THE PROBLEM OF PRODUCIBILITY

29 January 1953

1233

CONTENTS

	Page
INTRODUCTION--Colonel D. B. Diehl, USAF, Chief of Production Branch, ICAF	1
SPEAKER--Mr. John W. Pocock, Partner in firm of Booz, Allen and Hamilton, Management Counselors	1
GENERAL DISCUSSION	16

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1234

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COLONEL DIEHL: General Greeley, gentlemen: Yesterday Colonel Cave showed you a tommy gun. Its design called for forging and many intricate machining operations. Then Colonel Cave displayed a weapon that is actually superior in performance and reliability. It is the so-called grease gun and it looks just like it. It looks just like a gadget you could pick up in a five and ten-cent store. It was made of stampings primarily and so far as weapons are concerned, it is actually a ten-cent store item. What was accomplished in this instance was design for productivity, which is the subject to be discussed by our speaker today.

This problem exists because the research man feels that once his gadget works, anybody can produce it; but, due to our mass production techniques, it is usually necessary that a product be designed not only for its function but also to be capable of being mass produced.

Our speaker today, Mr. John W. Pocock, is actively engaged in industrial planning assignments. He is a partner in the management consultant firm of Booz, Allen, and Hamilton. This firm is devoting much of its effort to study in this field of productivity for the armed services as well as for industry. Today's appearance will mark the fifth time that Mr. Pocock has been called upon to lecture at the Industrial College. It is a pleasure, therefore, for me to welcome back to this platform and to present to you Mr. John W. Pocock.

MR. POCOCK: Thank you, Colonel Diehl. Today I wish to examine with you certain major aspects of the problem of producibility of some of our weapons and other equipments and devices having wartime use. Producibility is very simply that characteristic of a device which makes it possible to produce the device in the required quantities, in a short time cycle, and at a feasible economic cost yet with no practical impairment in the functioning of the device. To a great degree these factors must be considered in the design and production of any commercial device but the factors have sharper purpose and the penalties of noncompliance are impressively greater when we talk weapons production.

At the outset of our discussion we must realize that our producibility thinking and planning must anticipate the rigorous requirements of a full wartime program--yet we pray we shall never live to see this planning prove itself. Indeed, this very questionability of a producibility program's ever having to prove itself is one of the greatest single psychological barriers in the way of good programming. It's hard for most humans to throw themselves enthusiastically into a warm-up practice for a game which they hope will never be played.

This being the case, with the total need for good producibility engineering large and the top talent available limited, we are tempted to "take a chance" with less than the best since inadequate producibility work will probably never be found out. If we apply our outstanding talent against the task, we'll probably never get the satisfaction of the "prove-out" nor the chance to learn by seeing a practical demonstration of our errors. Furthermore, since money is needed elsewhere we can't spend much on the actual testing of critical elements of our producibility plan to avoid some "M-day" surprises.

This is quite different from the psychological environment of the production engineer of a large automobile manufacturer who throws his all into producibility work sheerly for competitive survival; who learns each year from last year's errors as demonstrated on the plant floor; and who is backed by production-wise management which has learned that early investment in producibility testing insures earlier profits at a higher level. While we may admit that this same urgency exists in the producibility of military devices (and even to a greater degree, since here we risk survival of the free world), we still have a hard time making ourselves do something about it.

You will now understand why, when I was asked to return this year and speak on the problem of producibility, I jumped at the chance. For to my mind this is one of the major problems--and a sleeper at that--that we have to deal with in our military industrial planning today.

In the course of my discussion I hope (1) to outline the present position of producibility or production engineering programs, (2) to discuss the nature of the problem itself, (3) to analyze the process of production engineering, (4) to suggest a certain pattern of organizational emphasis, and (5) to present some thoughts on pilot line and facilities policy to support production development.

The Production Development Gap.

About three years ago from this platform I was discussing weaknesses in our procurement and industrial planning. The general atmosphere at the time was one of restricted funds, cash for hardware only and much hatchet-man economy. While this situation does not exist today, signs abound that we must look harder for ways to give our Nation more real defense at a lower-dollar cost. This is the old story of providing the springboard. Against this background may I read what I said at that time.

> "Our Nation's military preparedness relies increasingly upon new technologies and the new weapons systems derived therefrom. We might give brief attention here to the way these new systems come into being. Although other terms may be used, the normal road of development moves through basic research, applied research (application of basic research to specific problems), engineering development (creation of prototype), production engineering and development,

production, and, finally, service in the field. The intelligence with which we guide our promising weapons developments through this sequence is critical in view of shrinking budgets and mounting defense needs.

"The Research and Development Board has watched over the early steps of the sequence. The Board's greatest activity has been in applied research, but has included basic research as well as spreading the other direction through engineering development and into some production development.

