THE PROBLEM OF PRODUCIBILITY

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Mr. Theodore A. Smith, Vice President in Charge of the Engineering Products Department of the Radio Corporation of America, was born in Brooklyn, N. Y., on 17 February 1905. He received his degree in mechanical engineering from Stevens Institute of Technology in 1925, and immediately joined the staff of "RCA's technical and testing laboratory at Cortlandt Park, N. Y. Three years later he was placed in charge of television development work at Cortlandt Park and became one of the pioneers of television development. He has advanced steadily through technical, commercial, and administrative positions since his start with RCA more than 27 years ago. In 1930 Mr. Smith entered the commercial engineering field as a district manager for RCA transmission equipment, with headquarters in New York. He was assigned to the Camden, N. J. headquarters of RCA Victor Division in 1938, and progressed through key posts in the fields of product coordination for commercial and military equipment, and military development projects to the position of general sales manager of the Engineering Products Department, RCA's organization concerned with the design and production of military and commercial electronic equipment. He was made assistant manager of this department in January 1951 and was elected by the company to be Vice President in Charge of Engineering Products Department on 5 June 1953. Mr. Smith is a member of the Institute of Radio Engineers, the American Society of Naval Engineers, the Armed Forces Communications Association, and is Chairman of the Government Equipment Section of the Radio-Electronic-Television Manufacturers Association. This is his first lecture at the Industrial College of the Armed Forces.

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COLONEL WALKER: Admiral Hague, General Greeley, gentlemen: Last Friday, as you recall, Colonel Diehl showed you a tommy gun. The tommy gun was made mainly of forgings and required many intricate machining operations. Then he also showed you the so-called grease gun. The grease gun was made mainly from castings and did look pretty much like a five-and-ten-cent store item as far as military weapons are concerned. The grease gun however is just as reliable and just as effective as the tommy gun.

Now, what happened in this instance was the development of a production design, or shall we say in more general terms, solving the problems of producibility. This is the subject of our speaker this morning, "The Problems of Producibility." These problems are caused primarily because the product must be designed not only for its function but also for its ability to be produced by our mass production techniques and other standard production processes.

These problems undoubtedly are much more complex in an organization producing many different products such as the Radio Corporation of America. Mr. Smith has had many years of experience in this particular engineering field with industry, and he is presently Vice President in Charge of the Engineering Products Department of the RCA.

It is a great pleasure to present to you this morning Mr. T. A. Smith.

MR. SMITH: Thank you Colonel. Admiral Hague and gentlemen: It is both a pleasure and a privilege to be invited to come here today and to have the chance to talk to you on the very challenging subject of producibility of equipment. Producibility of military equipment forms the core of the relationship between industry and the military which is so vital for our national defense. World Wars I and II demonstrated beyond all doubt that a strong, well-equipped American military force, backed up by the tremendous resources of our industrial capacity, could not be defeated. The combination of industry and the military met and solved many problems; but many production problems still remain to be solved. It is my purpose today to try to review some of these problems for our mutual benefit.

I have elected today to review some of the climate and the circumstances which lie behind the difficulties and which we experience. I shall try to describe some of the specific areas which seem to be

trouble spots. I will try to list some of the methods of solution which we found to be helpful, and I will conclude by trying to give you a case history of a situation where we felt many of the normal production problems were well licked.

In many periods of the past, military weapons and devices remained static for long periods of time. But today our comprehensive military planning requirements require that equipment be of the latest type, perform many new functions, and have advantages over that possessed by a potential enemy. Of course it must be available when required in sufficient quantities, it must be reliable, and it must have a reasonable cost. In these factors lie the basic problems of producibility.

Now, military needs are always changing toward greater performance and greater complexity. What about industry's ability to produce such high performance equipment? Industry, of course, does its best job when it produces long runs of completely designed and tested equipments of familiar types. Between these two concepts--(1) the new, the unusual, the better equipment needed by the military, and (2) the older, the known, the established with which industry is familiar--lies the area of most of our difficulty.

As the military contracts with industry for equipment, the number of any one item may be only a handful or it may be many thousand. The equipment may be very simple, in which case there is little problem, or it may be extremely complex, demanding the highest talents of our scientists and engineers, compounded with the ablest skills of our best production people. The equipment may be a standard item, in which case production is merely routine, or it may be a newly designed product.

Most problems of producibility lie in the latter area, where the fast-moving demands of modern technology result in increasingly complicated gear and in increasingly stringent specifications for producing it. It is in this field, where engineering research and development are "pushing the art," that the military specifications are typically demanding more than was ever before thought possible to be accomplished on the factory floor. But there is an even further step where science is unfolding entirely new principles which demand for their utilization the development of brand new ideas, new techniques, and new methods.

This broad area, where producibility problems are the greatest, is the very area which is most vital to us in this era of the "cold war." We can't afford to go along with ordinary peacetime progress. We dare not try to temporize. At the same time we cannot waste our time and resources in mass producing an endless succession of changes. For changes are coming fast. There is an almost daily procession of new research achievements. Which of them are immediately practical? Which of them are urgently needed for military field equipment? Which ones can wait?

The military services must always be faced with making the decision. In the light of the present and anticipated world situation, in the light of an inventory of our military assets and liabilities, and in the light of the country's economic abilities, it must be determined if these new developments should be incorporated in new field equipment and, if so, when.

In many instances it would be wise to stick with tried and true designs. Here there are few producibility problems. We can almost say categorically that the basic problems of producibility lie in changed design; thus, if the decision is made to build the new or greatly improved product, there will be a host of problems. One of the foremost of these is in the matter of timing. Even if the answer is "as soon as possible," there will be a long time cycle involved. And let us emphasize that in addition to the normal production time cycle there is a great time uncertainty as to new equipments. We can schedule to the best of our abilities but, after all, we will be dealing with the novel, the new, and the unknown. The proving out of the new equipments will be uncertain as to time.

This makes it much more difficult for the military decision which requires accurate timing in order to have all elements fit into the plan, no one element being an end to itself. In some cases the advantage to be gained from use of the new development may be of such great worth that the risk is justified. Perhaps the best known example of this is the original decision to produce the atomic bomb, although it was recognized that production might usurp too much of our national resources or might be completed too late to be of war use, or might even prove impractical.

Of course there are few decisions of this magnitude; but all such military decisions are important for the part they play in the whole picture. Not all decisions turn out well, either, and in some cases the definiteness and the crispness of the plan are sacrificed for some minor improvement.

