THE FUNDAMENTALS OF MASS PRODUCTION

7 March 1950

CONTENTS

Page

INTRODUCTION--Lieutenant Colonel F. A. Henry, USAF, Member of the Faculty, ICAF..... 1

SPEAKER--Mr. Wade R. Weaver, Director of Steel Conservation and Quality Control, Republic Steel Corporation..... 1

GENERAL DISCUSSION..... 11

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COLONEL HENRY: Gentlemen, in my talk to you on Friday I explained that for the purpose of the course we are treating production engineering more as a science than as a function of an organization. I neglected to mention that in the course of our lectures and seminars on the fundamentals that lead time and producibility will be the theme throughout. It is one of the elements that we call to your attention on which final reports will be made of the four fundamentals: product engineering, production planning and control, tooling for production, and quality control and inspection.

Now while our speaker today is presently Quality Control and Conservation Director for the Republic Steel Corporation, his recent experience in production has given him a wide background of all the elements in some form which are called "use." It is a privilege to introduce to you Mr. Wade R. Weaver. Mr. Weaver.

MR. WEAVER: Colonel Henry, members of the Industrial College of the Armed Forces--staff, faculty, and student body. It is distinctly an honor to be selected to present the initial lecture of the series on the "Fundamentals of Mass Production." This series is designed to present to you certain basic fundamentals which I am sure will be both interesting and valuable. I am confident that the inclusion in your curriculum of this particular phase of study will prove most useful in rounding out your knowledge of the problems of industry which will confront you, especially in the event of industrial mobilization for war.

There still is no substitute for experience, but frequently the accumulation of knowledge by experience alone is a slow, tedious, and sometimes painful operation. The wise and astute are wont to take advantage of the experiences of others. It is therefore up to those of us who have had industrial experiences to endeavor to present to you, whose major attention has been and must continue to be focused elsewhere, as much as possible of the results of those experiences. This we shall proceed to do.

A study of the history of the events and milestones on the road to modern mass production provides as interesting reading as the most fascinating novel. The magic word was "interchangeability," and the first successful application of the art was in the year 1800 when Eli Whitney--of cotton gin fame--produced 10,000 army muskets. This was unquestionably the first "tooling-up-for-production" job. This led the way to the necessity for greater accuracy in measurements,

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and the next milestone was probably the development of gauging equipment by Carl Johansson in Sweden, Brown & Sharpe and Pratt & Whitney in this country, and others; this occurred about 1885.

About 1900 the assembly line principle was inaugurated by R. E. Olds, the father of our present Oldsmobile, and since then the technological developments have come thick and fast. The wild imaginings of a crackpot writer named Jules Verne have all become commonplace, and today the world is searching for newer and better Jules Vernes. Even the dreams of the comic strip artists are no longer revolutionary, and it is the wonders of mass production which lead to making such things accomplished facts.

An appreciation of the complexities of mass production, whether it be a normal peacetime view or a perspective based on the potentialities of our industrial enterprise in the time of war, presupposes a rather fundamental understanding of the famous four "M's"—materials, machines, men, and money. You have perhaps seen some other terminology used. You might prefer other headings. I believe it is more a matter of interpretation than anything else.

Let us look at materials for a moment. The procurement of raw materials of satisfactory quality, in suitable amount, from reliable sources, and under proper schedule is a voluminous subject in itself and is to be covered in some detail elsewhere in your curriculum.

Let us jump down to money for a moment. It is simply a medium of exchange. There are those who would have us believe that there is practically an inexhaustible supply of same to be obtained by the simple expedient of legislation. It is a vital consideration in the peacetime competitive market conditions but declines in importance in the face of a national emergency, so perhaps we should place its responsibility in the hands of the financial people.

This leaves machines and men—today we must include women—each is valueless without the other; in an industrial enterprise of any type they become inseparably dependent. Too little attention is paid too frequently to either or both. Let us not be caught in that trap. The careful, thorough study and analysis of both will spell the difference between success and failure almost regardless of the job before you. With full cognizance of the importance of raw materials it can be safely stated that the true measure of our economic potential lies in the proper utilization of these two particular factors.