"The Munitions Board has centered attention on the production phase and the problems of procurement. However, service procurement agencies have to date been generous and included money in production (procurement) contracts to allow some production development work in connection with early production.

"Today the situation is changing rapidly. Budget pressures have caused both research and development and procurement agencies to trim fringe activities and concentrate funds on their major missions. Research and development people instinctively draw back from spending money beyond the prototype stage. Procurement people want to put their limited monies into product, not engineering. So as both groups retract their areas of fringe coverage, the production development problem is left uncovered.

"This production development gap is, therefore, the result of understandable pressures but is particularly unfortunate during this critical period. Our new weapons systems are becoming more complex and so the problem of reduction of complicated materiel to feasible production techniques is becoming more urgent. Furthermore, advances in manufacturing techniques in industry generally are obsoleting mass production experience gained during World War II. However, the application of these new manufacturing techniques to our new weapons can lag since peacetime production schedules do not force such application for capacity or economy reasons. Yet, if our collective national security rests upon our ability to move into mass production with the dropping of the first bomb, we had better be about this business--for it is a suicidal philosophy to assume that when we have created one successful new weapon model that we can create hundreds and thousands as well."

Only a few weeks later, the Communists crossed the Korean parallel and we had to use our springboard. In view of some of the production snarls during the ensuing two years, we can thank our stars that it wasn't a full-scale war. Yet today already there are some who are forgetting our troubles with this same producibility problem.

The Nature of the Problem

So much conflicting talk has been going the rounds during the last few years concerning this matter of the place and relative contribution of production engineering--making the design producible, if you will--to our armament program that I think first we should get back to the fundamentals of the problem. Some of my following discussion may seem at first to be academic and far removed from the everyday problems we meet in our production programs for military materiel. But I firmly believe that much of our recurring trouble in this area could be eliminated if all people involved in the formulation, administration, and execution of such programs had a clear idea of the basic concepts behind production engineering and producibility thinking.

Production engineering is generally referred to as the process by which a device is developed from the research prototype to the actual production model and which establishes the production processes to be employed. While the exact content of the province of production engineering may expand, contract, or shift emphasis according to the background and interests of the man defining the function, it is generally agreed to be the bridge between research and development activities (including basic design engineering) on one hand and manufacturing activities on the other.

Let us look first at the characteristics of the activities and the people in each of these functional areas which are to be joined through the medium of a production engineering function.

Research and development is essentially an activity of creation. Conceptually those people engaged in research and development have their thinking and programming oriented primarily toward a requirement to be met and the function of the device being developed. Their basic interest is to see that a functioning device is developed which satisfactorily meets the operating requirements placed before them. They solve this problem of function by bringing to the solution all of the scientific disciplines and engineering knowledge available.

They are primarily interested in how to make something work--not how to make it. It is highly improbable that the successful device will arise full-blown and meet all requirements of function on the first try. The achievement of the required performance is gradually approached through successive approximations and refinements. Thus there is a large indeterminate element in the scheduling of the development of a prototype. We don't know exactly when we will have an item which is "good enough," and we don't know just what "good enough" is. (And of course, we don't want to let go until we're sure we've really got it!)

This, then, is the basic atmosphere in which the research and development man works, with his primary objectives being the development

of devices which meet a functional requirement, and with his emotional rejection of all matters pertaining to program regimentation, schedule fixation, and design compromise for production considerations.

Manufacturing, on the other hand, is essentially an activity of execution. The manufacturing man is primarily interested in turning out a product--and he cares not what the product may be--at the right cost, in the right quantity, and at the right time; and, of course, the product must meet certain minimum performance specifications. He sees the device as a sequence of processes and a collection of parts to be assembled.

He may or may not have the slightest understanding of how the device he is manufacturing functions; he is not too much interested in seeing the performance of the device go much above the minimum performance standards stated as being acceptable--since this might mean that he is overmanufacturing somewhere. He sees the small radar antenna and the air bearing both as pieces of metal which must be rough cut and finished ground to the very tolerances noted in the specifications, if the part is to be accepted and the device function properly.

It is well and good that both of these functions retain and develop their individual primary orientations, if useful results are to come out of the team effort. Between these two worlds our problems are essentially those of translation. This, then, is the gap into which the production engineering function falls.

What Does Production Engineering Do?

Now let's trace the tasks which have to be handled by production engineering in bridging this gap. We should look at what I might call a "pure" example first, so that our understanding of the process is clear before we clutter up the problem with other important practical considerations.