Let us consider for a moment another aspect of this military decision--the choice of whether to make the equipment more convenient or all embracing, or whether to make it simpler. Should the equipment be practically automatic, even if complex and expensive, or should it be a plain apparatus with no complications? Of course the answer will determine the producibility problems we will meet and the length of the time cycle. In most cases we must strike a balance between the two extremes and do our best to come up with the proper military decision. A good example of this conflict in choice is found in aircraft. A single seater fighter requires much more automatic fire-control equipment than a two seater does. Advantages gained may justify extra cost, delay, or complexities. The need for more complex automatic equipment might be indicated if we must depend on relatively inexperienced flyers.

On the other hand, simpler gear may be more easily produced, with more definite and shorter time cycles, as well as being cheaper and easier to service. In general, the convenience or the all-embracing nature of equipment is achieved by recent technical developments, but with resulting production problems. Often the problems are worth while in view of the results gained. Sometimes they are not.

Sometimes production is almost taken for granted. There is often a lack of recognition that production is something of an art as well as is scientific development. Many in high places assume that if a device operates in the laboratory, it will be equally effective in the field after mass production. Transistors were demonstrated five years ago by the Bell Laboratories. Yet at the present time, in spite of the best efforts of some 35 leading companies, we cannot mass produce transistors to use in any type of high performance equipment.

The importance of timing the military decision works two ways. Sometimes it is well to wait for further technological advance; at other times the military will find it expedient to grab the latest improvement and rush it into production to serve a purpose--even if everyone realizes that it is still very rough and needs a great deal more work. Thus, in the early days of World War II, the laboratories produced a "magnetic airborne detector," a device which indicated a change, for any reason, of the earth's magnetic lines of force. For example, if a submarine were cruising under water, its metal bulk would distort the earth's lines of force. An airplane flying overhead could pick up this slight disturbance in its magnetic airborne detector and drop a few depth charges. This instrument was very crude and was not, by ordinary standards, ready for release. But, with German submarines lying off our coast, there was no time to wait--the instruments were rushed into production and we understand they were effectively used.

Although all industries have their own production problems, the problem of producibility is most peculiar to those industries which are involved in a rapid advance in scientific knowledge. Typical are such industries as aircraft, chemical, and of course electronics. I will confine my remarks and examples this morning to the electronics industry, where the problem of producibility is particularly acute.

Let us examine the electronics industry and the changes which have taken place and are occurring in relation to the ability of industry to produce.

In 1940 the total factory production of the electronics industry was only about 200 million dollars. During World War II the entire resources of the infant industry were devoted to Government service and it grew prodigiously. However, at war's end, production dropped sharply,

and 1947 production was estimated at 780 million dollars. Since that time electronics has been the fastest growing industry in the country and now produces more than 5 billion dollars worth of goods per year.

These last 14 years have been marked by rapid and steady progress in scientific and technological knowledge of electrons and their utilization. They have also been marked by the spectacular blanketing of our country with radio and television networks and programs and the near approach to a "television in every home." Meanwhile, production facilities have mushroomed while production methods and production knowledge have continuously improved.

This process is still going on all around us. This is no stopping place. The next half-dozen years will probably see as much advance as have the last. The credit for this spirit of learning and improvement should go not only to the industry but also to our Government, which has consistently pressed for higher and higher standards of performance and has paid a large share of the bill for research and development.

This research and development has certainly paid off. There has been a tremendous increase in electronic knowledge and its application. The electronics industry has realized that its future depended very heavily on continuing advances in the sciences. Its laboratories are seeking out secrets not only in electrical phenomena but also in physics, accoustics, optics, chemistry, and nucleonics.

The blending of the sciences has lead again and again to the development of principles and components for commercial use, which then have contributed mightily to the development of military gear. Thus, the creation of Magnetron tubes for ultra-high-frequency use proved of great military value when incorporated in radar equipment. Television techniques also helped its development to the accurate detecting and range device we know today.

For example, as I mentioned a moment ago, the Bell Laboratories announced the transistor in 1948--the first practical application of solid-state electronics since the use of the crystal and cat-whisker in the early radios of 30 years ago. The tiny transistor, when we can solve its problem of producibility, will be a milestone in electronics progress. For, if we can "prove it out," it will be a versatile, precise, and often economical means for controlling electrons in the circuits of electronic equipment for national defense, industry, and the home. It will permit smaller, more efficient, and more useful equipment in many cases.

Electronics has constantly advanced the use of new and relatively unexplored bands in the frequency spectrum. Some of the frequency

bands now in use differ as much from those used formerly as X-ray differs from light, and require different techniques. We must develop a whole new series of materials and components for each new band which comes into use.

These and other fast-moving developments require that not only our engineers but also our technicians continue their daily schooling, so to speak, because even the basic principles of equipment design are changing. Remember the "good old days" when we used to wire parts into a radio set? Today a radio technician almost needs a plumber's license. We use wave guides instead of wires, and horns or reflectors instead of antennas.

Printed circuit techniques are another step in the search for improved products and producibility. Although the idea of printed circuits is not new, it is only recently that the improvement in parts and components, together with the development of mass markets, promises to make this method practical for many products.

You are perhaps familiar with the Navy's project "Tinkertoy," undertaken by the National Bureau of Standards for the Navy, which has produced electronic assemblies by mechanized means. Others have introduced certain different types of so-called modularized construction. This whole concept of modular construction represents a long step forward in solving the problem of producibility. For this method opens the door to simplification and standardization techniques which we hope will be applicable to a wide variety of complicated devices. Modular design makes use of standardized modules or bases on which components are mounted and which may be connected together by means of printed circuit wiring or other techniques. By combining individual modules to form a major subassembly, entire electronic equipments may be constructed.

Modular construction lends itself to semiautomatic production, or perhaps some day to full automatic production and automatic testing. While there is doubt as to savings in the cost of products made by such methods, there is every reason to believe that reliability of the product will be bettered and time cycles reduced.

Many electronics organizations are interested in modular construction, and this effort is an example of the time, thought, effort, and dollars being expended in peacetime to help solve the problem of wartime producibility. For with the military services increasingly dependent for success on electronic equipment, the country will not be able to afford any bottleneck in emergency production.

All this development work requires large numbers of engineers. I am sure you are all aware of the general shortage of engineers in

our country, and I am not going to dwell on it. In spite of the industry's past efforts to expand its engineering staffs, the tremendous scientific advances in electronics in recent years have created new problems at an even greater rate. Therefore, new engineers have had to be placed on man-size problems very quickly. The customary mature engineering growth is missing. As a result we have had less engineering experience to apply to normal engineering. This is particularly true in the application of engineering theory to practical production. Many of the younger engineers, saddled now with high responsibilities, had scarcely seen a factory. Needless to say, they have quickly come face to face with the problem of producibility, with all its harsh, stern realism.