You gentlemen are particularly concerned with those cooperative and collaborative phases of productive effort which constitute the efficient production team. In the abstract consideration of an industrial entity—

what makes it tick?--you are interested in these subjects not only as they may apply to specifically, or supplement, your activities in your normal line of duty, but as you may be called upon to use them, in the event of war, to promote the speedy, but smooth, conversion of industry from peacetime to wartime effort. Much of what I shall say may probably be classed as fundamental but it is well to stress the fundamentals because sound decisions can be made only on sound fundamentals.

To facilitate the study of any given industrial process, it should be broken down into logical or convenient segments. Such a breakdown may be subject to personal whim, but for your purposes the following divisions have been decided upon, and they are quite typical:

1. Production engineering.

2. Production planning and control.

3. Tooling for production.

4. Quality control and inspection.

Each of these is intimately interrelated with each of the other. Each has its own supplementing and supporting adjuncts. Each has its peculiarities and requires specialized training for study and analysis. Each of these is predicated on the most efficient combination and use of our two "M's." Whether the problem at hand is the designing and construction of an entirely new plant or department thereof, or the redesigning and revamping of an existing one, the problems involved and the procedures used will differ but little, except that in the latter case one may be restricted by geographical or physical limitations.

Production engineering may be said to include all phases of plant and equipment design and installation, assuming the design and specifications of the part or unit to be manufactured are known and are at hand. Of course, in many cases there may be only an idea--an idea yet to be proven practical. In such cases, product engineering has to not only design but manufacture a limited number of a part and then prove its feasibility in commercial production and its ultimate practicability in use. Special talents called for here may be few or many as conditions dictate, but the heavy work will lie in the various engineering fields such as mechanical, electrical, civil, sanitary, chemical, metallurgical, ceramic, and others. Proper location with respect to transportation facilities and methods of materials receiving, handling, and storage are of paramount importance.

Right here the consideration of men must start, and this brings into the picture the legal and industrial relations phases. Suitable rest rooms, cafeterias, recreational and health facilities must receive due consideration. State and Federal laws may be involved and must be

complied with; occupational health hazards may exist. The welfare, comfort, and contentedness of the production people have been too often ignored. Careful study of space required for in-process parts or materials as well as finished products is a factor often not considered until too late.

While it is sometimes unavoidable, completely designing a process geared to a specific part or unit with little or no chance of revamping should be guarded against. Machines and equipment of as broad flexibility as possible should be chosen. Production swings are much more readily and economically accomplished with the use of all-purpose, utilitarian equipment as opposed to that specifically designed to do one specific job. Proper location of the selected equipment in consideration of lightening the work load of the operators and promoting the smooth flow of materials and product is a specialty of the work simplification or methods engineer. Failure to secure his advice may prove costly. The use of modern materials handling equipment and methods will cut costs and speed up production. There have been recent rapid strides in this field and an individual experienced in these techniques may literally be worth his weight in gold.

Safety is of supreme importance; call in the safety engineer for advice; examine the "good housekeeping" facilities; a clean plant is a safer place in which to work. Do not overlook provisions for errors or mistakes that are bound to occur. There is no such thing as perfection in a process so don't plan for it; leave an occasional loophole. Some scrap, rework, or rejections must be provided for, and full facilities for their handling must be engineered into the production layout.

All this sounds quite complicated; it is. The ultimate objective of maximum production at highest yield, the highest quality economically sound, the minimum costs, the most flexible, smoothest running process and the most satisfied organization positively cannot be attained without careful consideration of all these phases. Remember it is usually fairly easy to make revisions before you start and often impossible, or at least difficult, to do so after the project has been constructed. The quality control consultant assumes an ever-increasing place in modern production engineering and this will be elaborated upon later. This entire phase is a master plan of coordinating the varied activities involved and must be accompanied by a thoughtfully worked out time schedule.

Production planning and control is the general phase where the means are provided for the actual production process. This becomes much easier of solution if proper care has been exercised in the foregoing step of production engineering.

Production planning and control must consider a suitable supply of raw materials. This is, of course, left to the Purchasing Department

personnel and they must have various fundamentals well fixed in mind. Technological assistance and advice is often required. Probably some setup for receiving inspection to qualify vendors in order, particularly if the volume is considerable and there is more than one source for an item. This procedure is becoming increasingly popular to insure adherence to contractual specifications and to insure incoming product quality levels. Most important to production, after quality is assured, is quantity--quantity when and as required by production schedules. A uniform flow of raw materials, as demanded, is absolutely essential to smooth production.