In this "pure" state, let us consider that the research and development people have completed their creation and engineering of a functioning model and have approved it as ready to move into production. At the least, we have before us an awkward prototype device or a breadboard layout of a system. At best, we may have a very well-refined item which is surprisingly producible with little change as it stands. (The question as to which of these we get is a direct reflection of the imagination and understanding of research and development people as they consider possible production problems. And some of them do pretty well along this line.)

Our production engineer must now study this device along the following general lines.

1240

First he looks for simplicity of the mechanical or physical actions or the assembly. While pressures, leverages, strengths, electrical inputs and outputs, and so on, must be retained if the performance of the device is to hold true, he can look for simpler ways to do these jobs. He tries to combine parts, simplify linkages, accommodate existing units, and generally reduce the design complex to its least common denominator. In this he also anticipates service problems and provides access for maintenance, and so forth.

Second, he studies each part with a view to adapting it to available production processes and techniques. Will the part be die cast, coined, or machined? What direction may the design go with the next refinement of the device? Will the process selected now accommodate the probable direction of design change in the future? We want low-cost, foolproof production and use of the most flexible processing possible in line with cost and quality.

Third, he is interested in standardizing on materials--using materials which help the manufacturing process. He is constantly looking for critical materials and seeking acceptable ways for designing away from them.

And so on down the line, but out of all this analysis comes what we might call a production redesign. And in the course of arriving at this redesign, the production engineer may have changed the outward appearance of the product considerably.

As a result of this tentative redesign, we may now have parts or systems which require re-evaluation and retesting by development people to make sure that device functioning remains unimpaired. In fact if he is wise, he has consulted regularly with the original creators as he tampers with their creations. So he knows pretty well what he must expect in the way of tests.

On the other hand, he may well have certain parts and assemblies which, because of critical functional requirements, cannot be redesigned to accommodate available processes. The production engineer now must enter into process development work aimed at researching and developing the production process and equipments by which the stubborn part or component can be produced. This task of production and process development is a rapidly growing field. We will come back to it later, but may I point out here that when we are at work near the frontiers of knowledge insofar as physical design of devices is concerned--and this is the case with many military devices--we often have the problem of devices which function but for which no true production processes exist.

Once our redesigned device is tested and found to be functionally sound, and once we're pretty sure that we're on the right track with the new processes which must be developed, we get the final design down on

paper and move into the routine release of the design to manufacturing via (1) bills of material, (2) process sheets, (3) equipment and facilities requirements, (4) tool planning and designs, (5) quality control specifications, and (6) production standards, and so on.

The manufacturing program is tested by means of a pilot run, if possible, and then is turned over to the manufacturing people who continue to turn the crank (not an easy job necessarily).

Here I would like to make an important point. Too often, when people speak of production engineering they are talking only of the routine paper work I have passed over quickly as the "release of design" activities. They completely miss the point of the creative aspect of production engineering before release--the chance to take a device whose physical design is perhaps an afterthought to function and to completely recast the design so that it becomes a soundly producible item.

This Henry Ford did when he replaced the individual cylinders of his engine with the one-piece engine block--and so helped start the Model "T" on its path to glory. This a major automotive manufacturer did a year or so ago when he quite literally selected the processes which would give him the lowest production cost and then designed his new engine to these processes.

And this, not the paper work, is what engineering for producibility really is, and is what we must have more of. But it all takes money and time--and often time poses the most severe obstacle. Thus, the "pure" concept of having the research prototype turned over to the production engineer with a clean break--off point and the production engineer turning it over to manufacturing with an equally clean break just doesn't happen.

In our generation of new and improved military materiel, we are concerned with at least three things: (1) the adequate functioning of the device; (2) the lowest economic cost for procurement and operation of the device; and (3) minimizing the time of the total research, development, production engineering, and initial manufacturing cycle.

If we are to minimize the time in the research-to-manufacturing cycle, we must overlap the production engineering activities in both directions. But the question is, how far should we try to overlap?

We can, of course, at some point in the research and development process, begin to anticipate the probable production engineering problems which will be forthcoming if the research and development program continues along its then-identified track. In the same way, the manufacturing people can anticipate the probable shape of the production engineering program and begin to shift facilities, buy and move equipment, and hire and train people in accordance with that estimated program.

The more the overlap, the more we must anticipate and estimate probable results of the previous step (say research). The more anticipation and estimating there is, the more false starts or errors will be made in the following steps and the higher the total cost will be.

This risk because of increased overlap and program acceleration will vary from program to program. I am familiar with one project where it was forecast that 24 months would be cut from the total cycle under what I have called the "pure pattern," by accepting maximum overlap and therefore maximum risk. By maximum overlap I mean that production engineering would commence on each part or component developed as it was first developed, without awaiting knowledge of whether that part or component would be functionally acceptable in the completed system.