Incidentally, you might be interested to know that in my own operation, 50 percent of our engineers are under 30 years of age; 75 percent are under 35; 90 percent are under 45. Our present staff of about 1,000 engineers has doubled in the past three and one-half years.

But perhaps it is a good thing that electronics engineers are young. The science of electronics is young, too, and changing so rapidly that it takes a young man's boundless enthusiasm for vigorous growth and changes to keep up with it. For in many directions of electronics research we are still searching for basic principles; we are still collecting original working data while at the same time we are trying to reach out and push back the horizon of knowledge.

Let us look at another complex field of problems with which this young engineering group must cope. For there is another great area of producibility problems created by this rapid technological advance and pinpointed by difficulties with components. Let us call it the problem of component design catching up. It can be illustrated by discussing the situation in the important field of miniaturization and subminiaturization.

Within the last few years, giant strides have been made in the miniaturization of electronic equipments, and many equipments now being delivered to the military services are of a miniaturized design. However, today considerable work is going on in the electronics industry to carry this work forward even further toward the subminiaturization of electronic equipment. This involves the reduction in size and weight of the equipment to relatively tiny proportions. To do this requires the development of new components in subminiaturized size which have been tried and tested in circuits. The rate at which subminiaturization is being carried forward has not left much time for the development of these diminutive components, particularly with respect to realiability.

Also, because of the special requirements of the military services relative to humidity, altitude, heat and cold, vibration, shock, fungus,

and so on, these specially designed subminiature components have been very costly to produce. As more experience is gained and volume is increased, the production costs will decline. Great effort is being given to improving the realiability of these components and in learning the fine points of their use in electronic circuits. This must come largely from field experience, since this is the final test of reliability. Meanwhile, new laboratory techniques are being developed to accelerate the programs to obtain life-test data.

It is typical of the electronics industry that major producers of equipment obtain many components and parts from a host of other suppliers. It frequently is difficult to interest these suppliers in devoting the time, effort, and money necessary to develop and produce the relatively small orders for subminiaturized parts. It just is not worth their while. In many cases the tighter standards and increased requirements of the military specifications are simply beyond the engineering ability of the component manufacturer. So the large companies must carry the major part of the development burden, and often must go further and set up their own production facility.

I would like to show you an example of some of the problems of manufacturing smaller and smaller things. This (holding it up) is a miniaturized radio receiver which we developed and intended to be used in connection with the walkie-talkie model in use at the present time. It is quartz crystal controlled and uses military type components which will stand a very great range of temperature and humidity conditions. The battery will operate the equipment for about 10 hours. Perhaps even at a distance you can see the really tiny size of the parts. Nearly all those components are subminiature, including, incidentally, the plug which connects to the hearing aid earphone. The earphone cable also serves as an antenna. If you are interested in it, I will leave it on the table here, and you will have a chance to see it afterward.

As the military requirements become more stringent, industry is faced with the development of more and more complex designs to accomplish the given objective. It is an endless treadmill of striving toward an imaginary perfection. But let me say right here that the industry, in spite of its groans and grumbles at the difficulty of meeting military equipment specifications, is inwardly in complete sympathy. For we realize that not only are we in an international race for survival, but from a purely scientific viewpoint the only way to increase our knowledge and capabilities is to continually strive to achieve the "impossible."

The industry feels that it is the full-fledged partner of the military in doing its utmost to advance the performance of its equipment. This means we are ever trying to make an equipment smaller, lighter, and more reliable, while at the same time we are requiring it to perform more and more functions automatically.

Development work is going on simultaneously on many fronts. In addition to those already mentioned, I would like to tell you about a few others which are directly related to the problem of producibility.

The design engineer, with his head in the clouds of new theory, must constantly guard against stubbing his toe on the cold facts of production. Right off, there is the problem of tolerances. As nominal dimensions become smaller and smaller and the characteristics of the components more critical, dimensional tolerances, both electrical and mechanical, play a more and more vital part in the component design. In the old days, the gears on the mechanical drive were designed to normal manufacturing dimensions and tolerances. Today, a microscopic backlash in a gear train can be the difference between between success and failure in a piece of radio equipment. Extreme precautions have had to be taken in designing an antibacklash gearing which meets the requirements and, I might add, which increases the cost.

Associated with this idea of tolerances is the need for precisely controlled tuning. In the old days, the width of the frequency channel required to transmit a radio message was relatively unimportant; today, it is extremely important. Hence, components must be designed which permit the effective and controlled utilization of every bit of the available frequency spectrum. It would be extremely dangerous, for example, to depend on communications on a certain channel and, through failure to transmit on that channel, to have communications broken.

We are designing at the present time and building for the Air Force an airborne transreceiver which must be capable of selecting a channel of a certain number out of any 30,000 channels which are available on that particular receiver. Those channels have to be maintained so accurately that every receiver tuned to any one of those 30,000 channels will automatically pick up transmission without any tuning of any sort.

Every electrical device radiates electrical signals of one sort or another, and sometimes they are signals we don't want to have. As more and more electronic equipments are put into operation, the need to reduce interference between equipments grows at a tremendous rate. Both the industry and the military services are aware of the need to suppress these spurious signals. This is done by means of filtering devices which are costly, especially when used in highly sensitive electronic apparatus.

The wide range of military operations from the tropics to the Arctic and from the desert heat to the frigid cold of the upper atmosphere has placed increasingly difficult demands on all types of military equipment. Radio and electronic equipment which functions to perfection within normal temperature ranges may fail completely at 50 degrees below zero. To prevent this and to assure reliability of equipment at such temperature extremes has required the accumulation of a great deal of experience and test data.

Humidity and dampness have always been a source of possible trouble for electrical circuits. Today's equipment, with its complicated maze of fine wiring and tiny, precisely machined parts, would be an easy victim to moisture if extreme design precautions were not taken. In addition, elaborate tests subject the typical equipment to a barrage of fresh and salt-water sprays and baths in order to show up any possibility of service failure from this cause.

There is another factor adding to the complexity of modern military equipment--the need for automaticity. The jet pilot, fighting at near-sonic speeds, has no time to tune or adjust his gadgets; he rarely has time to push buttons! It sometimes is not nearly as difficult to design the basic equipment to do a given job as to design the multiplicity of associated components to make it work automatically. And don't forget we are always trying to stuff this equipment into smaller and smaller boxes. It is no wonder that the production line has its problems.