The "suitable" raw material supply having been assured, we are now ready to translate our customer's order into production language and proceed with processing. The backbone of this entire operation is a series of adequate control procedures. The number and magnitude of these would vary considerably with circumstances but the following are typical:

Order coding sees that all pertinent data appear on the production order.

Order and scheduling coordinates production capacities, timing, raw materials, and deliveries.

Production control keeps track of every order at all times, providing inventory controls and distribution of raw materials as required, rescheduling for shortages or rejections, checking production data on such items as pieces or units produced and times consumed, production rates, wage payment bases, and so forth.

Process control insures that the process as laid out is followed and that the various components are maintained at standard prescribed levels; heat treatment, electroplating, and paint mixing are typical examples.

Accounting is given the chore of maintaining the necessary records for cost control, wages, salaries, and so forth, and may obtain its own data or make use of that obtained by such branches as production control, process control, and so on. Strict accounting of material shipped is a prime function of Accounting as accountants are responsible for billing.

Shipping must handle weighing, packaging, and manifesting.

Adequate records all along the line are essential, but lacking careful study of this phase, an operation can easily bog down from its system. The famous "red tape" situation has been the subject of much discussion in certain familiar areas.

Tooling for production is usually construed as designing and providing the fittings for the actual production machines, such as tools, jigs, fixtures and dies, the materials and parts handling equipment, such as tractors, tote boxes, conveyors, and the like, together with the necessary maintenance setups to test, repair, and service these production tools and machines as well as to provide replacement for those of the expendable type. An equally important phase of tooling up is the manpower to effectively use, operate, repair, and adjust these tools and, while this phase is not overlooked, it may often be considerably slighted.

If we assume that drawings, specifications, and so on, complete with all details of the part or unit to be produced are at hand, the job of the tool engineer can frequently be simplified by the technical help available from the machine tool manufacturers, die makers, and others. A phase of considerable importance is involved in designing the fixtures and jigs and a real Rube Goldberg may prove a most valuable asset. Sometimes the most unconventional treatment may be most successful. A complete knowledge of machine, process, and tool capability is essential at this point and will be referred to later.

The movement of materials and parts may be relatively simple but can frequently be complex enough to require the services of a transportation engineer. Surely the industrial engineer and his engineering methods is a valuable adjunct. Other industrial engineering techniques are used to establish wage and incentive rates and it must be remembered that ignoring this phase has frequently built up a grand bottleneck to the operation. Wage inequities and unfair incentives are most conducive to mysterious lack of production.

New operations, new products, new standards, and so on, most frequently indicate a re-evaluation of available manpower. Careful analysis of capabilities is important, and provision for training or special attention should be provided. Particularly in circumstances of conversion might this be an important angle, and suitable forethought and planning could provide the missing factors before they actually became needed or at least before their lack caused trouble. Under wartime conditions the labor turnover is inevitably high, thus demanding careful consideration of instruction programs, safety indoctrination, and the like. The backbone of any production organization is its foremen, therefore, the leadership of this group must receive careful scrutiny.

Right about now it is pertinent that we bring in a topic of far-reaching importance. This can probably be best referred to as "lead time," and pertains to the unhappy custom of wanting, even demanding, "six carloads yesterday." This practice usually results from an inadequate understanding of the magnitude of the job at hand,

the complexity of the situation, and the absolute necessity for careful thought and planning. Prompt action can be taken, but too often at the expense of sound judgment. A full realization of the length of time required for all these interlocking phases of design, procurement, installation, training, and so on, will save many a headache later on.

It does not require very extensive searching to see many examples of "doing it the hard way" and this we should strive to avoid. Producibility should be the keynote and this means simplicity, or at least lack of complexity, smoothness, speed, accuracy, and results. Almost anything can be "manufactured," but a distinct difference is implied by the word "produced." Modern economic potential demands the maximum of production and quality and the minimum costs consistent; this can hardly be expected to obtain without suitable planning and forethought, which requires time.

Quality control and inspection is a combination of Shore Patrol, M. P., and G-2. The production must be patrolled for infractions of the rules, the population, or product, must be checked for conformity to regulations, and some fancy intelligence surveys must be continually in progress. The two terms, quality control and inspection, used to be rather synonomous and the Inspection Department was thought of as controlling the quality of the manufactured article. Modern concepts are quite different. Analysis of inspection operations by and large proves rather conclusively that they control nothing; their functions are generally confined to appraisal of quality or weeding out the defectives. The true control of quality would infer manufacturing control; production of good material only, so that a minimum of true inspection would be required, and modern trends are in exactly this direction.