The production engineering program on this basis was estimated to cost slightly over 2 million dollars. (No tools, equipment, tests, and so on, included.) It was possible that this entire effort would be wasted if the research and development people made too many poor guesses or had bad luck. If the entire program failed, the sum of 2 million dollars was lost, as was the 24-month prize.

Since the peacetime production rate of this important weapon was estimated to cost about 800,000 dollars a month, 24 months would give us almost 20 million dollars worth of the item. Very loosely speaking, the maximum overlap asked us to risk one dollar on the chance that we might have 20 dollars extra inventory of the item available by the time it might be needed. Taken in this light, this would seem to be an investment worth investigating.

Organization of Production Engineering.

Now having set the stature of the function and with some knowledge of what's to be done, let's see how we organize production engineering. No hard-and-fast rules can be laid down as to the exact spot in the organization or the exact breakdown of the function itself. An important consideration is the type of product and the manufacturing processes which exist in the company.

With extremely simple products and processes, production engineering (and also research and development) tend to be absorbed by and integrated into the manufacturing function. As the product and production processes become more complicated, the production engineering function grows in stature and importance in the organization, and at the same time finds its center of interest shifting away from immediate manufacturing interests to more specific interests in problems unique to high production design--a new technical interest.

For example, the problem of developing a better metal canteen, let us say, cannot be considered technically requiring when compared to the

development of an electronic computer for gun laying equipment. (I hope no canteen engineers are present). It is altogether possible that the plant engineer, along with his other duties of building maintenance, equipment selection, tooling, and so forth, may be assigned a project to develop a lower-cost canteen. In this case the development function and certainly the production engineering function (since he himself knows the simple processing required) is all tied up in the manufacturing organization.

As we move into moderately complex products, we find that the research and development activities take on a technical content requiring the application of special talents which go beyond and in many cases are incompatible with manufacturing talents. At this time a separation of the research and development function probably occurs and in all likelihood takes with it the design engineering task. It is probable that the production engineering function will remain as a part of the manufacturing department.

Now with an extremely complex product requiring unusual and complex production processes, it is probable that the technical ability and special experiences necessary to the proper solution of the producibility problem require men specialized in this field. They may then be organized into an independent department. Here then is your corps of experienced production design engineers who know how to work with research and development engineers to take their prototype thinking and reduce it to efficient production design without losing functional performance. Here the seasoned experts in all of the various processing fields, each up to date on work at the frontier of processing developments and ready to intelligently apply these processes to the product at hand. Here are process development laboratories, designers of special equipment, full-scale pilot line tryouts, and sophisticated methods of cost analysis.

The important devices and equipments used by the armed services fall largely into this last category and the complexity trend is increasing. Very simply stated, our wars are getting bigger and require greater quantities of materiel. At the same time our weapons systems are becoming more complex at an exponential rate. Putting the two of these together--far greater quantity and far greater complexity--we have a double reason for concerning ourselves with the critical problem of producibility if we are not to literally exhaust our economy to maintain minimum preparedness--to say nothing of the impossible situation we might find ourselves in during an all-out war.

After watching various companies struggle with this complex product problem, I find myself swinging more and more to the concept of an independent production engineering organization sandwiched between research and development and manufacturing. Here are some reasons why.

In the first place, I want my research and development people to keep concentrating on the creative development of new and improved devices. To be sure, they must be an understanding part of the whole management team and should have a certain talent for intelligent administration of their own internal operation. But I want them to concentrate on their assigned objective and I want them to organize best to meet that objective. I don't want their operations obstructed or effectiveness diminished by too much attention to unnatural functions.

On the other hand, I want my manufacturing department to concentrate completely upon the efficient utilization of my manufacturing capacity, the continual reduction of costs, the intelligent handling of labor, and the continuing planning for facilities and equipment expansion. I want their organization tailored to these ends. Their biggest problem will be administration of activities and operation of facilities. Again I don't want their chances of complete effectiveness jeopardized by turning their curiosity and interest into other areas.

Now my production engineering department must be the interpreter and at times the buffer between my department of creation and my department of execution. Philosophically, it may be a somewhat difficult position to accept. The production engineer must work with the creations of others turning them over to still others for execution. If a product performs especially well, the director of research and development will be the hero. And if the product is turned out on schedule, and at an exceptionally low cost, with ease and facility, my director of manufacturing will be the man of the hour.

And I am faced with an interesting organization problem. I must organize on the one hand to mesh with the research and development operations so as to receive their work in smooth fashion--and the work will be organized along product and functional lines. At the other end of my operation my organization must mesh with organization of the manufacturing department so that my planning can be cleanly introduced into manufacturing operations--and they will be organized by process.

One way to organize would be to break the department into two groups or levels, one organized by product, and the other by process.