Because of the complexities of today's designs, more and more engineering man-hours are required to prepare a new design for testing. Then, all too often, enough equipments are not available from the early production runs for thorough testing and for ironing out the problems that are bound to crop up in a new set. The equipments are needed so badly in the field that there's too little time to test them. This does not help the producibility problem. It merely makes us learn the hard way--and the expensive way. It is interesting that the mathematicians are helping us out by giving us statistical methods of computing the probability of reliability. This is a big step, and a timesaver in showing the priority of urgencies for further design improvements. But, to the man in the plane, 50,000 feet in the heavens, statistics means nothing if the equipment fails. Therefore, the eternal search for design accuracy goes on, hand in hand with the search for production perfection.

I would like to mention briefly the importance of test and measuring equipments in producing modern electronic products, for they are used in almost every step of the process. Once again, our chief problems are created by the rapid advances in the art. For now we often find that the selectivity and the refinements of the newly devised military equipments surpass those of the test equipments. Even when the test equipment is calibrated daily, it is often barely able to give sufficiently accurate readings for dependable test results. It is desirable that the production test equipment be of the same type and design as that used by the engineers, as even slight deviations in production test equipments may give misleading test results and hold up production.

We are currently producing an equipment for the Air Force and we have two subcontractors who are making special assemblies for us. We have found it necessary to cross-check the three sets of test gear weekly in order that we can all talk the same language.

I hope that in mentioning all of these problems which exist in the production of military electronic equipment I have not given you the impression that nothing is ever produced. Quite the contrary, a great deal is produced, much of it on schedule, and most of it of excellent quality. We admit that our problems tend to give us sometimes a peculiar viewpoint. We get it from coping with these problems everyday; but we manage to survive.

Now that we have discussed a number of the problems of producibility, let's talk about how we go about solving them. In order for a company to carry a military order from the stage of cost estimates and original bid right on up through all the stages of product design, production planning, and manufacturing, to final delivery to the customer, it is necessary that it utilize all the tools and techniques of modern management. The large company especially must have a well coordinated, smooth-running organization which knows how to set up sound standards and to use effective methods and procedures, for the large company is in a uniquely advantageous position to organize for the problem of producibility.

For example, let's take the field of components. The "equipment design engineer" must design his product to meet the military specifications. In the past he was able to work away at his basic problem and when it came time to select components, he merely reached for his catalogue and selected the desired items. Now, however, in this age of rapid development he finds that the military specifications are so advanced and so stringent that the catalogue components no longer fit. He is faced with the problem of designing his own components and he may not be equipped or experienced to do this; and so a delay results. Many companies have been able to organize for this by setting up specialized groups to become specialists on particular components. This not only assures a better and faster job on the component, with less likelihood of later production difficulties, but it also frees the design engineer for his responsibility of circuit design and overall performance.

Other problems, such as those involving tolerances, are solved by specialists from the standards group. Or, if they involve radio interference they are in the hands of the experts who are available for advice on shielding, filtering, and other techniques; for the specialists, who spend their full time in a single field, provide the safest and surest protection for producibility.

One longstanding but seldom-mentioned problem of producibility has been to get everyone to talk the same language. What is "square?" What is "flat?" What is "straight?" We used to get different answers from the designers, the vendors, the subcontractors, the toolmakers, and from the production floor. Now we have standards in the form of

a specification sheet of manufacturing tolerances. Everyone knows that "square" means true within .015 of an inch per linear foot. Similar standards for "flatness" and "straightness" are defined in the tables.

No longer do we get arguments and bickering over workmanship. The workmanship standards are spelled out, together with specifications which establish the limits of quality for burr removal, hole location, bends, radii, parallelism, roundness, finishes, riveting, and many other characteristics or working methods. Any time the designer wishes stricter tolerances, he must so specify in the drawings; otherwise the standards will apply.

Those are a few of the essential tools used by management in running a large-scale organization. But even if all these and other tools are well used, it does not guarantee producibility. In this day and age of rapid advance in engineering and science, one design change begets a flock of others. Indeed, it now seems that the typical military specification demands capacities, outputs, and performance which have never before been achieved in production, and permits no deviation from these demands. So producibility becomes a great big question mark!

First we know that we will have to do a superlative job in the management functions outlined above. Second, we know from past experience that in spite of our best efforts there will be a host of "bugs" in the first production run. Third, to eliminate these "bugs" and meet the specifications will take all our know-how, initiative, judgment, and patience.

This is the interesting part of the producibility problem. Did I say interesting? Rather, it can be most dismaying, galling and, at times, positively terrifying. You have seen it happen. Equipment after equipment is coming off final assembly, after passing numerous component tests, and then failing to pass final inspection. As they pile up day after day the engineers are systematically and, it seems, all too slowly, grinding out the solutions. Sooner or later they do solve the problem and the bottleneck is broken. But by that time a new crises has arisen somewhere else.

We feel that the ability to solve these producibility problems is a major asset of the military contractor. It involves more than having available a pool of engineering talent and a wealth of production know-how. There is a definite technique of solution.

In the first place, it has been truly said that "a proper statement of the problem is half the solution." When an equipment fails in a test, the fault may or may not be obvious. And all too frequently, the real cause turns out to be, in fact, well veiled.

The major problem we have in bringing out a new piece of equipment is in putting it through the test, watching the performance characteristics. If we find one of them is not completely satisfactory, the thing to do is to find out what causes the trouble. It may be one of the many component difficulties in the apparatus itself. What we try to do is find out whether the difficulty is a pattern difficulty or merely a random difficulty. We go over it with our statistical methods. Then we go about trying to solve the pattern difficulties, as we realize that when we correct those we will be correcting a great many others at the same time. After that we go after the random difficulties and try to eliminate those as a matter of procedure.

The problem of producibility is always with us. How bad it is at any time, or in any one company, is largely a matter of degree. For even with the best engineering design, with complete and accurate blueprints, there is still the need for production know-how. First, there is the experience which teaches the wrong and the right way of following the blueprints, for there are assembly "rights" and "wrongs" which don't show on any blueprint. Then there is also the "fingertip" know-how--the accumulated skill and dexterity in the labor force. But even more important than these is the knowledge of how to go about solving difficulties easily and effectively. With a smooth working team of experienced production supervisors, you are a long way toward solving the problems of producibility.

Sometimes experience can anticipate trouble and take preventive steps to forestall it. For example, in preparing an aircraft transceiver for production, it was realized that the best coils we could obtain from our customary source would be operating at their extreme limits. Further study indicated that the likelihood of failures and troubles would be considerable if these coils were used in this apparatus. Therefore, the decision was made to set up our own coil manufacturing section where we could keep close watch on the process and insist on the most exacting standards. The major reason for our getting into this coil manufacturing business was to avoid the troubles which we could foresee.