During the early stages of the last war, the inspection problems appeared to be insurmountable. Unprecedented amounts of material had to be produced, in many instances by companies totally unfamiliar with the product. All this material had to be in conformance to standards hitherto believed impossible. Identical parts produced by several suppliers in various parts of the country simply had to be interchangeable at the point of assembly, or for replacement throughout the world wherever our armed forces might be. There was a definite shortage of trained inspectors and there simply was not time to train them. Out of the drawers marked "Top Secret" were drawn the elements of a new system of control, statistical quality control, and qualified individuals were put to work simplifying and coordinating numerous narrowly known techniques. Some 2,000 members of industry were trained by a special staff under the War Production Board and an entirely new concept of quality control was born.

Originally designed around inspection problems majorly, it soon became evident that the procedures used could be backed up into the production process itself and could help in making possible the production of articles to specified standards which required very little final inspection in order to maintain an assured quality level. Specific instances intimately connected with the armed services whose knotty problems were unknotted are legion. The mass production of large caliber ammunition, fuses, and so forth, the Norden bombsight, high standards of radar equipment components, evaluation of the ammunition for the Normandy invasion, and the steel cartridge case are a few of the more publicly known ventures, the solution of which was greatly aided by quality control techniques. Those intimately connected with these problems tell us that many of them could not indeed have been solved without the use of these techniques. The submarine detection devices, proximity fuses, and pin-point bombing techniques are specific examples.

This new tool is really a bag of tools; a series of related techniques which make possible the analysis of data to obtain facts as contrasted to opinions or guesswork. Various statistical techniques, as well-founded mathematically as is the mathematics behind navigation or astronomy, have been simplified so you and I can use them. Taking advantage of the variability that exists in all things, the behavior-ship of large numbers, the laws of chance and probability, data from any operation or process—and a process need not be a manufacturing or mechanical process, but may be one of nature, sports, finance, shooting dice, playing poker or bridge, and so on—can be analyzed to produce facts hitherto impossible, or at best, extremely difficult of solution, and with comparative ease and dispatch.

The modern understanding of the words "quality control" means much more than simply guarding the quality of something. It can, and does, mean controlling the quality of a manufactured article during production, but its aspects are even very much broader than is implied by this. In modern industry there is virtually no phase which cannot be attacked by one or more of the techniques in the kit bag of "quality control." Let us see how our operations, as already discussed, can be affected.

A modern Quality Control Department is an entirely separate entity, usually, although not necessarily, reporting directly to management. It sets, or helps to do so, the standards; inspection merely referees how well those standards have been met. How can it do this? Because it knows, or can and should find out, what the process or machine is capable of doing; not what some engineer would like to have the machine do, not what some tool designer thinks the tool ought to do, not what some metallurgist or industrial engineer read in a book it should do, but what it actually can do and what we can expect it to do. Quality control must have an important say in design of tools, fixtures, and

machines; also an important say in raw materials quality. In fact, its knowledge of process or machine capability plus customer or consumer reaction must be considered heavily by Product or Production Engineering right at the start. Repairs and maintenance, process adjustment, manpower training, employee relations, wage and incentive rates are much better evaluated with the assistance of study by qualified quality control people. Elimination of the condition whereby tool design and production, inspection, and sales are continually trying to outguess each other is one of the important contributions of quality control to production.

It has been a rather common practice for a great many years for Tool Design to place a tolerance of a part to be manufactured somewhat by guess. If they feel that a tolerance of five thousandths would be desirable, they know that the Inspection Department is going to cheat a little bit anyway, so they place three thousandths on the drawing. It goes in to Production. Production knows that Engineering Design didn't intend for them to hold three thousandths, so they take five; Inspection knows that Sales doesn't need five, so they take seven, and sooner or later we get into trouble with the customers, and then it starts all over again. That elimination of guesswork is a very, very important consideration. Each division becomes more familiar with the problems, limitations, and capabilities of the others and guesswork is eliminated and confidence results. In a smaller organization quality control is sometimes an adjunct to inspection, but such a setup definitely limits the scope of a valuable management tool.