The first level on my office chart would be my production project engineers. There would be one for power plant, one for guidance and communication systems, one for chassis or structure, and so on--roughly the breakdown of the research and development activities. These production project engineers would be the lead men, with responsibility for getting their piece of the product into production at lowest cost, in minimum time, and so forth. They themselves would, or within their assigned group, turn out the production drawings, the bills of materials, the necessary control specifications and perhaps the process sheets.

The production project engineer would control the budget and would make or coordinate such estimating as was necessary. In all of these activities he would use the service of the second--or process--group.

This other level on my chart would be made up of process supervisors. There would be one for sheet metal, one for machining, one for electrical assembly, one for welding and fastening, and so on, and probably a metallurgical supervisor and materials specialist. These process supervisors would each be fully knowledgeable on what equipments and processes were available in the plant, what was available elsewhere, what new was being done in the field--and he would know relative costs. Very probably he would be conducting some process development experiments on his own. He would be responsible, at the request of the production project engineer, for developing the specific processes selected, for selection of equipment, and for design of tools.

With this setup the production project engineer would quite literally shop around with the various process supervisors, weigh alternate methods and costs--then select his processes and tell the respective process supervisors to go ahead on the specific parts and assemblies assigned. It is then through these process units--which are organized roughly as are the manufacturing operations--that the work is fed into manufacturing.

And thus we have accomplished our translation of the device to a series of processes through production--or producibility--engineering.

Three points may immediately occur to you in regard to this pattern of organization.

First, is the point that with many products the processes are typical and relatively fixed--even traditional--by components or assembly. If this be the case, cannot the production project engineer and process supervisor be combined in one man or group?

I agree that the foregoing does appear to be the case in many instances. But if we combine the two jobs, doesn't the project engineering task become dominant and doesn't processing become just an automatic and traditional secondary routine. If so, we kill creative producibility engineering right at the start. If an engineer only knows one or two ways to make something, he probably isn't a very good production engineer.

A few years ago the engineer working with jet engine compressor blades machined a forging--and that was it. Everybody did it that way. Today he looks at fabrication and welding, centrifugal casting, powdered metallurgy, cold forming, and other processes as competitive alternatives. And producibility has gone up and costs have come down. All this because of the competition between process minded people. So go slowly with combining the production project and process jobs.

Second is the point that my two tiers--production project and process--can be split. The production project task can be assigned to the design project engineer along with his duties of product creation. The process engineering task can be assigned directly to the manufacturing people. We now need not worry about the added load of a production engineering group.

This pattern has worked well in the past and is working today in many important and successful companies. But as this producibility factor grows to dominating proportions, don't we need to assign the task of creative production engineering to a group whose sole responsibility it will be, rather than split it two directions as secondary responsibilities of people whose primary interest lies elsewhere and who now must work on producibility problems in a "committee" fashion. I think there are growing reasons to fear this.

Third is the point that this organization would fit only a relatively few large situations. With this I agree. The picture is drawn here to emphasize an important pattern of relationships. The exact organization can, of course, be varied widely as long as the basic philosophy is accommodated.

Now operation of a production engineering program on this scale takes money. The exact costs are hidden by our military contracting and accountability systems. But the amounts are large, often considerably in excess of research and development costs for the device. However, they are small in comparison with the continuing procurement costs and the savings achieved therein.

It is difficult to bring out any specific arithmetic formula which has general validity here. However, I can give you an example which may set some magnitudes for you. A year or two ago, certain programs, all headed for production, were reviewed and costed. Among other things, the production engineering and planning costs were estimated. These costs as estimated were roughly representative of charges for those activities which we have described as production engineering. They involved the redesign of product for more efficient manufacture, the development and testing of new production processes, the detailed tool planning, and the actual design of the special tools required. Pilot operation time and materials were included, but capital cost for pilot facilities was included in a separate production facilities estimate.

For these programs the total estimated production engineering and planning costs ran in excess of 45 million dollars. The time for expenditure, including the overlap into the research and development schedule and the tapering off into the manufacturing schedule, averaged about 30 months. This 45-million-dollar figure was the same magnitude as the research costs and appeared to be a stiff price to pay.

On the other hand, the minimum peacetime schedules for these missiles called for procurement outlay of approximately 20 million dollars a month, or 240 million dollars a year. These procurement costs represented the estimated costs after effective production engineering had been completed. If costs were cut only 10 percent by the engineering, it would have paid for itself in less than two years at the peacetime rate.

But of critical significance was the fact that the production engineering was geared to production of materiel at all-out mobilization schedules vastly higher than the peacetime requirements. During mobilization period therefore, the total savings might well have been paid for within a month or two, to say nothing of the preparedness value--the insurance--of having the items processed and tested for the high production program from the start.