In another similar case, our decision was a little different. The switches used on a Navy receiver were inadequate to meet the new specifications. But here, we were able to set up a rework operation to take the new switches received from our source and build them up to meet our needs.

Another of the standard methods used in industry to keep engineering and production on the same track is to use "coordinators" or "liaison engineers." Their function is to take the responsibility for being sure that everything is done properly to keep a project on schedule. Since they are usually staff men and are working through line bosses, their

job is no bed of roses. All of them are electrical engineers who can talk turkey to the design engineers, while appreciating the engineering problems involved. Each coordinator is responsible for shepherding one or more projects from the status of initial cost estimates and bids through engineering design, purchasing of materials, tooling, and production. He sees to it that schedules are prepared and agreed to by all line bosses; and then he sees that each one stays on schedule. He anticipates troubles; he checks up on delays; he forestalls shortages. He goes to any expense to keep costs down. He has to keep a dozen balls in the air at a time and can't let one bounce. Although he isn't an expediter he does a lot of expediting. He is constantly making decisions, using his knowledge of the progress that is being made in a dozen different sections. He is continually being asked to make changes, to speed up this part, to hold up that schedule. And through it all, he has no responsibility for ordering people to do things--only for getting them done.

I have discussed with you some of the changing aspects of the electronics industry which introduce problems of producibility and some of the management tools which we use to help to solve the problems. Let us look for a moment at situations which create production problems and those which make the job easier.

If we assume that there is a requirement for a new piece of electronic equipment, it can be designed and produced more easily if it is to perform a single function than if it is to do a great many things in different situations. This is only logical, yet today it presents a major problem to most electronics manufacturers.

If the requirement provides for delivery in less than a reasonable time, and many do, you can be as sure of production problems as of death or taxes. This compressing of schedules does not permit adequate safeguards for each step of the production cycle--for breakdown, ordering, fabrication, assembly, or test. A few jobs can be handled on a crash basis but only those of highest priority. Trying to do many jobs on a crash basis results only in confusion and extra cost.

With a reasonable amount of time and with concurrence of the military, there will be opportunity for a pilot run of a small quantity before large-scale manufacture begins. This saves money and headaches for everyone. It permits bugs to be ironed out before too much money has been spent or before the production schedule is missed. It lets the engineers determine the advantages or disadvantages of changes. It permits orderly planning of large-scale production. There is no substitute for a pilot run in smoothing out production problems. Yet too often schedules do not permit pilot runs or, because insufficient time is allowed, the pilot run overlaps the large-scale production and the real advantages are lost.

Field testing of the equipment is important to the manufacturer as well as to the military. Sometimes latent defects are revealed, the correction of which results in preventing numerous problems of production. Early and rapid field tests help everyone.

Excessive invoking of specifications makes the production problem greater and costs the Government money. An equipment which will never be used at very low temperatures but which must meet subzero acceptance tests is a burden on everyone. Few airplane motors will start at low temperatures without heating. It is cheaper to heat a piece of electronic equipment than to design and produce one which will function without heat at minus 50°C.

Another major production problem is that of engineering changes. There are thousands issued for every piece of electronic gear made. Some are due to changed requirements of the military; some are due to the contractor's engineers finding better ways to accomplish results. Some are caused by production problems and some are made to make production easier. If the engineers on the job, both those of the military services and those of the contractor, will sign things off and make up their minds before production, it helps considerably, although it does not eliminate changes.

If the contractor establishes a production program which assumes that everything will go smoothly, he is fairly certain to have a rough time of it--at least in the electronics business. But if he assumes that there will be problems and makes provision for them and schedules time to solve them, he will usually be on solid ground. This is often a trap for the unwary. The inexperienced contracting officer, who accepts the shortest time schedule, may find he is getting a much longer delivery than if he had accepted a more reasonable schedule. We were awarded one contract as a second-source supplier several months after a job had been given to a company promising fast delivery. We beat his schedule considerably because, as a matter of fact, he never did produce a single equipment.

And now for one last word on the general problem. There is one thing we always try to do because it is of utmost importance. We try to work as closely as possible with the military customer. We feel that we have been asked to custom-make a product. It must suit the customer. We would like the customer to work closely with us in understanding and meeting troubles which may arise. We are convinced that only in this way will the customer get the best possible product at the lowest possible price. The problem of producibility is tough enough to demand the best efforts of all of us, working hand in hand, to solve it.

I am proud to say that we have had many, many instances--and in fact I think they are typical--where the military representative has done his best to understand our problem and to help us, to the full extent of his authority, in obtaining correct and proper action. In the next few minutes I am going to have the opportunity of giving you an outstanding example of what I consider perfect teamwork between industry and the military.

During the first part of World War II, GI's were struggling with communications gear that was both heavy and cumbersome to carry. Then there were introduced the famous SCR-300, BC100A, and similar models of World War II walkie-talkies, which added a new concept in communications. They provided our fighting men with a complete two-way radiotelephone system contained in a single pack which could be strapped to the back and operated during actual combat. However, even before World War II ended, the Signal Corps engineers were putting ideas on paper for a new walkie-talkie which would give many advantages over the old equipment.

In June of 1946 RCA was awarded a research and development contract from the Army Signal Corps to develop improved walkie-talkie communication equipment AN/PRC 8, 9, and 10. The total value of this contract was about 279 thousand dollars.

Now if I may I would like to show you a few slides (slides were not reproduced.)

Slide 1 shows the contrast between World War II walkie-talkie at the left, and the new PRC-10 model developed by RCA, at the right.

In order to comply with the list of specifications outlined by the Signal Corps, full use would have to be made of the newly unfolding art of subminiaturization. This called for drastic reduction in the size of all parts used in the walkie-talkie--transformers, condensers, resistors, tubes, screws, and even the redesign of wires.

Slide 2 is a good example of subminiaturization. The discriminator assembly with its cover is shown at the lower left. This single plug-in unit takes the place of all the other components shown in the picture and as used in the World War II walkie-talkie.

We had one rather baffling trouble for a time. Some finished sets in final tests would drift off frequency. It was not easy to locate the trouble because it might be caused in so many ways. The slow process of isolation finally narrowed the trouble down to the discriminator unit--this little device you now see on the screen. But we were still stuck until we found that the tiny germanium diodes sometimes displayed

poor temperature and aging characteristics. They were not uniform and that was difficult to prevent or correct. We finally were able to substitute a different type of diode, which solved the problem.