The conservation of raw materials, in-process materials, and manpower is a vital necessity to economic potential. Waste, rework, scrap, lost man-hours can be top-ranking items of cost and all these are spotlighted by quality control and the causes pin-pointed by introducing factual evidence on which corrective action can be taken. Records are available proving the conservation of over 400,000 tons of steel in one year, and its subsequent profitable consumption into finished products, in one company alone. Millions of dollars worth of strategic materials actually wasted during the last war need not be so wasted in the future if we take advantage of the techniques available to us. Many modern industries have special organizations devoted to the study and control of such losses.

A properly integrated quality control program might be defined as "the company system for coordinating the quality maintenance and quality improvement efforts of the various groups of the organization so as to enable the production at the most economical levels, and under the most satisfying conditions, of products yielding full customer satisfaction." Present increasingly aggressive competitive conditions no longer tolerate a product which is only "relatively"

good nor a cost which is "pretty fair." Under potential conditions of conversion to wartime production, this would unquestionably be greatly magnified. Observe the many functions to which a properly integrated quality control department is tied: product engineering for producibility; market analysis--where, what, and how many; tool design; purchasing raw materials; and so on down the line. Almost every phase of modern production has its tie-in with the properly integrated quality control system. And of course it is an extremely valuable tool to inspection.

Inspection, properly interpreted, can cover any and all phases of the production process, from receiving materials inspection to evaluation of the final finished product as it goes to the customer. In many instances special tools are involved, such as small hand tools, gauges, and others. The modern gauging field has likewise been geared to quality control, and the gauges themselves are a far cry from the scale and micrometer of a few years ago. This frequently involves the services of a gauging expert for standardization, adjustment, checking, and servicing. Many of the modern inspection tools are electronic devices requiring specialized service attention. Progress in this field is currently extremely rapid and is outstripping trained personnel, which adds still further to the problems of training in industry. Application of quality control techniques to industrial processes requires some specialized, though not complex, training in itself. Inspection results must be properly interpreted, from customer satisfaction back to engineering and design of product in process to complete the cycle of industrial satisfaction.

Adequate inspection to maintain assurance of a specified quality level is fundamental today. Reproducibility is a must. Present-day competition demands higher quality than ever before. Technological advances are continually forcing us to narrower limits, closer tolerances, higher accuracy, and improved performance. The job of inspection has become a science--inspectors are no longer born; they are made. The old practice of transferring the machinist or crane operator, whose eyesight was failing him, to the Inspection Department, is a thing of the past. Modern trends are toward less inspection but better inspection. Even the "quality" demanded of inspection is constantly under pressure.

From beginning to end of our modern industry, be it a complicated or a simple process, the mandatory consideration of a fuller and more appreciative understanding of its complexities--what makes it tick--is required. The full realization of certain fundamental facts is a valuable asset to the individual who would undertake to cope with industry today. Essential ingredients are care, patience, study, analysis, forethought, planning, realization of time factors, and a lot of the "milk of human kindness."

Gentlemen, I thank you for your attention.

COLONEL HENRY: We are ready for questions.

QUESTION: I am a little interested in the relationship between quality control as you were explaining it this morning and the quality objective, that is, in certain items that you may be manufacturing, you could go up to a certain quality, conceivable at a certain price on the market, or you can make the decision to sell a higher-priced article and perhaps go into greater refinements in quality. How is that limited or brought about? Does quality control as exercised in the manufacturing process carry it out?

MR. WEAVER: Well, certainly the application of quality controls can help answer that question. Usually there is a market survey of some kind indicated. There is always that problem of whether to sell a little higher-quality article at a little higher price and fewer of them or to reduce the price and, at a shorter margin of profit, sell more. That is the old economic question that too often has been answered by guess or by opinion and not by fact. I believe that the most valuable part of quality control's place there is that it presents facts on which to make a decision.

QUESTION: Mr. Weaver, my question may have a little long explanation or introduction, if you don't mind, but it deals with what might appear to be a fundamental conflict in economic mobilization or especially military production for war; that is, a conflict between the philosophy of mass production and the military concept of the prerogatives of a commander. They give a commander a mission; there is no degree of success allowed in that mission. So the tendency is to give him everything he wants to accomplish it. Some commanders more or less expect that it means they have the right to demand quality, quantity, and priority--all at the same time. On the other hand, the customer doesn't seem to have much direct influence on the product which he receives. He goes down to the automobile dealer or the Five and Ten Cent Store and buys what they offer. It seems to me that in mass production, quality is a provision of quantity. Now can you offer any reconciliation or any resolution to this conflict which seems to exist between quality and production control?