The Pilot Line Test of Producibility.

If we accept producibility as a cardinal requirement of a weapon or other military device, we must revise our ideas on the testing and acceptance of the weapon or device.

Traditionally, we accept a new weapon when the prototype demonstrates that the functional performance requirements have been met. Our pilot line runs are primarily to provide limited numbers of these weapons for test and evaluation. The product is important--not the producing weapons.

Economy holds our investment in facilities to a minimum--just enough to turn out what's needed the hard way. Production engineering is nonexistent or of a very sketchy nature. We're lucky if our production line holds together long enough to produce the pilot quantities.

If further production is required, we first try to patch up our pilot line or perhaps augment it a bit. Failing this, we may move on to a re-engineering of the plant and perhaps the product, in line with the economics of production at the stated peacetime level. And we get our requirements produced at a low total cost if our programming has been well done.

But as those entrusted with the technical aspects of our Nation's defense, our task is not the most economic peacetime procurement of hardware. Rather, it is the provision of a weapon and a production program which will meet the vastly greater requirements and conditions of all-out war. The processes which produce small quantities for peacetime and semimobilization requirements may be a military liability in all-out war and bankrupt us in labor, material, and facilities.

Since our task is to develop a producible weapon--producible in the meaning of the wartime economy--this producibility becomes an important military characteristic of the weapon and must be tested. The pilot

line should, therefore, be regarded as the proving of the production engineering and processes to be employed in peak quantity production as well as to produce limited quantities of the weapons for test and peacetime requirements.

Under this concept the weapon should be completely re-engineered for peak production and one each of every tool, machine, and equipment to be employed should be placed in the limited production operation. This even though some machines of high capacity are only used a few minutes each day. As a part of this program, the new machine tools and modifications of existing equipments should be created. We have developed the device, now we must develop the tools to make the device. It's of no value if we can't make it. The production processes need testing too if we are not to be surprised on "M-day."

Furthermore, if we don't develop and test the improved tools now, we won't do it. For once a war starts in earnest our machine toolmakers and other concerned with equipment invention will have their hands full just producing the tools already developed.

In the light of these requirements it would would seem proper to consider a policy objective that only upon demonstration of the production processes to be employed in quantity production will the weapon be considered as finally acceptable for mobilization planning purposes. Monies should be earmarked for this purpose and the pilot line program be regarded as the required final step of a successful research and development program.

The Corallary of Stand-by Facilities.

Now I want to take one more step. We've argued that the growing complexity of weapons systems is causing producibility to become one of the mandatory characteristics of the device--along with its immediate military characteristics. We've explored the province of the production engineer and discussed the rising importance of the function and the growing technical knowledge requirements for creative producibility engineering. We've suggested that the pilot line concept be expanded to require the pilot test of the production processes--not just weapon function. We have brought our discussion down to focus on the production plant itself as a key element.

What is happening is simply that over the last decade or so there has been a growing realization that the plants which produce the weapons systems are themselves, with the growth of production complexity which requires unique facilities, becoming an integral part of the whole weapons system!

Once we had a musket; gunpowder, shot, and simple tools to make the musket were our planning worries. Then, in due time, we came to the machine

gun and our problem increased. But we mounted the machine on a tank and then we forgot the machine gun and its relatively simple programming in face of the more difficult programming of tanks, without which the machine gun wasn't worth much.

But now we began amphibious operations and had to develop special ships to carry the tanks which carried the machine guns. These landing ships were unique for the purpose and really created programming problems of a new magnitude. But without the unique ships, the operation would be far less effective--the ships had become an integral part of the system.

And now we arrive at the point where certain of our production equipments and facilities are unique to the producibile device--without these unique equipments and facilities, our employment of the device is critically restricted. Quite literally, our plants have become weapons. And in view of the long lead time required to produce a plant, we must select the most important plants and literally stockpile them.

This is, of course, the purpose of the stand-by plant programs now being argued. I admit to some irritation with the title "stand-by plant" since it implies a certain current uselessness and questionable drain on the economy. Perhaps some title such as "defense production units" would bring a sharper picture of current usefulness, for such plants would currently serve a useful purpose. They serve the identical purpose, awaiting their task of all-out production, as do the jet interceptors on our airfields which grow old and obsolete or wear out never having fired a gun in anger. I do not advise eliminating the interceptors, but we must have some of these plants in being and idling gently, ready to pour forth their torrents of weapons at the first attack.

Certain considerations must be given attention if this course of action is to be of maximum effectiveness.

1. Stand-by facilities should have regular use in "pilot" production to insure equipment readiness.

2. Equipment should be regularly replaced as it is made obsolete by more advanced tools.

3. A skeleton organization should be designated and ready to step into management of the stand-by facilities at a moment's notice.

