to do some crystal gazing in terms of availability of many kinds of material over the expected life of the new design, and in addition call upon both the laboratory technician in terms of kinds of new materials and even better materials.

That is--again--a problem of the over-all coordination of design for interchangeability and an extremely important portion of it. For instance, as Dr. Juran was pointing out in our talk just before the meeting, it is of vital importance in this day and age that particularly high quality manufacturers, who have built into their specifications high quality requirements, keep abreast of all the new developments in materials as substitutes to those materials of high quality which are now and are going to be in short supply.

One further aspect of that--and it is a responsibility that we, at least, like to think our Design Engineering has with all of us--is that every effort is made to utilize in designs some of these materials which will be in larger supply, and which perform with equal satisfaction or greater satisfaction, than material which will be in short supply for a considerable length of time.

COLONEL DIEHL: Mr. Feigenbaum, on behalf of the students and the faculty, I thank you for a most comprehensive and informative lecture.

(19 Mar 1950--350)S.