Nearly every component had to be redone and, to top it all off, new circuits devised to add flexibility and to increase efficiency and effectiveness. The basic aim of this development program was to reduce weight, size, and silhouette, and to develop a wider range of frequencies, and to increase power and reliability.

Slide 3 shows an interior view of the newly designed set, showing its very small size and the maze of tiny parts.

Slide 4 shows the bottom side of the same PRC-10. Every bit of available space is used. How well this was done is shown by the facts. Bulk decreased almost 70 percent; weight is down from 38 to 25 pounds, a reduction of nearly 35 percent; range increased from 2 to 10 miles; and endurance of power increased from 4 to 24 hours.

Slide 5 shows the set in actual use in Korea. It provides a flexible, effective means of coordinating infantry men with armor and artillery.

RCA collaborated closely with the Signal Corps engineering in building and testing a succession of improving models until, late in 1949, they had completed the unit which engineering-wise met all the requirements for mass production.

In August of 1950 RCA was awarded a production contract for 1 PRC-8, 5 PRC-9's, and 10,285 PRC-10's and associated equipment with a total value of 5,652,000 dollars.

The production schedule had been set so that the first models would come from final assembly in 55 weeks. However, the urgencies of the Korean War created a sudden critical demand, and so we all sat down together to devise ways and means of cutting the schedule. The schedule was shown on a large display board, and each manager was given a pair of shears and the opportunity to "trim his schedule."

Slide 6 shows the schedule board, divided into three parts from top to bottom. At the top is the standard schedule; the middle area was the "promise" area; and at the bottom was posted our success in "beating the promise." Each area shows the schedule or progress for major operations.

	Scheduled	Promise	Actual
Engineering	21	20	18
Inventory control	16	11	8
Purchasing	16	11	8
Purchased material inspection	2	2	1
Fabrication	18	13	10
Assembly and test	16	11	9

Those figures of course actually overlap. Obviously you are doing some work on one function while another is going on at the same time. The actual production of the equipment, which started out with a promise of 55 weeks, then reduced to 44, and actually performed in about 36 weeks. This was accomplished by having the managers form themselves into a team with one thought in mind, of beating our promise. Periodic meetings were thereafter held by this group to review the progress and to join in breaking the existing bottlenecks.

Many ingenious devices and plans were used in achieving an actual delivery in 36 weeks of a PRC-10 completely type-tested and field-tested 8 weeks ahead of the reduced schedule.

During the engineering stages, new ideas were introduced which would improve the performance and reliability of the PRC; these too were incorporated in the initial production run. A typical example is the case and panel which housed the PRC. Originally they were welded fabricated metal parts, but the combined thinking of manufacturing and engineering changed them into die-cast parts with all markings included in the die. These markings were permanent and could not be destroyed by wear or sharp articles. Also, the cases were more rugged and saved welding manpower and facilities.

Engineering continued their operations by phases, and as each phase was completed, hot blueprints were rushed into the assembly plant and to our vendors.

This was frankly a "crash" job. Because it was high priority, we tackled it on such a basis. However, we could obviously not perform in this manner in every case.

Whenever a manufacturer starts a new project, he knows that numerous problems and production bugs must be resolved. The assembly plant knew full well that problems would be twofold, as this was industry's

first venture of mass producing subminiature equipment. It was decided that 50 sets of parts would be procured as rapidly as possible in an effort to make known and resolve these new production problems. Studies were performed and techniques developed for subminiature assembly such as:

1. Use of small soldering irons.

2. Utilization of magnifying glasses for inspection purposes.

3. Performing all leads before assembling.

4. Development and training of personnel in the use of tweezers, small pliers, and so on, for assembly.

5. Use of heat dissipators guarding against overheating of critical components.

6. Development of new type benches and chairs to relax the operator while assembling subminiature parts.

7. Development of use of pinball technique for automatic circuit checking.

Slide 7 shows the wiring of the intermediate frequency subchassis. You can see the girl putting in some of those parts. There are six stages--with transformers and tubes and all associated resistors and capacitors. The whole business is only three inches long and two inches wide, so it's no wonder that she needs tweezers.

There are five intermediate frequency units and one discriminator in this subchassis.

Each intermediate frequency unit is of the plug-in type. In fact, these were early examples of subminiature, modular-type developments, all hermetically sealed. Once sealed there is no way of adjusting them. They must be able to pass extreme temperature tests and violent shock treatment, yet a movement in alignment of the interior coil of only .001 inch would mean a 1KC shift in center frequency. Of course, we had troubles at first, and have had to set up extremely accurate fixtures and a complete master test set up to maintain the required extremes of control. Another producibility problem is solved.

Slide 8 shows a part of the final assembly line where the PRC-10 is completed. As you look at it you can see it looks more like a watchmaker's shop than a radio mass assembly production line.

Slide 9 shows an additional stage in final assembly where they also check and test the circuits.

It might be interesting to tell you about a typical bottleneck and its solution. We were only getting 8 watts output instead of the required 10 watts in the final test. Investigation showed that a certain miniature multipurpose tube, the 5A6, was the cause of the trouble. But the trouble was inconsistent; it turned out that there were peculiarities in certain lots of these tubes; further, that in some lots the tubes gave adequate power output for a brief time before rapidly deteriorating. We worked closely with the manufacturer and discovered that he too had a producibility problem. His early prototype tubes, such as were supplied us by the Signal Corps for our engineering development, had been excellent, but when he put the tube into mass production he had trouble. He finally had to devise special tests and select and stamp lots for our use. But that wasn't the end, either. Pretty soon the tubes began to come in with too much power output. This was even more serious since it would cause short life, burnouts, and drained batteries. This problem too was licked by even more careful production and testing procedures.

Slide 10 shows a typical example of working on the set. The work requires a lot of know-how and skillful fingers.

In addition, our manufacturing resources were called upon numerous times to assist our vendors. We dispatched our tool, welding, and assembly experts to help them design their tools, fixtures, and to aid in resolving their problems. On many occasions our Purchasing Department was called upon to assist in procurement problems for our suppliers. The field expediting force was available to them. On numerous occasions our engineers went to the vendor's plant and stayed until the supplier was out of trouble. A typical example was our coil supplier; our coil engineer stayed at the vendor's plant setting up controls, established standards, designed test and checking fixtures, and guided production until it was stable.

This problem was increased as RCA policy was to establish multiple sources for component procurement, assuring a constant flow of required materials. RCA supplied each vendor with a standard which provided interchangeability and standard performance.

RCA would not have been able to deliver 8 weeks ahead of schedule without the fine cooperation and assistance of the Signal Corps. This provides an outstanding example of the results which can be achieved by the industrial-military team.