4. Provision must be made to train and maintain a skeleton labor force to man the stand-by facilities.

5. Material stockpiles and components should be maintained in balance with the proposed production program of the facility.

Of course, only plants for critical outputs should be so maintained--with enough capacity to sustain us through the early onslaughts and while

our remaining national capacity is being converted. We will buy far more real defense with our dollars this way.

My purpose today has not been to educate you as production engineers. You do not become a first-class production engineer in a casual fashion. As in other engineering disciplines, creative competence comes only with considerable experience on top of a sound technical base. In fact incompetents too often can do real harm, getting acceptance of their inadequate programs by an unsophisticated administrative agency with the display of an extensive vocabulary but no real experience. Don't be lured into substituting yourself for a contractor's production engineers any more than you would insert yourself into an atomic research program as a participating scientist. It may look easy, but there are at least one or two cases on record where the officer has looked somewhat less than brilliant. And it isn't necessary.

My aim today has been to create an awareness in your minds of the shape of the problem and the growing intensity of the need. None of you will probably ever achieve top competence as a production engineer--this you must leave to your contractors. All of you can become familiar with the importance and place of producibility--and so intelligently support your contractors as they require such programs.

Concentrate your energies, in the posts to which you will go, on the constructive promotion of producibility thinking and the eternal truth that in the long run the weapon is only as good as its production base.

Thank you.

QUESTION: With reference to this production-development gap and your proposal to help close it by the creation of a production-engineering element between the development end and the manufacturing end, does this mean that we would invariably or usually have to place a development contract with the company which is going to do the manufacturing or do you think we can actually separate those in the organization?

MR. POCOCK: Do you want an answer to that all wrapped up in three sentences? May I discuss that just briefly because you have a very important point there. May I use two or three specific examples showing different ways it has been handled and the problems which have come up. I am sure many of you are familiar with these.

I think that the most interesting example of this problem to me--and ultimately a solution to the problem--occurred in the jet engine program of company "X." Company "X," had many excellent production engineers in many of its other divisions, but when it initially entered jet engine development during the mid years of the war, its jet division was essentially a research and development organization. There was not

much time to do production engineering and it turned engines out only in a limited quantity. Finally, they developed a very high performance engine, still in use and still retaining much of its effectiveness. This engine was turned over to company "Y" to manufacture. The reason for turning it over was simply that company "Y" had developed an awful lot of know-how and technique in the manufacture of engines. This may well have been the correct decision to make but it certainly hurt company "X." It hurt the company very badly.

Only a few years later it had developed a new engine, which was the direct offshoot of the old--more power, a little larger in some elements but to a degree interchangeable. The company decided it was'nt going to be trapped. When it came in this time its representatives were going to be ready to show they could produce those engines. Their designs, drawings, and production plans were much more sophisticated than any earlier attempts they had made. One of their plants is now the largest unit producing jet engines in the world today--unless you have information from behind the Iron Curtain which I do not have.

It may interest you to know that company "X" today has what roughly would correspond to a production-development department. It does many of these things, not exactly the same, but many of the things I talked about as being essential in the production-engineering function. I don't want to necessarily advertise company "X" as the most effective outfit in the jet field, however, I think its effectiveness is very good. It is certainly right up with others. There are several good producers. But company "X" will tell you that it is a heck of a lot better than it was several years ago. This is an example where a splendid development contractor was almost lost because we wouldn't give him a chance to manufacture.

Let us take another example, which is company "Z"; it has been traditionally a brilliant research and development outfit. For many reasons its emphasis has had to be forced in that direction. It has had understandable problems, in view of its situation, in bringing some of its items down into production. I know people there and I know that they would give their all to be able to put more time in on some of this producibility thinking, but what we are interested in getting out of them as their product, is research and development, and we can find somebody else, we think, that will grind it out. And so we have repeatedly taken some of company "Z's" products that it has proprietary right to and turned them over to other people for production. I am not arguing right or wrong. This is just the factual case. But aren't we asking a lot to have that company forego production in quantity?

That brings up this problem, the proprietary right to a device. Generally speaking, we regard the proprietary right as residing with the outfit that develops the device. Remember this: you don't make money off research and development. You make it off the production of the item

which you have developed. So if you do take an item such as that away from the research and development contractor, you automatically impose a limitation on his commercial profitability--if you want to put it just that bluntly. This has to be considered very, very strongly. This is a basic point of discussion among contractors of all the services today.

Might I give you a third example, and I will leave this one nameless also. Here a special device of great importance was developed by an independent research laboratory. Its representatives knew from the start that the device was not going to be manufactured by them. Indeed, they had no facilities or interest in manufacturing. The device was turned over to another contractor with extensive production experience and great knowledge in the field. It was there re-engineered and thrown into production.