MR. WEAVER: I never have felt that increased production necessarily meant a sacrifice of quality, but I know a lot of people do. They say, "We can make so many at this quality level. Now if we have to step up production, quality will suffer." I don't believe that. I don't think it should. I know it has been all too common, but I think it is our lack of understanding of what is involved there that makes the less favorable results.

Your statement that the military man apparently wants quality, quantity, priority, and everything at the same time is right. He does

and he expects he is entitled to it. At the moment nothing should be more important than that particular mission, whatever it is.

During peacetime, of course, production industry, is dependent on its customer reaction, but its representatives are somewhat inclined to try to force the issue and feel that "We will give them this; they will buy it." Well, sometimes they do and sometimes they don't. The old law of supply and demand usually governs that. In a military venture we shouldn't think of supply and demand. It is the one thing at the moment against which all our efforts should be directed—that particular mission. Industry's thinking throughout its experience of building up isn't that way, and it is a little hard for industrialists to see your perspective. I think maybe you will just have to be a little patient with them for that reason.

QUESTIONER: My contention also is that perhaps the military man should be a little less demanding. In other words, we get quantity, but we also have gotten pretty good quality from mass production—if we waited long enough.

MR. WEAVER: I think you are entitled to expect good quality and I think quality control procedures will materially aid in keeping that quality level at whatever point is desired even with increasing production. They are definitely designed to do that.

QUESTION: Mr. Weaver, within industry, methods and procedures of inspection have been pretty well accepted and established. Would you care to hazard an opinion within industry as to how this new technique of quality control has been accepted by management, engineering groups, and the production people?

MR. WEAVER: Yes. We have all levels of acceptance, from not only no interest but actual antipathy to a complete acceptance and confidence all the way up the scale. I believe there is no question that the eventual solution of the thing is going to be a much more uniform understanding between you and me—or between you and someone else; between this company and some other company; or between the customer and the vendor—of what is quality. How are we going to define quality? Who is going to say whether this material meets that standard or whether it doesn't? Up to now, the thing has been pretty much hodgepodge. You bought an automobile because it meant that particular car stood for certain things which in your opinion were the type of quality you wanted. Perhaps I didn't want that at all, or I thought I didn't. Actually what we both wanted was the same thing, but we didn't know how to evaluate the different manufacturers. The same thing is true between almost any two articles you can think of. The differences of opinion that exist between armed forces procurement and industry's production are typical examples. Too often, I think, neither knows what the other is talking about. We are now commencing to get more closely knit on this thing and

have a better understanding of what we both want. Ultimately, our wants are the same, so we must get on common ground, talk the same language, and have confidence in each other so when we approach a situation we will both know what it is. I have every confidence that this is rapidly coming about.

QUESTION: You spoke of taking the guesswork out of what could be allowed in the way of manufacturing tolerances. Could you give us a specific example of how that could be done?

MR. WEAVER: Well, the design engineer works by a surprisingly large number of old-fashioned, rule-of-thumb measurements. He takes something out of a book or he knows that 2 plus 3 and minus 2 is a pretty handy tolerance; or we made something like that once before and we had that tolerance on it; or they get a competitive article, check it, and find it works pretty well with certain tolerances, so they put something on just out of their experience with no reference to what the process that is going to manufacture that part or article actually can do.

Now there is no sense in our saying this is what we want unless we must have it. If the process that is going to produce the part in mind can easily do what we require of it, that is all right; but so often the process actually cannot do that. We have been trying for years to make a certain process do something that fundamentally it is not capable of doing; therefore, in our lack of understanding--or ignorance, if you like--we have been butting our heads against a concrete wall by trying to do something that just can't be done with the present process or machine.

Now we have ways of finding out factually what the process can do. If the part that is required must have properly functioning tolerances that cannot be met by this process, then we have to go out and design a new one. There is no use trying to make it with the present process. We know by facts today, or we can find out, just what that situation is. There is no guesswork about it. We can tell within extremely narrow limitations just what to expect. So the design engineer has a chance for his alley. He can either modify his ideas or he can say, "We must design a new process; the one we have is not adequate."