I would like to review a few of the things the military did to help us on this production.

1. The Chief Signal Officer, Major General Akin, assigned Colonel John Leidenheimer to assist RCA in procurement and to break bottlenecks. His assistance was invaluable.

2. A proposal was made for a "red tape cutting machine." This took the form of a streamlined procedure of handling "technical action requests" which provided for a negative or positive answer within 24 hours and, in many cases, the answer was obtained verbally via the telephone and confirmed in writing. RCA would process variation and deviation requests to one man appointed by the Signal Corps engineering labs, and it was his responsibility to obtain a reply in 24 hours if it were possible. The usual manner would take from two to three weeks for a reply. This kept RCA moving, as answers were fast in coming out of the labs.

3. Another proposal accepted by the Signal Corps, which materially assisted in speeding up delivery, was the assignment of a design engineer as project engineer in place of a production engineer. He was vested with the authority to approve deviations from the specification and drawings, provided it did not involve an increase in contract price or a delay in delivery. The project engineer was always on hand to witness our problems and suggested solutions. He was in a position to accept or reject. This saved many man-weeks in processing paper work and answering questions on the phone, or in personal visits to SCEL to present facts to substantiate our request.

4. The Signal Corps agreed to hold in abeyance all test specifications until the pilot-run production was completed and evaluated. In many cases, specifications were tightened, and in other cases they were relaxed, as they didn't affect operation of performance or reliability. In a few cases discrepancies were corrected with minor changes.

5. All type testing was conducted at RCA under the watchful eye of the project engineer. This move saved from three to four weeks. Only field testing was conducted away from RCA. Of course, most laboratories try to harness the forces of nature for constructive purposes. However, in the type test lab forces are marshalled for destruction. Here the masterpieces of engineering and production ingenuity are tossed, shaken, submerged, chilled, heated, blasted, and otherwise subjected to all the abuses that equipment is exposed to in each type of service for which it is designed. For the PRC-10 this is considerable!

a. Slide 11 shows the care we use in production designing some of our equipment. This is one of the temperature-humidity chambers.

b. Slide 12 is another view showing a chamber in which we can produce arctic cold or humid, tropical heat. We have great numbers of these chambers. This is one example.

c. Slide 13 shows the 400-pound hammer in the mechanical shock-testing machine. It is about to be released to test the shock-resistant qualities of the equipment shown. Almost as bad treatment as the doughboys gave the walkie-talkie.

6. RCA was permitted to initiate production while type tests were being conducted. Production was at RCA's risk--this was not normally permitted by the Signal Corps. Another RCA risk was procuring material in excess of production requirements, feeling that the Signal Corps would require delivery of maintenance spares concurrent with equipment. Provisioning and ordering of these maintenance spares took place a couple of months before equipment delivery. But we had sufficient material on our assembly lines to fill the spares requirements as we had anticipated the need and scheduled delivery of materials in excess of our production requirements. Delivery of the first unit was made in April 1951 and accepted by Major General Akin of the Signal Corps.

Slide 14 shows a picture of Major General Spencer B. Akin accepting the first production model of the receiver.

There was only one trouble. With the delivery of this successful equipment at a unit price of 579 dollars, RCA lost 1,414,000 dollars on the crash program. However, RCA felt this was one step in the program of the walkie-talkie and so it proved to be, because we have received substantial additional business. We have had a five-phase program under a five-year plan for development of the walkie talkie equipment.

Phase one--the first phase was to produce the equipment initially.

Phase two--the second phase was to undertake an internal cost-reduction program. Our assembly sections were charged with the responsibility of proposing improved, lower-cost methods and techniques. Our buyers in the Purchasing Department were required to do an exhaustive sourcing job to get better prices on parts. We started this program in February 1951 and completed it in December. The results showed a 12 percent cost reduction on the equipment, which of course we were able to pass on to the Government in the succeeding contract.

Phase three--RCA proposed a development contract for reducing costs by design improvements. This proposal was accepted and sponsored by the Signal Corps at a cost of 147,000 dollars. The contract was accepted in July 1952 and was completed in January 1953. The results were evident when we submitted a bid showing a 75-dollar unit saving for a 6,000 quantity, and a weight reduction of one pound.

Phase four--in February 1953 RCA took on a contract to further improve reliability. This request was made after analyzing the field experience gained on Korean battlefronts. The engineering task was completed in December 1953.

Phase five--RCA submitted a proposal to the Signal Corps for the development of transistors for the walkie-talkie. This development would also improve the reliability, depending on the availability of the transistors. If this proposal is accepted soon, we feel we can release for production this new version of the PRC by the fall of 1955, completing our five-year plan initiated in 1950.

Altogether, RCA has worked with the Signal Corps on 426,000 dollars worth of development contracts and has received production contracts totaling about 30 million dollars.

In addition, RCA has done all in its power to cooperate with the Signal Corps program of establishing a second source. Our responsibility was to start the Admiral Corporation in the PRC-10 business, as quickly as possible, in the spring of 1951. We furnished it with full and complete information, including our plant layout, all engineering drawings and information, and all procurement sources and cost information. We authorized the use of our tools by Admiral at vendors' plants and expedited material and equipment for them. We have given complete drawings on all test equipment and processes and have loaned them test equipment. We furnished assembly processes and time-study rates. We provided two complete sets to use as models and 50 sets of parts for use in their pilot-run production. In addition, we loaned factory supervisors to help them get started, and we set up an RCA resident engineer at Admiral. We have advised the supervisors immediately of engineering changes and improvements, and have sent them copies of drawings simultaneously with giving them to our own factory.

To complete this story on walkie-talkies, perhaps I ought to say that we are already setting up the next five-year plan, and it promises continuing advance. You see, we didn't get into this military business just to utilize some floor space. We feel that military business is an integral and important part of the future growth in electronics. It will demand continuing engineering advance in all phases of electronics. And electronic engineering is our business. Furthermore, we believe that the problem of producibility must be solved by engineering-type companies whose whole interest lies in the long-term development of the art and who are properly manned with qualified research and engineering staffs to coordinate with the vision and the needs of the military services.

COLONEL WALKER: Mr. Smith is ready for your questions.

QUESTION: Mr. Smith, does the armed services electronic standards agency add to or decrease your problems in producibility?

MR. SMITH: They are very helpful. It sometimes takes a long time to get things approved, as you might expect, but in general they have been very helpful to the industry.

QUESTION: Mr. Smith, you mentioned the results that have been attained by the statistical approach to evaluating reliability. What progress has been made toward evaluating complexity of military equipment, and specifically electronics equipment, so that you can have some yardstick against which to measure the relative complexity versus reliability?