However, this contractor also had some research and development of his own. Now I think it is pretty human to want to make our record on the devices where we have the proprietary interest rather than on taking somebody else's development. So what happened here, with the terrific work load facing this contractor across the board, was that his top team was assigned to his own development and we got somewhat of a second team operation so far as developing our item was concerned; this didn't work either.

I would say as a general thing it is extremely helpful if you can select in the research and development phase a contractor who can go on through to the production of the device. I know there are limitations on that. I would say, secondly, if you cannot do this, the understanding must be clear at the outset and the contract for research and development has to consider all of the aspects of the research and development contractor for potential loss when he turns a research device over to somebody else for production.

On the other side, the outfit that is eventually going to produce the item has to be brought into the research game at a very early stage and have a production contract ready to move along with the development of the device. That has to be set up and understood at the start.

I don't know that this answers your question but that is about as far as I can go with my own thinking.

I might use a moment here to go into something a little bit more specifically. Colonel Bartlett suggested that it might be interesting to some of you to have me give a specific example of some of these things that have been re-engineered and some of the problems that have been hit.

I might take, for example, one that I am familiar with in a guided missile where the aft section of the missile--I am not talking about a

booster, which would house the control elements and so forth, was designed originally as sheet metal fabrication. It was a cylindrical section with a clam shell design. The mounting brackets--there were many of them inside--were formed out of sheet metal and riveted to the skin. The internal stiffening was riveted in; sheet metal parts were put in and spot welded or riveted. This was the fastest and cheapest way to make the device in the development phase.

When the company got ready to produce it, the fellows began to consider how they could make these clips faster, whether the clam shell should have three instead of two segments. The production engineer who finally got against the job said, "We are going to use precision casting for the whole thing." Some said, "It can't be done." The engineer said, "Yes, a little shop up here at so and so is doing just that sort of thing in another device." So they redesigned it. This takes a lot of redesign. But the tail section came out with an entire casting and it turned out to be much more interchangeable.

I might talk a little bit about some of our aircraft wing surfaces. There was a time when we used sheet metal almost entirely for all of our wing surfaces, not on all internal structures but the external surface of the wing was sheet metal. There were some extrusions perhaps for spar caps and inside stiffeners.

Then we moved into increasing complexity of the product. We moved into a very thin wing section. High-speed aircraft quite literally didn't have enough room inside the wing to put in the structure required to carry the loads. We got around that for a while with some very intricate sheet metal fabrication which very soon headed for a point of diminishing returns.

So we went into an integrally stiffened skin whereby we really extruded a skin in a cylindrical section with stiffener sections, then split the tube and flattened it out. When it is flattened out, we have one surface with the "I" sections becoming an integral part of the skin itself. That whole sheet can be machined and worked as the skin and structure.

Going a step further in wing design--if I talk quite a bit on guided missiles, that is where much of my personal experience has been--there was one missile which was going to hit high production rates and which had a wing plan and loads like a high-speed interceptor. The engineers were thinking, let us go to integral stiffened skins. But no, we could go one better with this. We didn't have a manned missile so we didn't have to worry about the safety factor and the fatigue factor quite so much. It was a one-shot deal. Why not think about going into complete magnesium casting? Well, it was done. It worked out a completely different production process, requiring a knowledge of the design,

stresses, strains, the qualities of materials completely different from that used in sheet metal or even the stiffened skins construction.

I suppose many of you have thought about the heavy press program in connection with some of these things. I remember being very much impressed with some Messerschmitt fighters and others which were brought back during the war for some of us in production engineering to examine, and taking a look at some of the parts in there that were obviously forged and quite honestly wondering how in the heck they ever did it. There was nothing in the world that pushed out parts like that. After the war we learned very quickly what Germany had been doing with heavy presses and we have carried out that thinking to a much greater extent in our heavy press program. I don't know whether it will turn out to be right or wrong. Time only will tell. But I do believe it has sufficient possibilities so that investment is justified.

If you talk about the heavy press program, you get the design engineer in with the program engineer and they say, "How do you design for the presses?" They don't know. Once again you hit a problem. Take a process which holds opportunity for decreasing cost, for more efficient production of highly complex structures and for rapid production in a high wartime output--if that is important--you have to go back and learn how to redesign all parts to suit the process. So I think it is only natural that some of our design engineering groups are a little skittish about going back and trying to learn how to design for these processes. I think that will come in time.

Perhaps some of those examples will serve to illustrate what I am talking about when I talk about really creative production engineering.

COLONEL CAVE: Mr. Pocock, I see we are up against 12 o'clock. Thank you very much on behalf of the College.

(24 Mar 1953--750)S/sgh