QUESTION: Can you apply that to a scientific illustration of what tolerances you do require in the finished article so that you won't ask for more than necessary even if you can get it?

MR. WEAVER: Yes, a lot of that has been done. Of course in the final analysis, it is the performance of this unit. Now what do you require by way of performance? What does it have to do? If it is a high-speed rotating part, it has to stay in service and

usually those things are determined the hard way, by finding out the practical limitations in service. But you can use these principles to determine the range within which satisfactory performance will probably lie. Again, it is the final testing of the part, either in some kind of predetermined test or in service, that counts. The automobile companies are rather famous for that. They design a new car or a new part, a new feature, or something, and they give it every conceivable kind of test, and it just stands up beautifully. Then they put a few of those cars in our hands, we, the public, and we go out and ruin them. So it is rather hard to find out just what is required of the article in the final analysis for that reason, the functional performance.

COMMENT: Mr. Weaver, please allow me to supplement that. There are cases where the functional requirements are exceedingly severe. Let us take, for example, the ball bearing. To make those balls economically, the best we can do is to make them alike, within about one-thousandth of an inch. But to have a normalized bearing, all the balls in any given bearing must be within about 25 or 50 millionths of an inch of the same size. So we make them to the thousandths and then we grade them according to size, which is a matter of selective assembly, so that we do meet a condition where a process is not good enough to meet our functional conditions. Then we must pay the price of selective assembly rather than interchangeable assembly.

QUESTION: Sir, many organizations have a comptroller. How does that tie in with this quality control, two types of control going on in the same organization?

MR. WEAVER: Well, I believe there is a very distinct difference there. The comptroller is usually interested in the financial structure of things more than he is in the actual expenditures within a department or on any article. I can't see that there should be any particular confliction of authority there, or results.

QUESTION: It seems to me that there would be two different approaches on quality control for products which are being manufactured for the open market and products which are being manufactured specifically for the armed services, particularly in wartime. When you manufacture for the open market you have the opportunity to go out and evaluate public demand and the tolerances as between price and quality that you can expect the public to manifest. But it seems to me that the armed forces would be much more definite in setting their own tolerances, so to speak, and their own performance standards when they come up with an order, and those performance standards might not necessarily conform to the general run of standards that would be satisfactory in an article which is offered to the public.

Now it would appear to me that there would be a problem there which would require quite considerable integration between the armed forces engineers, who work on their products, and the manufacturers. Is there any such organization now integrating with you on quality control in industry?

MR. WEAVER: No, I think not. That must ultimately come. A simple example, of course, of what you are thinking about is ammunition. There is not too much at stake if I buy a box of shells and go out deer hunting. If one fails to fire, I just don't get my deer--that is all. But you can't afford to have that happen very often in the Army. It is going to happen once in a while; there is nothing perfect. But the incidence must be greatly cut down, that is true. If quality control in industry does its job, it will be able to evaluate its process to know its capabilities so that in the event an armed forces requirement is given, then industry will know whether it can meet it, and, if it cannot meet the requirement, what it probably will have to do to revamp its process, its machinery, or whatever it is, in order to meet the high-quality level. That is somewhat automatically taken care of under certain conditions--particularly in material acceptance procedures--by the type of plan used for analyzing material at hand, but there must ultimately be some way for coordination of that kind to interpret those standards and apply them. That will come.

QUESTIONER: It seems to me that quality control has to work both ways because it may be that the qualities demanded by the services are excessive for what is actually needed and that industry could be of some help in establishing more liberal standards through its quality control system.

MR. WEAVER: I expect that could happen, yes. There again, if the job is done right within industry, the industrialists will be able to help interpret those things. There is going to be a better level of understanding of each other's problems and capabilities than there has been in the past.

QUESTION: Mr. Weaver, as I understand quality control, it has replaced to a large extend the in-process inspection we used to do. Now an operator of a machine, a lathe or what not, a grinder of some type, periodically takes a sample of his work and marks the in or out tolerances down, which is later checked by the statistician. Now this piece varied in some subassemblies; it goes to the larger assembly. How do you keep that operator honest? I mean, by lack of attention or by bad work, he can possibly buckle up a lot of pieces. If he notes it on his chart or in his sampling procedure, he is going to get some kick-back from the foreman. Before, the in-process inspector would catch these things as they occurred. Now you can bury them in assembly, as I see it, unless you have some form of in-process inspection along the line.