MR. SMITH: I don't think there is anything I can point to too concretely. One of the things we have done is get a statistician, an expert on the laws of probability, in our Engineering Department. We take a new design and have this fellow look it over. He tries to get data on the reliability factor of the various components, and then tries to come up with the probability factor of the equipment's working reliably. That has been done to some degree by others as well; yet there are no standards at the present time. All we can figure out is what the percentage of outages will be on some of the very complex equipment. When you get into such devices as electronic computers, where you have three, four, or five thousand tubes, the tube reliability factor becomes the controlling one there.

QUESTION: Do you increase the maintenance advantage with this subminiaturization or not?

MR. SMITH: What we try to do is resolve that problem at the outset. We are building at the present time the ARC-21 for the Air Force. That is pretty much subminiaturized equipment. What we did is to design it in sections which can be easily removed for service. During the process of designing it, we had the Air Force people in with us to discuss the maintenance problems. We tried to take the maintenance problems into account along with the design of the equipment. I would say that well-designed subminiaturized gear is as easy to service and maintain as the older type gear.

QUESTION: Mr. Smith, how do you cope organizationally with the problem of bridging the gap between your research and development group and the project engineering group?

MR. SMITH: We try to do so by having an advance development group located in the manufacturing operation. Our research facilities are separate. In the case of RCA we have our own research laboratories,

which are a separate division of the company. We have in our manufacturing operations an advance development group who work very closely with the research people. They take the research experience and put it into practice to advance the type of product that will be manufactured. From there we go into the design group.

QUESTION: Can you tell us some of the production problems which are preventing the production of transistors?

MR. SMITH: Actually, the situation is that we are making a new type of device and we don't have the automatic machinery for making it yet. To produce the transistor depends on taking a material such as germanium and making it as nearly pure as anybody knows how to make it. I have forgotten the exact figures but the purity is of the order of one part of impurities in 10 million parts of germanium. That is done by artifically growing crystals to eliminate impurities. After that is done a small percentage of desired impurities is introduced into the material. The performance of transistors depends on the impurities in them. There are other factors which must be controlled very highly if the transistor is to be other than the point-contact type. For example, one process depends upon the diffusion of indium into germanium blocks. The depth of diffusion is critical and must be controlled to ten-thousandths of an inch. Obviously such processes are difficult to control in large-scale production. At the moment we don't have automatic machines whereby we can push a button and get the desired results. Some day I guess we will.

QUESTION: I heard about a year ago that the Japanese had a pretty good miniature radar set. Do you know anything about the Japanese competition in that field?

MR. SMITH: No, I don't. I am sorry I don't have the information.

QUESTION: In the production of some of your radar equipment do you also look into the problems of producing jamming equipment which has the capability of jamming your equipment and will also jam the Russian equipment?

MR. SMITH: The subject of electronic countermeasures is a very current one. The services have been putting a lot of pressure on industry to undertake more work in that field. Frankly, one of the problems the military has run into is that in the past there has not been much demand for production of such equipment. It is mostly an engineering problem. The services have had some difficulty in getting manufacturers to take on engineering problems without the incentive of any substantial production. We have taken development contracts, and I expect we will take more, to develop various aspects of countermeasures, including jamming.

QUESTION: I noticed in your slide that it appears that your assembly lines are not on the basis of moving the work down on the line. Is that true?

MR. SMITH: That is correct. There are two types of electronics production. One is the so-called mass production, such as that for making television receivers, radio sets, and so on. In that instance the work is moved along a moving belt in front of the workman. Most of the military equipment is not mass production, long-running equipment. We make a certain number of articles, then stop and make changes, and then build something else. In that case it is more economical to have the workman sit up at a bench and actually, in effect, hand the equipment from one to the other; it may be that one person or several people will work on it for a long period of time, depending on the size of the equipment. Most of the military equipment is built on what is called a job shop basis.

QUESTION: Do you use the assembly line in it?

MR. SMITH: Yes, we use the assembly line in the factory even though not of the moving belt type. There are some exceptions to what I said a moment ago. Such things as proximity fuzes, made in large quantities, are built with mass production techniques, moving belt, and so forth.

QUESTION: Mr. Smith, you mentioned a very difficult problem of engineering changes during production. Do you have any recommended basic points that might be followed by both the military and industry to keep those changes to the absolute minimum?

MR. SMITH: Actually some changes are very beneficial. If you make a change to make the production better, to find a way to do the job more simply, with less cost, it is desirable to make such a change. The problem we run into is that a great many changes are made for reasons other than those. One solution I know is to try to get the contractors' engineers and the military's engineers to decide what they want and stick to it. That is one of the seven most difficult things in this world.

QUESTION: Mr. Smith, what is the source of your manpower, or, in this case, womanpower, for assembling and manufacturing?

MR. SMITH: It is local. We have in the Camden-Philadelphia area a number of radio and electrical businesses, so that a pretty high percentage of the population is trained to do electronics work. When we got into a high-scale military production we had to train a lot of people, and we did run into a number of shortages. We could not get

enough test people. So we instituted a training program. It took a number of months to train testers to handle complex equipment. We have done a lot of training of all our people, from the factory people right up to and including the engineers.

QUESTION: This is a rather broad question, Mr. Smith. On the subject of industrial preparedness as against the possible fact that the next war is going to be rather fast, and so on, do you feel the technological advance in the electronics industry is having a great effect on the capability of the electronics industry in a future possible war to produce? Do you feel it lessens the capability of the industry machine-tool-wise and facility-wise?

MR. SMITH: That is a difficult question to answer. Of course, with progress moving so fast, you try to set up a plan which takes into account the current state of affairs although by the time the emergency arises your plans may be obsolete. On the other hand, there are ways of preparing yourself in general. I mentioned, for example, the subject of modularization and printed circuit techniques. Some of those techniques will permit you to build anything, new or old, in a shorter period of time than going about it in the old way. I think that a lot of work is being done by industry on its own account, with the stimulation of the military services, to try to standardize circuit elements. This will shorten the time cycles, because we will be prepared to build such standard elements rapidly. I don't feel that we can design equipment, make tools, and expect such tools to be useful in the indefinite future because of the rapid progress in the art. We can prepare ourselves by being ready to make standard elements quickly and then assembling them in the manner desired for the particular equipment.

COLONEL WALKER: Mr. Smith, I am sure we all have a much clearer idea and a better understanding now of industry's problems of producibility. On behalf of the College, I thank you for your splendid lecture and discussion.

MR. SMITH: Thank you.

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