MR. WEAVER: Are you familiar with banking prodedures at all?

QUESTIONER: No.

MR. WEAVER: Did you ever hear of a bank examiner? We have a lot of records in a bank, but we have a way of checking on those records. The same is true of quality control. You can put quality control on quality control, but if the system is properly set up, this won't happen, because the control is at the point of production, right where this article is being produced, not where it is being assembled. Again, there is no such thing as perfection, and whatever care you might exercise in the production of this article or part, something can happen. So a certain amount of inspection at assembly is required, but in the properly set up system, that need be only a minimum because the control lies right at the point of producing this article, or this dimension, whatever it is.

That can range all the way from operator control. I have seen setups where the operator practically never produced a defective part as attested to by the Inspection Department and the assembling operation following, because he was provided with a means to know that he was not producing defective parts. He had long since learned by experience that if he tried to cheat, he would be caught. Human beings, for the most part, don't like to do that anyway. We take a pride in doing things well, most of us, and the man who doesn't is soon singled out and trapped. No, the thing can very definitely be set up so that cannot happen or exist for very long. The properly set up system will police that adequately.

COLONEL HENRY: I would like to speak for just a moment in this connection on the armed forces. During the war, I think we all know that we had requirements that far exceeded our needs. We also had procurement agencies--when they had Operations on their necks--willing to take anything they could get so long as it was quantity. In the Navy Bureau of Ordnance we have set up a Quality Control Division, which stands between the perfectionist's idea of design and that of getting a quick idea of procurement, and we arbitrarily make design justify the requirements on the one hand and make sure we get them on the other. That is the general trend, I think, throughout the armed forces. That will be discussed in one of the seminars later. I think it is important to this group.

QUESTION: Mr. Weaver, my question has to do with the gap between research and development and production and timing of the product. I know before the product comes out of Research sometimes it is being sold by the Director of Research. Other times he is trying to hang back. The question is: When do they stop developing and start producing? At the time of the inevitable conferences between the vice president

in charge of sales and the rest of the people, does quality control reach into those conferences or does it come into play after the decision is made to put the article on the market, or does it even reach into the Research Department?

MR. WEAVER: Yes, very definitely it reaches into Research. I believe up to now a very high percentage of the use of quality control has probably been after production starts, in some cases much too long after production starts. The relations of the full scope of the thing is still to be developed. There has been, as I said, an excess amount of concentration on inspection procedures because that was the big problem in our last war when this thing unfolded. Not enough industries have come to realize that it should be up in the top councils and should be applied before they ever start to engineer the idea that they have developed a need for something and Research has come up with what they think will fit the need. Certainly right there quality control should start, but in very few cases, by proportion, does it do so today. But it is rapidly becoming possible in those fields.

COLONEL HENRY: Gentlemen, just bear with me. When one makes the decision, it will have some influence on the problem, that is on methods in process engineering. In my section chart that I use, I lump them. They could be one and the same. My explanation is a little different from the way you use them, and I know the seminar panel member that we will have a little later will have one different from this. In order to get all sides of the question in their final papers, would you explain your differential between methods engineering and process engineering?

MR. WEAVER: I would rather feel that the process engineer was the man who designed and constructed and policed the various phases that this article follows as it goes from raw material into a semifinished and finished part.

COLONEL HENRY: Would that include selection of the machines?

MR. WEAVER: Yes, it could and in many cases does. Whereas the methods engineer would be more concerned with placing the machine this way instead of that way, in having this machine a little farther from that one to allow for a certain space consideration, or to place two machines here so that their product can discharge and go in one direction. He is more interested in simply the movement of the pieces themselves rather than controlling the level or requirement. The process engineer would be responsible for setting up the heat treatment on parts, but the methods engineer would be more interested in how do I get those parts from the preceding operation to this heat treatment and away from them, the most simple and quickest method.

COLONEL HENRY: I guess we agree. I thought from the chart we didn't. I know we are going to have disagreement from the panel.

MR. WEAVER: The things are different between one plant and another. The terminology would differ from one place to the other, the terminology and actual functions of these men would differ. They are bound to.

COLONEL HENRY: Mr. Weaver, on behalf of the Commandant and the College, I thank you for a most informative lecture.

(1 May 1950--650)S